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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. I.

DESCRIBING THE

LAURENTIAN, HURONIAN, CAMBRIAN AND LOWER SILURIAN 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 this First 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; since which date office work has been continued for the completion of its publications; chiefly the last sheets of the Anthracite survey, the maps and sections of the survey of the New Red belt of Bucks and Montgomery counties, the completion of the Bituminous colliery map of Western Pennsylvania, and a new Geological State Map. These will be published in the coming summer, together with the Second and Third volumes of this Final Report.

In writing this Summary I have quoted from more than a hundred volumes of reports published by the Board since 1875, a complete list of which, with an Index to their subjects, will be found at the close of the third volume.

In every case I have given credit to and thrown responsibility upon the assistant geologist who made the observation, or reported the fact quoted, by a reference in text or foot note to date and page of his report.

Most of the illustrations are photo-electrotype reductions, and therefore fac-similes of the drawings made by the assistant geologists, or in the office of the Survey from their sketches, or from data in the text of their reports, published in their reports during the course of the Survey.

The smaller illustrations are grouped on page plates to diminish the cost of the publication and to hasten its completion. They form in fact an illustrated index to the maps and sections to be found (on a larger scale) in the series of reports.

The names and districts of all the assistants on the survey will be found in a list at the end of the third volume.

I have endeavored to confine the text of the book to general and systematic statements; and have therefore placed all the detailed local and ancillary matter in foot notes. I trust that this will accommodate the reader as much as it has lessened the size of the book.

I have written it also in Saxon English, as far as a work of physical science can be so written, as it is intended for the use of the people of Pennsylvania, in whose vocabulary Norman English has never been domesticated, who greatly prefer before and after, or before and behind, to anterior and posterior, and overlaid and underlaid to superimposed and subjacent, as I do myself, and who are mostly or wholly ignorant of Latin and Greek.

Although the personal element can never be entirely suppressed from any work of man, I have endeavored to avoid dogmatic statements not made by a consensus of the geological opinion of to-day, and to place the many differences of that opinion still remaining unsolved in such a light as to show that our science is not an oligarchy but a democratic republic, in which every voice has a right to be heard, and that even after the vote has been taken there remains the right of calling for a re-consideration of it.

The book is almost wholly a practical description of facts discovered or verified by the observation of the members of the corps of the Geological Survey in their several districts, not at all influenced by geological theories, but simply seen and measured, and placed in their true relations to one another.

The arrangement of the book will be seen by consulting the Table of Contents. The order of description is chronological from oldest to newest, but the representation of of each formation is made as in a columnar section from the top to the bottom, by which the mental conception of the pile of strata is enforced by the eye. A descriptive section with the bottom bed on top is an old-fashioned abomination repudiated now by all good geologists.

The page plates of fossils, placed in all cases at the end of the chapters of the several formations, are half-sized reproductions of the figures of fossils given in Report P4, Dictionary of the Fossils of Pennsylvania and the surrounding States, published in 3 volumes in 1889–1890.*

The Dictionary has been so successful that the demand for it has long since outrun the edition; and the office of the survey is in receipt of requests for it which cannot be answered because the edition is exhausted. It has been a completely successful experiment. But there has been a call for the classification of the figures under the head of the formations to which the fossils properly belong, and I have endeavored to meet this call by grouping the figures of each formation in a series of page plates, which will sufficiently index the Dictionary for geological purposes.

In the case of each series the grouping begins with plants, and proceeding upward in the order of life through species of bryozoa and corals, brachiopod, gasteropod, cephalopod, phyllopod and lamillibranch shells, annelids, crustaceans, insects, and vertebrate fish and reptiles, so far as the formation in question contains these. Where references to authority and locality are wanting the reader must consult the Dictionary. These page plates are for popular instruction and not for the use of experts.

J. P. LESLEY,

1008 CLINTON STREET, PHILADELPHIA,
February 13, 1892.

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* P4, Vol. 4, Appendix, was forbidden by the Board to be published until after the final report and other publications of the survey had been printed, for fear of delaying these. In consequence of this action, I have been precluded from inserting in these page plates many of the fossil forms found in Pennsylvania and elsewhere recently, many of them of the most interesting character.

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VOLUME I.

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Chapter I.

Our Geological Knowledge.

A summary description of the geology of Pennsylvania implies a condensed account of all the work done by the geologists of the state survey for fifty years, together with the knowledge produced by some thousands of private explorations. It is a task made difficult, not so much by the extent and diversity of the territory to be described, as by reason of the great number of rock formations which appear at the surface, and the erratic courses which their outcrops pursue; by the local variations of character exhibited by them; by the complicated structure of the underground; by the multitude of mineral beds having an economical value; by the eruptions of volcanic rocks in different places, and the extensive metamorphism of the older formations in the southeastern counties; and by the concealment of a considerable portion of the rock surface of the northern and western counties beneath a covering of glacial drift.

So great is the variety of objects of geological interest which present themselves to the eye of a skilled observer at every point, that we may justly consider the number infinite which offer themselves for investigation in an area of 50,000 square miles; that is, within the limits of our state. A small spot upon the surface of the whole globe Pennsylvania is nevertheless a world in itself, to the just contemplation of which the liveliest imagination can rise only by a great effort; one of those objects of contemplation presented to the mind of man before which it bows with all its faculties of logic and rhetoric in reverence, imperfectly comprehending what it sees, and hopeless of framing an adequate salutation to it. For, the longest and most intimate conference with these phenomena of Divine operation will not enable the greatest genius to do justice to their description.

The geology of such a territory is a history of the works of nature through a lapse of time, which, if compared to the life of a man, or even to the existence of the human race, is little less than an eternity. Events of the greatest magnitude and complexity have followed each other in uninterrupted sequence, without known beginning, and without yet reaching an end. Geologists spend their lives in deciphering the hieroglyphic records of this history, only a part of which are legible, and the largest part is concealed entirely from view. One fact at a time may easily be noted; a group of facts may be compared and discussed with pleasure and safety; but the geological drama has been played out upon an imperial stage, by combined and conflicting natural forces in company, according to a plot not yet revealed, beginning in ages previous to the creation of any living being. The drama was played without an audience. Therefore, the geologist who makes himself its reporter is soon lost in amazed bewilderment; and when he takes his pen in hand will pray for the pardon of innumerable mistakes before he yields to the necessity of committing them.

The great English historian of the last century, Gibbon, has left for our instruction a luminous description of the difficulties to be overcome and of the successes to be achieved by a narrator of human events when twenty years of zealous preparation is followed by twenty years of patient execution. He tells how many languages had to be acquired, how many previous works of genius mastered, how many original documents deciphered, what toil, what doubts, what discouragements had to be endured. He paints a touching picture of the mingled pain and pleasure with which he ended his task, and closing his book bade a lingering adieu to the occupation of his life.

The geologist is a historian in every sense of the word; subject to the same disabilities and exposed to the same deceptions; handling a mass of fragmentary records; cross-examining unintelligent and unsympathetic witnesses;

judging conflicting testimonies; following trains of events which pursue parallel lines separated along shifting boundaries but mutually affecting each other's characters.

But while the historian of human affairs writes under the safe guidance of well-known and well-understood principles of human nature, the motives of which he has himself experienced, and by which he may interpret with a near approach to truth the actions of his historical characters, so as to fill out the rude and slender sketches of tradition, or detect and amend the mistakes of ancient documents, it is the ill fortune of the geologist to be compelled to write the physical history of the globe, or a part of it, in almost complete ignorance of those fundamental principles of his science on which he should rely for all his explanations. It is true that the collection of geological facts has become incredibly great, but it is also true that from this very wealth of facts springs the impossibility of any description of them which shall satisfy the common mind, while the geologist himself, if not completely lost in the wilderness of details, either becomes a slave to his own favorite theories, or stands uncertain between the views of jarring schools.

None of the greater questions in geology have yet been answered. We know nothing of the interior of the earth beyond a depth of about five miles and that only at a few points. We are ignorant as yet of the exact cause of earthquakes, and of the origin of volcanoes. The history of the crystalline formations remains mysterious. We cannot yet explain the elevation of a continent, with its systems of faults and folds; nor the submersion of the ocean bed. The relative distribution of land and water has been changed in every age, but how, how much, or why, we do not know. Consequently no geologist has succeeded yet in even plausibly mapping the surface of the earth as it was at any past time, with river drainage on land, and its deposits in the sea. The courses of those ancient ocean currents are unproved which distributed the river sediments. Ancient lakes, with or without outlets, are known to have existed, but their limits have been destroyed and their extent is a matter of guess work. The connection of even great formations in distant countries has been broken and cannot be restored. The migration of living creatures from one region of the globe to another, under the stress of a change of temperature, or the prevalence of enemies, introduces an element of deception into the arrangement of any time-table for the globe, or even for a subordinate division of one continent. We know not if the sun has always shone upon the earth with the same energy of light and heat. We know not if the tides in past ages have or have not been more efficient at their work. The composition of the atmosphere may have greatly changed, nor have we any means for settling that question.

The geologist then must examine and describe his special region in a deceptive twilight of science. Detailed reports of business properties are not affected by such fundamental difficulties, but a description of a region like Pennsylvania pretending to display a summary of our knowledge of it, must cautiously handle all the generalities and be content to leave great questions unanswered and a thousand facts unexplained.

CHAPTER II.

Geological Time.

Time and space are the two eyes with which man looks upon the world, the two lenses which he uses for examining, defining and measuring whatever has attracted his attention or excited his thirst for knowledge. In every branch of science, in every business, in every handicraft, in the fine arts, well-defined and common standard measures of time and space have been invented, and in the present century refined to the utmost precision by delicate instruments.

The science of geology has its own apparatus, and no description of the geology of a place or of a region can be either written or comprehended unless both the writer and the reader are inspired by the sincerest respect for an accurate application of the standards of time and space to all and each of the whole series of observed facts.

The idea of time is the most fundamental of all geological ideas, and at the same time is to most minds the vaguest. To count the minutes in an hour, the years in a century, or the centuries in the Christian era has become a familiar and easy mental operation for all educated persons, and the few who have pursued historical studies possess clear notions of dynasties for two or three thousand years before the time of Christ. But to the majority of mankind any statement respecting previous ages in the geological history of our planet is unreadable because written in a time-language which they cannot appreciate. The great operations of nature have been so exceedingly slow and have been carried on through so many ages, each of vast duration, that untrained minds become confused and weary with them.

Nevertheless the geologist is compelled to describe rock formations in an order of their successive deposits; and he can make their nature clear in no other way than explaining the comparative quietness, or the comparative commotion of the age of each. Going backward in time and downward through the rocks, he is compelled to give *time-names* as well as *mineral-names* to the formations or groups of beds which he describes. But his *time-names* can only be comparative, such as new and old, newer and older, recent, ancient and archaic. And his *mineral-names* also can only be comparative: upper, middle and lower. These terms, however, can present no well-defined idea to any mind but that of a geologist, for they are the terms in daily use among men for events which run their course in a few days, or years, or centuries of human time, or for things which are measurable by inches, yards or miles in the country where those who use them live. A single one of the principal rock formations of Pennsylvania required more time for its deposit than the duration of the human race from its first appearance on the planet until now. The age of our primeval forest can hardly compare with the age which one large coal bed reached before its life was destroyed by the invasion of the overlying sands. If the limestone deposits of the Cumberland valley could be measured not by feet and yards but by years and centuries, and compared with events of human history, we should merely get a vague notion of enormous time, expressed by the old phrase "a thousand years is as a single day."

Nevertheless, however ineffectual will prove the effort to frame a clear idea of the whole course of geological time, or even to define with any distinctness its major sub-divisions, it is absolutely indispensable for the understanding of the geology of any region to suspend our habitual estimates of human events, and substitute for them the largest possible conceptions of geological time, upon the grandest scale which we are capable of imagining.

To the human individual who seldom lives beyond threescore years and ten, and whose short life is crowded with business affairs, time is considered a precious commodity to be spent with economy, its loss and its waste lamented, and its use converted into a religious duty.

But these ideas are products of the latest age of human history, and are essentially ideas of the modern factory and counting-room. Disembodied immortal spirits would value time by a different standard. Science, especially the science of geology, dispenses time as the commonest drug in the market of the universe.

The idea of precise time is the product of the routine of civilized human existence. It is unknown in the vegetable and animal worlds; it is disregarded by nomadic races. The idea took root when the home was organized by woman, and meals were cooked at fixed hours of the day. It became confirmed when superstition organized priestcraft, and religious ceremonies demanded a calendar. The moon was the first clock. The invention of the water-clock by the ancients was made for the benefit of the wealthy and ceremonious. The first mechanical clock in Europe was one sent as a royal present by the Caliph Haroun-Al-Rashid of Bagdad to Charlemagne. Even now, with all the chronometers of christendom, it is still a fact that nineteen-twentieths of the human race have never seen a clock, and have no practical need of one.

The idea of absolutely precise time came with the invention of the steam engine, the locomotive, and the telegraph, and with the erection of modern observatories. It bears the same relation to the crude instinct of time in the mental constitution of the race that the few and costly ingots of aluminium bear to the sum total of common clay with which the world is full. But, with the spread of civilization, and the multiplication of machinery, popular education will in the end fix it in the minds of all.

Whatever moves with regularity, continuously, by steps or stages equal to each other, and therefore countable without being accountable, or disturbed by perturbations, is a clock—is a measurer of time—a scale by which the rate of the course of events can be recorded. A locomotive, a power loom, a printing press, any engine adjusted by a governor to invariable motion, a sewing machine driven by a well-directed foot, is a clock. All reciprocal motion, all rotary motion can be set to keep time. The melting snow water dropping from a roof will furnish a geologist with a measure for calculating the annual rate of growth of stalagmites in a limestone cave.

The essential nature of a clock is its regularity ; and that depends on the energy which moves it; while the rate of its own particular motion depends on its construction, a short pendulum ticking seconds,a long pendulum ticking minutes.

But while the geological world is full of natural time-markers, they are of every variety of construction, and therefore furnish no *common standard* of time. The geologist who seeks to investigate the age of the globe stands like a purchaser in a clock-maker's shop, surrounded by a thousand time-keepers all ticking at once but not together, independent of and indifferent to each other's rate of going, and waiting for their turn to be adjusted to a common rate ; the little ones, like children out of school, rollicking in an ecstasy of quarter seconds; larger ones soberly stating their movement in seconds ; here and there a great pendulum disdaining to record its relations to universal time oftener than once a minute.

In the world of physical science entomologists, conchologists, ornithologists apply to use only the little patent levers and repeaters ; while the mineralogists, the geologists the astronomers, in their several calculations work only with cathedral clocks. But in all branches of physical science without exception the differentiation of time is accomplished naturally and is illustrated scientifically by natural phenomena in one way or in another, on a smaller or on a grander scale, and at rates so immensely different that, while whole series of thousands of one kind complete their cycles of existence within the lifetime of a man, others require a thousand centuries to substantiate one item ; and this is what happens in geology.

Now, for such phenomena geology has as yet failed to find any precise measuring time-machine, any clock, and must still content itself with rudely divided scales of relative proportion without knowing the actual sizes of their aliquot parts. But geologists, being now emancipated from the superstitious belief that God created the world in six days, or in six ages, are free to gaze back along an interminable vista of events, having modern human history with its accurate chronology of days and years in the foreground, through the middle distance of classical and monumental history measured by olympiads, centuries and dynasties, into a background of pre-historic and glacial times unchecked by any measurable records; beyond which is dimly seen an infinite extent of geological times, ages and formations, vanishing in the extreme distance toward some absolutely unimaginable beginning.

In contemplating this grand picture from day to day, as the geologist is obliged to do, two sentiments take possession of him: an admiration for the variety and multiplicity of the things which have happened; and a profound conviction of the slowness of time, the infinite patience with which the world has been made. And these sentiments are the product of observation; are neither a fancy nor a faith.

It is evident to observation that the clock of nature has ticked regularly; that the same physical forces have operated through all time in the same way as they are seen operating at the present moment; that in every age rivers have been delivering leisurely their burdens to the sea in obedience to the varying rainfall of the seasons; that the forests have spread and disappeared again, successively occupying for centuries the soil; that living creatures of a million kinds have made their appearance on the planet in an orderly series, the rule of which we do not understand, but the order of which is plainly although not completely revealed by fossil remains imbedded in the rocks. For it is impossible for any sane man to doubt that the rate of life with which we are familiar now was in every geological age the rate at which animated creatures were genererated, grew, propagated their kind and perished. No reason can be given for supposing that the cockroach whose form is imprinted on a shaly roof of a coal-bed lived either a shorter or longer life than the cockroach of the modern dwelling; or that the Eurypterids in the Darlington shales of Beaver county had a different life experience from that of any modern lobster on the New England coast. The great pachyderms whose skeletons have been transferred from the clays of the Rocky Mountains to the museums of New Haven, Philadelphia and Washington, by Leidy, Cope and Marsh, no doubt lived each one as long a life as a modern elephant, rhinoceras, tapir, horse or elk. The ancient coral reefs of which the limestone beds behind the Blue Mountain at Stroudsburg, Danville, Lewistown, Tyrone City and other places in middle Pennsylvania, must have grown as slowly as grow now the Madrepore reefs off the Florida coast.

But beyond this general conviction that the ordinary events of nature in the mineral, vegetable and animal worlds have been pursuing the even tenor of their way through all geological ages, we cannot go. We cannot divide geological time into centuries, much less into years; but we can and must apply the conviction thus obtained that geological events have slowly come about to explain how they came about and in what order they occurred.

When this fundamental idea of immense stretch and succession in geological time has become familiar to the public mind the greatest difficulty will have been removed from the path of the geologist in his efforts to describe the geology of any district or region like Pennsylvania ; and only for this reason is it insisted upon here. To make it still more plain the following illustrations of its truth will be adduced and specimens will be given of the calculations of geological time attempted by recent writers.

The annual growth of trees, interrupted by the winter, is marked by their rings of bark, so that the age of a tree can be discovered by the number of these rings. In like manner the deposits of a river are more abundant and of a coarser quality after long-continued rains ; so that a section of a sand bank or mud flat at the mouth of a river should mark the course of time by thin layers of fine clay and coarser sand alternately. This fact has been taken advantage of by those who have investigated the history of Egypt. The regular inundation of the Nile, commencing at midsummer and lasting a hundred days, covers the valley and the delta with a sheet of fertile mud. The turbid waters then fall, the land emerges, the winter passes. In March the hot dry khamzin blows, and clouds of sand sweep across the surface, depositing a layer of yellow desert dust upon the previous layer of Nile mud. This takes place year by year with the regularity of clock-work. Shafts have been sunk through these alternate layers to the floor on which some monument of antiquity was erected four thousand years ago, and the counting of the alternate layers has verified its recorded date. In some of these shafts sunk to a greater depth fragments of human pottery have been discovered, and by the number of layers of mud and sand it has appeared that human beings pursued their handicraft at least fifteen thousand years ago. It is evident that, were a proper site on the shore of the Mediterranean between Rosetta and Damietta selected by the Egyptian government, and a shaft sunk deep enough to reach the original bed on which the delta of the Nile began to be deposited, it would be possible, either by counting the alternate layers of sand and mud, or by simply estimating their average number in each foot or yard of the descent, to calculate with considerable accuracy the geological time at which the drainage of old Æthiopia adopted the present valley of the Nile for its most convenient route to the sea.

The Nile indeed in this respect stands alone among all the rivers of the world; the only river which receives no side streams for fifteen hundred miles of its course, resembling thus the unbranched date palms which spread their annual plumes at the top along its bank; the only river which deposits all its burden during half a year, and waits to give the atmosphere an equal chance for depositing its special burden of a different kind. But all the rivers of the world have seasons of copious outflow and increased deposit; therefore all the river sediments of the world are composed of alternate layers of coarse and fine material; and as we go back in geological time, making sections of older and older river sediments, more and more packed and consolidated, hardened, dried and converted into shale and sandstone rocks, the geologist observes in all of them this fundamental character of *alternation*; the incontestable proof of their origin as river sediments: affording an irresistible conviction that they grew, layer upon layer, annually, through ages of immense duration rudely measurable by their several thicknesses.

The same lesson is taught in other ways; as, for example, by the annual layers of autumn leaves which have been blown upon the surface and sunk to the bottom of still water ponds and little lakes in the forests, with the eggs of insects attached to them, and the wings or bodies of dead insects imbedded with them. A deposit of this kind in Switzerland is described by Heer as thirty feet thick, and shows thousands of such alternate layers of black vegetable matter and fine white clay, each no thicker than a sheet of paper, marking the quiet alternation of annual seasons for many thousand years.

The influence of wet and dry seasons in tropical countries marks the annual stalactite growth in limestone caves. For in the rainy season an abundance of water falling on the surface finds its way to the roof of the cave charged with carbonate of lime, and the dropping in the cave goes on with great rapidity. But in the following dry season the growth of the stalactite stops, just as the life of a tree sleeps during the winter; and thus the stalactite has its annual rings of growth like a tree, from which its age can be estimated. The stalagmite floor of such a cave consists of successive sheets: and in the case of one Brazilian cavern, thirty thousand of these annual sheets have been counted.

There is a little brook in Switzerland called the Tiniére, which has its springs in the mountains of Berne, and descends through a narrow ravine which it has cut for itself down to the bank of the Lake of Geneva near Vevey. Fed by rains, cloud-fogs and melting snows it wears away the rocks through which it passes and spreads sheet after sheet of sand and clay over a little fan-shaped mound which it has accumulated at its mouth. A railroad has been cut through this mound, showing its dome-shaped structure, and the slow and gradual way in which it has been made. In the sides of the railroad-cut three long black streaks are visible one above the other. They make three long arched lines. They consist of vegetable matter mixed with fragments of charcoal, pottery, and the implements of man. They represent three times at which some tribe of Swiss aborigines selected the mound as habitable ground, residing upon it awhile until destroyed or driven away by some unusual violence of the little river descending from the mountains, or by some pestilence or invasion of hostile foes. Although the three arched streaks are separated from one another by only a few feet, the intervals must needs represent great lengths of time; for, the three settlements were made by different races; for, in the lowest arch no tools were found except stone axes, and chisels, and needles of bone. In the middle streak were found beside these instruments made of brass; and in the upper streak, manufactured tools of iron were discovered. Therefore centuries probably elapsed, the mound always growing higher and higher very slowly, new tribes coming into the region with advancing civilization seeking places to live on. As no alternate layers in the mineral constitution of the mound could be made use of for calculating this rate of growth, the Swiss geologists resorted to another method, which is one of universal application in the geology of sedimentary rocks of the globe. They measured the amount of water annually flowing down the Tiniére; they measured the quantity of solid matter held in suspension by the little river at various seasons of the year. From these two data they calculated the thickness of stuff spread over the whole extent of the mound in a single year, taking this thickness as a unit of measurement for the depth of the lowest streak beneath the present surface of the mound. It resulted from the calculation, that the people who left their stone axes in the lowest streak lived about seven thousand years ago; and the approximate accuracy of the calculation was confirmed by a similar process of thought applied to the case of human habitations buried in a little delta at the mouth of one of the rivers of the Jura, by the gradual enlargement of which the lakes of Neufchatel and Bienne, originally one lake, has been separated into two. In this case also the age of the human remains was found to be about seven thousand years. But in both these cases, which are exceptionally favorable for estimating the time of the occupation of the mounds by man, no knowledge is obtained respecting the far greater lapse of time previous to their first occupation during which the two rivers mentioned had been doing the same work in the same way, work the beginning of which goes back into the last geological age.

A bridge was built by the Romans from one vertical wall to the other of a deep and narrow ravine in the center of France. For unknown ages a river of Auvergne had been working its channel down through a lava bed, undermining and throwing down one after another of its basaltic columns, grinding them up into black mud and delivering the mud to the Loire to be deposited in the Bay of Biscay. The Roman bridge is broken, but its arches still cling to the walls of the chasm, showing that this has not been sensibly widened in two thousand years. A flagrant proof of the extreme slowness with which the erosion of the surface of the earth has ever been going on ; and we may turn from the basaltic columns in Auvergne to the great cañon of Colorado or any of the gaps in the mountains of middle Pennsylvania with a sentiment of profoundest conviction for their vast antiquity. The process of destruction is evident ; it goes on before our eyes daily and annually; but unless we have a sound conviction of its *infinite slowness* we shall fall into the popular superstition which prattles about convulsions of nature which never occurred, and fails to realize the true character of the events which the geologist has to describe.

The lesson of geological antiquity is taught with equal clearness by the series of volcanic eruptions which mark the whole history of the earth from the beginning to the present day; and although evidence of the exercises of the eruptive forces on an exceptionally grand scale at certain times is not to be mistaken, corresponding to the greater and the more widespread earthquakes which have sometimes varied the importance of calamities in human history, they cannot be considered in any other light than as exceptions to the regularity of the whole series of volcanic phenomena, which in the gross has undoubtedly been as regular, and has proceeded as leisurely as any other function of nature. Vesuvius at the christian era had been asleep from beyond the earliest traditions of the inhabitants of Italy; its old crater was a cattle ground of Umbrian cow-herds, and accounted so safe from all commotion that Spartacus encamped his army in it as an impregnable fortress. When the first eruption awoke the mountain to renewed activity, pouring a sheet of lava over Herculaneum and covering Pompeii and the surrounding country with ashes, men were as much astonished as we should be were the old vents in York and Adams county to be again re-opened and fresh streams of lava pour from them over our cultivated fields. Since Pliny's day the activity of Vesuvius has been continuous, its eruptions recurring every few years, yet without sensibly increasing the size of the cone. Therefore, the construction of the cone must date back in ages previous to the appearance of man. Every volcanic mountain in the world has grown like a vegetable bulb, skin over skin, through wastes and wildernesses of time of which the human imagination can form but a vague idea, and which the science of geology can only indicate by reference to the geological age of that particular formation in which the first appearance of such cones can be recognized. Every geological age had its own volcanoes, its own outflows of lava and its own tufa beds. The backward vista is interminable ; the cause is unknown ; their phenomena have pervaded the ages from the beginning.

It is a seductive temptation to the speculative geologist to translate the vague ideas of geological time into figures. But whether the results of any calculation thus mathematically stated increases our knowledge or clarifies our ideas may well be doubted ; for after all, when the product of multiplying large numbers reaches into the millions it merely generates the idea of vastness. To write the sum of a hundred million years helps us no better than to write the words infinity or eternity. Yet the effort at such a calculation is a useful exercise of the mind and furnishes an opportunity for examining the facts which must be used in making the calculation. With this end in view one or two such calculations will now be given.

The western coast of South America has been lifted from the ocean to a great height in the air by successive earthquakes, one of which suddenly lifted it three feet since the settlement of Chili by the whites. Marine shells can be broken out of the rocks at a height of 16,000 feet above the sea. The average rate of this upheaval is of course unknown; but should we base a calculation upon the observed rise of the land of northern Scandinavia, namely, five feet in a century, the rocks containing these fossil shells would be 320,000 years old. From the character of the shells we know that the rocks which hold them were deposited in what is called the Jurassic age. But if all known geological time were represented by the twelve hour divisions on the dial of a clock, the Jurassic age would be at about nine or ten o'clock, and therefore the highest antiquity we could give to the mountains of South America would represent but a portion of geological time.

While parts of the crust of the earth are slowly elevated other regions are slowly sinking into the sea. In middle Pennsylvania we have a series of great formations lying one upon another, all of them originally deposited in succession in a great water basin which in early times occupied the area of the United States. Some of these formations were spread upon the bottom in deep water; some of them in water so shallow that they exhibit mud cracks, ripple marks and foot-prints such as travelers notice everywhere on sea beaches. They hold both shore-living shells and coral reefs. These facts compel us to believe that the bottom of the Pennsylvanian sea kept on sinking through all the ages during which these deposits of limestone, sand and clay were made in it ; and probably at a rate proportionate to the inflow of the solid materials from the rivers around it. The *rate* of sinking is of course unknown, but must have been as slow as the wearing away of the surrounding lands. The total thickness of these deposits, measured from the top of the coal measures down to the bottom of the great limestone of the Nittany valley at Birmingham in Blair county, is not less than 40,000 feet. If the geologist prefers to take the Scandinavian rate of elevation as a measure for his calculation, five feet in a century, he gets 800,000 years. This result is indeed a most uncertain approximation to the truth, and is of no scientific value whatever, but it will serve admirably well to impress upon the mind the reality of the vast antiquity of that part of the surface of the globe which we are competent to examine. Considering the fineness of nineteen-twentieths, say ninety-nine-hundredths of the 13 formations which appear at the surface in middle Pennsylvania, the rate of their deposit must have been lower than five feet in a century, and consequently the length of time required much greater than the result of the calculation. The tidal layers of red mud in which were found at Pottsville by Dr. Lee and Professor Rogers the foot-prints of shore-feeding animals, measure 2,000 feet in thickness. The fine dark mud and sand formation through which the belt of roofing slate in Lehigh and Northampton counties runs is at least 6,000 feet thick. The Carboniferous formation at the top of the series, with its slow-growing coal-beds, and its slowly deposited limestone, fireclay and shale beds is 3,000 feet thick. Taking these three formations together, apart from the other ten, we have 12,000 feet of sediments which might have had a rate of deposit no greater than a few feet in a century, requiring a million years.

In another part of this book will be described the folding of the Paleozoic formations of middle Pennsylvania, with basins five miles deep, and arches five miles high; Alpine ranges which once traversed our State ; now reduced by the frosts and waters of ages to within a thousand or two thousand feet of the level of the sea. A whole world of rock has been dislodged, ground up and carried by the Juniata, the Susquehanna, the Schuylkill and the Delaware into the Atlantic. All southern New Jersey, Delaware, Maryland and the general Tide Plain of the southern states have been constructed by the rivers which have been engaged since the age of the coal measures in eroding the great rock folds of the Appalachian belt. Can we find in what goes on before our eyes to-day a measure for this erosion. Certainly not one of any accuracy. Yet one is at hand which will give some good idea of it.

The Juniata river is said to pass at Millerstown in Perry county about 24,000,000 cubic feet of water per hour; holding enough sediment in suspension to represent in the course of a year about 1,000,000 cubic yards of the rock waste which its innumberable branches are robbing from the mountains. Considering the whole water basin of the upper Juniata, the erosion going on must lower its general surface about one foot in 1,500 years. The original surface of the region was on an average say 9,000 feet above the present surface of the country. This gives us 13,560,000 years as the length of time during which the Juniata has been carrying the rock waste of its own special upper country into the sea; and all the other rivers of the Atlantic coast have been doing the same work at the same rate during the same length of time. No wonder we have the great lowlands of the Atlantic coast, now cultivated by man; and the vast sloping sea-bottom which has its continuation under water from the line of coast far out to the submerged precipice which the soundings of the Coast Survey have shown to be the border of the gulf stream.

The work done by the Mississippi river has been ascertained with considerable accuracy by the United States Army Survey under Humphreys and Abbott. At its present rate of work (which alone can be studied) it removes from the face of the immense region between the Allegheny and Rocky mountains one foot of surface depth in 6,000 years. It is impossible to state the original height of the general surface of the Mississippi water-basin in the coal era when the great river began its operations. From some districts like middle Kentucky and Ohio it has removed all the formations from the top of the coal measures nearly to the bottom of the series, a thickness of say 10,000 feet. In other parts, as at Pittsburgh, the erosion amounts to only 2,000 feet. If an average of only a thousand feet be assumed the age of the Mississippi would be 6,000,000 years.

The science of geology in its present stage is like a river bearing variable quantities of solid matter which can be seen and felt, and quantities of invisible chemical solutions. It consists of an abundance of indisputable facts, mixed with innumerable fugitive suggestions, hypotheses and theories, changeable in their nature and subject to present and future criticism. The accumulation of facts which remain the permanent body of the science increases continually and at an accelerated rate from year to year. The study of one mineral bed after another and one geological locality after another is gradually procuring a sound and useful knowledge of the structure and mineral wealth of regions. Thus the beneficial work of good geologists is in favor of the business community, which troubles itself little about questions of cause and effect, and is well content with definite statements of quality and quantity, seeking only to learn where the useful can be found and how it can be cheaply got. Yet the discussion which forever goes on in the geological profession respecting the origin and age of minerals appeals strongly to the intelligent curiosity of educated men of all classes, and, in so far as they can be understood by laymen, make an important part of the general education of the community.

The race of man differs from the races of animals in possessing not only a more powerful reason, but the faculty of imagination, by which man sees the invisible, and can appreciate the past. In science the business of the imagination under the guidance of mathematics is as important as the business of the judgment under the guidance of the senses. Without imagination men would be like savage tribes before the horse was tamed. The prosaic mind goes afoot and travels in a narrow circle around its dwelling place, knowing so little of the world beyond that it cannot comprehend its own vicinity. The geologist finds such minds everywhere. They are incapable of seeing what he sees both in the distance and in the depth, because the imagination which they possess has not been cultivated like his own. He rides his imagination like a winged horse in all directions, far and near, collecting knowledge from every quarter. In telling his science he speaks from horseback to men on foot. His steed may be better or worse. He has his own adventures with it. It sometimes stumbles, sometimes he is thrown, and sometimes he is run away with. When the imagination is of the finest quality it must be ridden with a curbed bit and a strong rein. The tendency to exaggeration in geology is especially great. It gathers force and velocity by indulgence, like a rock descending a mountain slope. So, exaggeration in the estimate of geological time has been carried by the vivid imagination of some geologists to a wholly unreasonable excess, yet always under the form of mathematical calculation, dealing with absolute facts which the most sober reasoner cannot deny, and which are the products of the most careful observation and the most skilful investigation by geographers and chemists. A single illustration of such exaggeration will suffice.

An English geologist of eminence has recently discussed with great ability the quantity of soluble and insoluble substance carried into the sea by rivers. Combining Herschel's estimate of 2,494,500,000,000,000,000 of tons of water in the world ocean, with Frankland's analysis of 100,000 tons of sea water holding 1,017 tons of the sulphates of lime and magnesia, and 49 tons of the carbonates of lime and magnesia, he gets 1,222,000,000,000,000 of tons of carbonate of lime and magnesia in the world ocean, a quantity sufficient to cover 50,000,000 square miles of land with a layer 13 feet deep, and 25,000,000,000,000,000 of tons of sulphate of lime and magnesia, a quantity sufficient to cover the same number of square miles with an additional layer 265 feet thick.

He estimates that the rivers of the world remove annually, on an average, from each square mile of continental surface 100 tons of rock matter; and that the proportionate amount of its various substances would be as follows: Of carbonate of lime, 50 tons; sulphate of lime, 20 tons; silica, 7 tons; carbonate of magnesia, 4 tons; sulphate of magnesia, 4 tons; per-oxide of iron, 1 ton; chloride of sodium, 8 tons; and alkaline carbonates and sulphates, 6 tons.

Taking first the carbonates of lime and magnesia, removed from the land surface and deposited in the sea at the rate of 54 tons per square mile per year, it must have required 480,000 years to charge the ocean water with the amount of these salts which Frankland says it holds.

Taking next the sulphates of lime and magnesia he gets 25,000,000 years.

Treating the chlorides in the same way he gets 200,000,000 years.

Estimating the amount of mechanical sediments or solid matter carried by a river to the sea at six times greater than the chemical solution, that is, 40,800,000,000 tons per annum; and considering the total surface of the globe 197,000,000 square miles (one cubic mile weighing 10,903,552,000 tons) he concludes that it would require for covering the whole globe with a rock formation of every kind one mile thick, 52,647,052 years; and, therefore, if the geologists estimate all known formations taken together as measuring 10 miles in depth, we must suppose that the first rocks were deposited 526,000,000 years ago.

All that can be said respecting any such calculation is that it has no scientific value whatever, although based upon acknowledged facts; but, as has been already said, it will help to make far lower estimates of the age of the world intelligible and credible.

Chapter III.

Geological Dimension.

The second fundamental element of geological thought is the idea of space in its three dimensions of length, breadth and thickness. Any transcendentally imagined fourth dimension must appear to be absurd. Astronomy deals with unimaginable and infinite distances, as its sister science, geology, deals with unimaginable if not infinite operations of time. In both cases the common mind is subject to a thousand deceptions. Who can believe that the moon when it rides in a clear night through the atmosphere to all appearance no higher than balloons could mount or an eagle soar, is in reality 240,000 miles distant from the spectator, sixty times the radius of our globe. And yet this distance is the smallest of the heavenly spaces. The sun's mean distance from us is 92,000,000 of miles; while the light of the nearest fixed star traveling at the rate of 200,000 miles a minute does not reach us until after a journey of eight days. Such ideas would seem to be useless to the practical geologist. But no truth is useless; all knowledge is practical either in its direct application to facts or in its education of the finer qualities of the mind. No man can rightly understand the descent of a coal bed or ore vein from the surface into the depths of the underground unless his imagination is disciplined to estimate properly the dimensions of space, and by habituating himself to the measurement of distances of all grades, long and short, he acquires the power of calculating those lengths and breadths and depths which are within the scope of mining operations.

To the practical astronomer our globe seems as small to the surrounding solar system as a grain of sand compared with the mass of a mountain. To the practical geologist who compares the whole globe with the spot on its surface which he is studying for practical purposes, it seems infinitely great. It is hard to conceive the depth at which the center of the earth lies beneath our feet; it equals the distance from San Francisco to Newfoundland or from Philadelphia to Berlin. Only those who travel extensively can estimate the size of the continents and oceans of the world; those who circumnavigate the globe; he who travels round it in 80 days. Were a continuous first-class railway laid like a hoop of iron on a great circle, an express train running at a schedule rate of 40 miles an hour would require 24 days to come around to its starting point.

Of this great globe nothing is known by the geologist except its thinnest skin. The deepest boring has penetrated it only to the depth of little more than one mile. If all known sedimentary and crystalline formations at their greatest thickness were added together, the sum total would not amount to 20 miles. These 20 miles in depth of rock carry us back through all the known ages of geological time. The rest of the globe, unknowable and unimaginable, must represent an infinite lapse of previous time.

In describing an area of the earth's surface like the State of Pennsylvania, the first thing to be done is to get a right idea of its actual size, not so much in relation to the whole surface of the earth as in relation to the whole area of the North American continent, over which its rock formations spread and in which they may be studied far beyond the limits of the state. Pennsylvania is about 300 miles long and 150 miles wide, a mere spot on the surface of the globe. Its geological formations extend into surrounding states with areas as large or larger than its own; arranged in the same order of superposition one upon the other; exhibiting similar characters and structure, and carrying the same mineral wealth. As geological truth depends upon the comparison of all like facts affecting a given case, the geologist of Pennsylvania must make himself familiar with the geology of the whole Atlantic seaboard and the whole Mississippi valley; and he will often find the solution of his own local problems five hundred or a thousand miles beyond the border of his own state. On the other hand the geology of New York, of Ohio, of Maryland, of Virginia, of West Virginia, of Kentucky, gets a still stronger reflected light from investigations pursued for fifty years in Pennsylvania, where all the great formations between the fundamental rocks and the coal measures are in a more complete series, and at their greatest known thickness. In this respect our state, small as it is in relative area to the whole Appalachian region, is in fact a standard of comparison, and occupies in geology as in politics the position of the keystone in an arch. The reason for this will be explained hereafter; at present it is only needful to enforce the fact, and to stimulate the imagination to its proper comprehension, namely, that our geology is not local but general; that the rock formations of one county of our state are not confined to that county, but extend in immense sheets, with practically the same character, and lying upon one other in the same order, beneath the surface of many of the other counties of the state, and also of extensive regions of neighboring states; forming in fact successive floors beneath nearly the whole United States; sometimes rising to the surface, so that their edges can be examined along lines and belts of greater or less length; and sinking again to depths of several miles, *where it is to be presumed that their nature is unchanged;* and this presumption is the sole basis, but a practically sound and reliable basis, for the little knowledge which we possess of the earth's interior.

The three dimensions of length, breadth and thickness then applies in practical geology to every rock formation. (1) To the length of its outcrop, which (in Pennsylvania) runs in a northeast and southwest direction; (2) to the distance which it extends underground from southeast to northwest before it rises again to the surface in New York or in Ohio; and (3) to the number of feet, or yards, or hundred yards of its thickness as measured from its bottom bed to its top bed, wherever it appears at the surface. These are its three elements of size and quantity; and with these three elements all the measurements and calculations of practical geology are accomplished. If the slope (or angle with the horizon) at which a formation sinks into the underground and rises again to the surface be carefully observed, it becomes possible, and is usually an easy matter, to estimate with truth its bulk or solid contents, the number of square yards or tons which it contains, and its distance beneath the surface at any given point where it may be desirable to bore a well or sink a shaft to work it.

This is the first business of the geologist, and it is more successfully pursued than people imagine, for it proceeds upon the well-established application of geometrical rules for the treatment of the length, breadth and thickness of all solid bodies, rules that are invariable.

If rock formations were absolutely regular in their shape, of equal thickness everywhere, this practice of geology could be conducted without the least chance of mistake, and business men might depend with absolute reliance on the assertion of a competent geologist that a certain rock formation would be struck at such and such a depth. But the case of a perfectly regular rock formation is one of the rarest in nature. Not only every bed of limestone, sandstone, shale, clay, coal or iron ore varies in thickness within its own particular limits of variation, but every group of beds, and every formation composed of groups of beds, thickens in one direction and thins in another, or thickens and thins alternately and irregularly throughout its whole extent. So that, were it not for the many times and places at which rock beds rise to the surface to be measured again and again, these irregularities would present an insuperable obstacle to the accurate practice of geology. In this respect the folded structure of all middle Pennsylvania gives to our study of its geology an immense advantage, and makes our knowledge of it extremely accurate. But where the whole series of formations lie entirely flat, and only the highest members of the series can be seen at the surface, as throughout western Pennsylvania and the greater part of the Mississippi basin, they completely conceal their underground irregularities of thickness and quality. The only knowledge we can then obtain of such irregularities must come from a comparison of the records of well borings.

The exact number of wells bored in western Pennsylvania is not known, but it must exceed 50,000. Many of them have gone down only a few hundred feet, many more are 1,000 feet deep, few reach 3,000, and the deepest, the experimental borehole of Mr. Westinghouse, at Pittsburgh, and the wells at Erie, Franklin, and Wheatland are respectively 4,685, 4,460, 3,880, and 3,484 feet deep. Had the records of all the wells bored since 1859 been carefully kept and the character and thickness of every rock stratum been accurately observed, our knowledge of the underground geology of western Pennsylvania might be considered perfect. As it is, nine-tenths of this knowledge has been lost. But the one-tenth which has been rescued, taken in connection with the innumerable outcrop exposures along river cliffs and in ravines, is quite sufficient to make the geology of that half of our state more accurate and reliable than the geology of any part of the known world; that is to say, to the depth of about a mile. All the underlying formations which only outcrop in middle Pennsylvania, and the great crystalline floor-rocks which outcrop in southeastern Pennsylvania, are absolutely unknown in western Pennsylvania.

The expression *absolutely unknown* is true indeed only in its precise sense. Probabilities are of every grade of force, and sometimes rise nearly to the level of certainties. When eye-witnesses cannot be obtained, circumstantial evidence will in many cases prove sufficient for conviction. If the head of a nail is seen on one side of a board and its point projects from the opposite side, no reasonable person would think it necessary to split the board to see if the nail went through from the head to the point. If the *Corniferous limestone formation, No. VIII a*, which runs along the foot of the Bald Eagle mountain for a hundred miles, from Muncy, past Williamsport, Lock Haven, Milesburg, Tyrone City, Altoona and Hollidaysburg, to Cumberland, in Maryland, and so on south, as a continuous formation, descending vertically, or dipping steeply northwestward, as if to go under the Allegheny mountain—if this limestone makes its appearance in a similar outcrop along the Mohawk valley, in the State of New York, and keeps on in a nearly straight line westward to Niagara Falls, reappears on the southern shore of Lake Erie near Cleveland, and runs south through the State of Ohio to the Ohio river above Cincinnati, and so on across Kentucky into Tennessee, no reasonable man can refuse to believe that it underlies, in a practically unbroken sheet, the whole region enclosed between these two lines, and must surely be struck by every oil well if the drilling goes deep enough.* It is for the geologist to calculate what that depth would be at any given point in the region; and this he could do with mathematical certainty were the overlying formations perfectly regular in thickness. Since they are not thus regular, some law of irregularity must be discovered, and this can only be done by measuring the interval between the *Corniferous limestone* and some coal bed or limestone at the surface, on the two edges of the region, the one in middle Pennsylvania, the other in central New York and central Ohio.

Such measurements have been made and repeated until a pretty accurate average interval has been obtained on each of these lines of outcrop. The difference between them is so great that no better example of the irregularity of our formations could be selected.

The Devonian and sub-Carboniferous formations in Ohio measure, all told, only 1,175 feet; in Erie and Crawford counties, 3,000′; in Clinton county, 9,274′; in Blair county, 10,909′; in South Huntingdon, 11,546′; at Cumberland, in Maryland, 11,510′; at Catawissa, in Columbia county, 12,212′; on the Susquehanna river, above Harrisburg, 16,285′; on the Schuylkill river, between Pottsville and Schuylkill Haven (they stand vertically) 20,000′ (?); on the Lehigh river, in Carbon county, 15,970′; at Broadheadville, 13,550′; at Stroudsburg, in Monroe county, 13,000′, and at Port Jarvis, along the Delaware river, in Pike county, 12,750′.

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*It has actually been struck by three wells, the Presque Isle well at Erie, at a depth of 1,400; the Wheatland well in Mercer county, at 3,384, and the Conway well, nine miles below Franklin, at 3,880? But its southward dip carries it down below the bottom of the Westinghaus well at Pittsburgh. (See I 5, Carll's last Report, 1890, pages 72, 185, 188, 230.)

It is thus easy to see that formations VII, VIII, IX, X, XI and XII, which occupy the interval, are thicker in Pennsylvania than in Ohio, and as they are all deposits of sand and clay in sea water, and are not only thicker, but of a coarser character at the east than at the west, four conclusions may confidently be drawn, namely, (1) that the deposits came from the east and were floated out toward the west; (2) that the finer material was carried farthest out to sea westward; (3) that the difference of thickness had little or nothing to do with the depth of water; and (4) that the westward thinning must be gradual, if not regularly graduated.

If now we could be sure that the westward thinning was not only gradual, but regularly gradual, its rate would be easily obtainable, and then the thickness of the interval could be calculated with great precision, say for every ten miles on a line drawn from Altoona to Pittsburgh, and from Pittsburgh to Columbus in Ohio.

On such a supposition the depth of the limestone underneath Pittsburgh would be almost exactly 7,600 feet.

But here a disturbing element enters into the calculation. The outcropping edges of formations IX, X, XI and XII can be followed up the West Branch Susquehanna for many miles and all the way around into Ohio. They are also brought up to view and can be measured in the mountain gaps at Johnstown, at Confluence, at Blairsville, Latrobe and Connellsville in southwestern Pennsylvania. We can see how they all diminish in thickness from the Allegheny mountain westward. We see also that the red formations IX and XI diminish in thickness more rapidly than the others, and become so thin before reaching the Ohio line that they can hardly be recognized. This complicates the calculation, so that we are forced to conclude that the *Corniferous limestone* must lie at a depth beneath Pittsburgh *considerably less* than the 7600′ above stated.

The law of irregularity of ocean deposits illustrated by this example on a grand scale holds good for all the sedimentary formations of the world and makes itself felt in the case of every individual bed in every formation, producing local thickenings and thinnings of every conglomerate, sandstone, shale or limestone bed; obliging the careful geologist to repeat his measurements everywhere, and restraining him from making too confident predictions of what the boring tools are to find, or the precise depth at which any desired bed will be struck. This will be explained more fully in describing the oil regions.

Returning to the subject of the westward thinning of our formations, and reversing the direction, they are seen to increase in thickness from the Allegheny mountain eastward to their final outcrop along the Blue mountain which borders the Cumberland valley. In this middle belt of the State we have uncommon opportunities for studying irregularities of rock thickness. The strata rise to the surface and sink again several times in a breadth of 50 miles; and every time they rise for examination going southeast they show themselves coarser and harder and thicker. If we took in our examination only the direction from Altoona to Chambersburg we might suppose these sediments to have been produced by the destruction of the South mountains of Fayette and Adams county; but the formations thin away southward through Virginia into Tennessee, as they do westward into Ohio; but in the other direction, northeastward, they increase in thickness toward the Catskill mountains.

Comparative measurements made at Altoona, at Huntingdon, in Perry county, along the North Branch of the Susquehanna in Montour county, along the Lehigh river in Carbon county, and along the Delaware in Monroe and Pike counties, must remove from every intelligent mind the popular and mischievous opinion that what is called a general section of a series of rocks can be used for the practical purposes of exploration by anybody who has it in hand, whether he be a geologist or not.

CHAPTER IV.

On General Sections.

It is necessary to explain clearly what this term "general section" means, and it will then be seen that the common practice of writers of geological reports and text-books in placing a general section of the series of rocks which they are about to describe on the first page of their description to enable their readers to keep in mind the order, character and thickness of the rocks, while in one way it facilitates the understanding of the description, leads in another way to the most serious practical errors, whenever that description is taken as a guide to the special study of a region or locality.

A vertical section of a formation or series of formations means a representation or drawing of a deep cut in the earth from the surface downward, like the cut made by a knife through a pile of buckwheat cakes at the breakfast table. The character and thickness of each cake is thus revealed and the order in which the cakes lie one upon the other. If the various layers lie smooth and flat the section shows it. If the layers be crumpled the section shows it. If they differ in thickness anywhere the section shows it. And if they have a general slope or inclination in one direction, the lower layers rise toward one end of the section, and the upper layers sink at the other end. It is called a vertical section because it is made from the surface directly towards the center of the earth.

A columnar section is merely a small portion of a vertical section, showing the same facts of order, character and thickness, by a narrow column placed at one side of the printed page, drawn without any regard to the slope or wrinkles of the rocks, and representing them *as if they were lying flat.* The measurements are made at right angles to the beds, and are intended to express the exact thicknesss of the several beds. It is evident that a hundred such columnar sections may be made along the line of any one vertical section; but that where the beds of a general section are very regular one columnar section will be enough to show their character, order and thickness along the whole line. If, however, the rocks of a vertical section be variable in character and thickness then a dozen or more columnar sections will be required to exhibit these variations. Yet many geologists are satisfied with one, and the readers of their reports and consulters of their text-books are left to gather the nature of such irregularities from descriptions of them in the text.

Now, what is true of one vertical section is true of all. The line along which any vertical section is made is selected by the geologist where it can be best studied in his district; where a river has exposed the rocks for a mile or miles; where railroad cuttings, lines of quarries, ore banks, mine shafts or oil borings furnish him data for his measurements. Such sections are of the greatest value, and are in fact the foundation of all accurate geology. But these natural lines of section do not often run in the most convenient direction; run sometimes diagonally across the strike and dip of the formations. They must be swung around to cross them at right angles, if the true structure of the district is to be exhibited. Consequently the geologist must make as many such sections as possible in all parts of the district. Some will be short and some long according to circumtances. To represent the whole geology of the district he must put them together. He constructs thus what he calls a *general vertical section*, and gives that as expressing a summary view of the geology of the whole district. This summary view will certainly give some general idea of it. But a general idea of the geology of a district, however good it may be, will be mischievously bad in one respect, in that it will lead people who are not judicious field geologists to believe that that general section represents accurately the geology of each and every portion of the district. They will act on that assumption. They will apply that general section to the discovery of minerals in parts of the district where local facts do not correspond at all to the general section. In fact nothing has tended more to bring into popular disfavor the work of field geologists than the serious embarrassments to which laymen have been subjected in trying to apply the general section of a district to some special locality in which they are personally interested.

What has just been said has greater force in respect to *general columnar sections*, which are intended to furnish a quick and easy key to the order, character and thicknesses of the rock-beds of a district. Even in the hands of an experienced geologist such *general columnar sections* are dangerous tools to work with. They impose upon the imagination, and through the imagination upon the reasoning faculty. They seem to reveal clearly what in fact they conceal; they mystify it, distort it, and change the truth into positive error. They give the impression of regularity in geology; whereas *irregularity* is the only law of geology which can be called absolutely universal.

Even the experienced geologist is strongly tempted to recognize a general columnar section as true at every locality. Only with an effort can he keep in mind that it is a fiction, a construction, not a reality; a generalization; a sort of dressed up official representative of thousands of facts for which it speaks, but the various natures of which it cannot correctly express. If one of the beds of any such columnar section happens to be 20 feet thick at one end of his district and 100 feet thick at the other end ; or, if it be found to measure 20 feet at one point and 100 feet at another—even if these two figures be known to represent the thinnest and thickest sizes of that bed within a given district—the columnar section will either say that the bed varies from 20 to 100 feet, or it will say that its average thickness is 60 feet. These are the two plans ordinarily adopted in constructing a columnar section ; but they do not relieve it of its mischievous character. For in the first place there may be places underground to which no one has had access where the bed may not exist at all, or where it thickens to 200 feet. Should a shaft be sunk or a borehole drilled at such a point the general section is at once discredited, and even whatever value it has will be denied.

But even if the geologist has been able to discover the greatest thickness which the bed has anywhere, and its thickness at that place amounts to 100 feet, it may be an exceptional and purely local fact. Perhaps the bed throughout the district varies little from 20 feet. To say then in the columnar section that the bed varies from 20 feet to 100 feet gives a wholly false and unpractical description of it. If the second plan be adopted and the average of 60 feet be marked on the edge of the column, it becomes a false guide everywhere in the district, for there may not be a single locality where this average of 60 feet is realized.

What, then, is to be done? Shall there be no attempt made to exhibit in the form of a column the order, character and thickness of the rock formations of a district? Shall the reader be left to manufacture his own ideas of it from a confused mass of detailed descriptions in the text of the report? If he be thus left to his own devices he will undoubtedly construct some general columnar section for himself, and it will probably be a worse one than that which the wise geologist has discarded.

There is a plain road out of the difficulty. A *typical columnar section* should be substituted for the so-called *general columnar section.*

Among the many local columnar sections which the geologist constructs (along his numerous lines of vertical section), each one giving the precise facts at the place where they present themselves to the eye for examination and to the hand for measurement, there will always be one or another more precise and more complete than the rest, showing more distinctly the order, character and thickness of the beds of the district, and as accurate in its statement of the facts as any of the rest. Such a columnar section, vouched for in all of its details, and marked with the name of the locality where it was studied by the geologist and can be studied by any number of observers who choose to verify the accurateness of his observations—such a columnar section, rightly called *typical*, is at the same time good authority and of practical value. It leaves nothing to the vague imagination. It is a reality to be depended upon. It will serve as a useful guide. It stands only for what it is worth. It makes no pretensions to general truth. It says nothing respecting the stratification or structure at other localities in the district, being only one of many, all different from each other; and it can be referred to in explanation of similar appearances not so well exposed to examination. Above all, it will enforce upon the mind of everyone who uses it for comparison with other local columnar sections *that law of irregularity or variability* on which the genius of geology must forever insist, as the first to be recognized and profoundest to be felt of all the laws of our science—a law that cannot be too often or too earnestly inculcated—a law both of the highest theoretical and the most real practical character, governing both our calculations respecting the outspread of continental formations and the minutest details of our mining operations.

CHAPTER V.

The Appalachian Sea.

The arrangement of land and sea upon the surface of the globe, with which geography makes us familiar, appears to the human mind to be fixed and unchangeable. The religious traditions of mankind have taken this for granted and explained the creation accordingly. But this is not a fact. By the fossil forms of many extinct animals and vegetable creations embedded in the rocks of all ages, it appears that all continents have been formed beneath the sea, and have emerged from it into the air. By the way the continental fossiliferous formations lie one upon another it appears with equal plainness that the lands have emerged and been submerged alternately many times in the course of the history of the world. But when the bottom of the sea is lifted into the air the water which covers it flows away from it, lifting the general sea level of the world in proportion to the amount of land which has become uncovered. The lifting of the general surface of the sea resubmerges lands which were previously out of water. The crust of the earth has been subjected in all geological ages to such movements, and such movements are going on still; movements both upward and downward. They are not upward movements of the land and downward movements of the sea bottom, but alternate upward and downward movements of both the dry lands and of the ocean bottoms. The upward movement of a continent draining its edge, lifts the sea level and submerges the edges and low-lying plains of other continents. The downward movement of one continent drawing the ocean over its low-lying lands, lowers the sea level and causes an apparent elevation of other continents; but the elevation is only apparent; the ocean coast is extended outward by the fall of the sea level;

submarine banks like those of Newfoundland and off the Alaskan coast, are left like great islands exposed to the air and ready to receive the seeds of a new vegetation, and the immigration of new races of animals to feed upon them.

For the same reason, whenever the bottom of the sea has been lifted there has been a rise of the sea level and an overflow of the lowlands of all continents. On the other hand every downward movement of the earth crust beneath the ocean has lowered the sea level and drained the coasts of the continents. It is a geological speculation unsupported by sufficient evidence that the oceans have always been oceans, and that the ocean bottoms have always been descending. There is sufficient evidence to the contrary; and such evidence is afforded in the clearest manner by the geology of Pennsylvania. For many ages the crystalline floor kept going downward, draining the sea water from the rest of the surface of the world and exposing to the air more and more of the coasts of then existing continents. At first the downward movement, if not sudden, was relatively swift, and a deep ocean was early established along that part of the earth's surface now occupied by our Atlantic states ; but this is not certain.

This ocean first received the Cambrian sediments, and afterwards the Silurian, Devonian and Carboniferous. Its original depth may be imagined from the fact that on top of 15,000 feet of Cambrian beds lie in middle Pennsylvania 6,000 feet of lower Silurian limestone (regarded by most geologists as a deep sea deposit)* and 6,000 feet of fine sand and mud-slate, on top of which lie 30,000 feet of Upper Silurian, Devonian and Carboniferous strata.

Now if this Appalachian ocean had been established at once, by a sudden drop of the crust of the earth to a depth sufficient to receive all these Cambrian, Silurian, Devonian and Carboniferous strata, that is to a depth of 7 or 8 miles, the general sea level of the world would have been lowered many hundreds of feet. But we are forbidden to suppose a sudden movement on so grand a scale. But whether

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* But of this assumption I am very doubtful, as will appear in the Chapter on Formation No. II.

quick or slow, such a downward movement of one part of the earth's crust should in all probability have entailed as a consequence a corresponding elevation of other parts of the surface of the globe, parts of the then existing ocean bottoms, as well as parts which were already dry land.

There is nothing but a theory to oppose the supposition that what is the Atlantic ocean now (or a portion of it) was in all Palæozoic time a continent exposed to the erosion of the rainfall, supplied with rivers, and bestowing the waste of its rocks in the Appalachian sea. Its smaller rivers, descending rapidly from its highlands, would supply conglomerates; its larger rivers meandering from its back countries, with longer and more gentle currents, would supply the slates and clastic limerocks.

It is, of course, impossible to decide between the opposing probabilities of a faster or a slower rate of the downward movement which established the Appalachian sea basin. All we can say is that the great limestone deposits are very early; and supposing them deep sea deposits, we must conclude that the establishment of a deep Appalachian sea basin was of early accomplishment; that the downward movement was at first comparatively rapid; and that it continued (perhaps more and more slowly) to the end of the coal age.

The two thoughts which are here fundamental to the knowledge of our Pennsylvanian geology are these: (1) that what was the continental area of crystalline rocks became by the downward movements of the earth's crust an Appalachian sea basin of unknown depth, and was in the course of the Cambrian, Silurian, Devonian and Carboniferous ages so completely filled up as to become at last a great marsh or archipelago of marshes, bearing the vegetation of the coal; and (2) that this whole area was then lifted high into the air; that a corresponding contemporaneous downward movement established the Atlantic ocean or parts of it, as the thrust which elevated the Appalachians came from that direction; and that submergence of other lands of the world must have been occasioned by the general rise of the sea level.

All this took place in the Palæozoic times, that is in the first great geological age of the world of animal and vegetable life. The coal measures, which were the last deposits in the Appalachian sea, taken as a whole, is inconceivably ancient and remote from the present day.

A second division of geological history then succeeded: the Mesozoic or Middle age of animal and vegetable life.

Then came the Kainozoic (Cenozoic) or New world of animal and vegetable life, ending with the appearance of man.

Each of these three ages of the world's geological history has had its own series of continental elevations and depressions; its invasions of the continent by the ocean and the reappearance of land surfaces on the retreat of the water into the sea basins; its own peculiar sequence of sediments brought by rivers and deposited in the sea, all of them preserving in their mud and sand layers the waste of successive forests, and the dead remains of genera and species of animals.

All the greater mountain ranges of the world are composed of such sedimentary rocks, which have been lifted out of the ocean into the air in successive ages since the deposit of our coal beds, and mostly in Mesozoic and Kainozoic times.

Movements on so grand a scale must have altered materially the relation of lands to seas, modifying more or less the geography of the whole earth's surface. Therefore, I find it hard to believe that oceans have always been oceans, and continents, continents, even if other facts than those alluded to above were not known to prove the opposite.

Chapter VI.

The Names of the Formations.

Everything has to have a name. It makes very little difference what name is bestowed upon it, provided that name be generally accepted and is different from the name of anything else, so that the name shall always stand for that one thing and for nothing else. In science great pains have been taken to invent names which signify the character, or some characteristic feature, of the nature of the thing named. But in a science like geology, which includes several sciences, structural geology, chemical geology, fossil geology (palæontology) and economical geology (mining engineering, etc.) different geologists will each one look upon a rock formation with that particular interest which it has for his special studies or work, and will wish to name it accordingly. Geologists in different regions will give different names to the same formation, each affixing to it the title of some locality where he finds it best exposed to view, most easily studied, of greatest size, or most valuable for the community. Geologists of different countries, speaking different languages, have given many different names to the same stratum or series of strata. All this is inevitable. No international congress of geologists can either hinder or help it. The confusion arises out of the multiplicities and irregularities of nature itself. Those who wish to profit by geological investigations and discoveries must submit to the burden of geological nomenclature and learn *all* the names, even if they choose to use only some. It is impossible to macadamize or asphalt the highways and byways of knowledge.

All our state geological surveys have invented names for some of their formations, and for others have borrowed names already given to them in neighboring states. Geological formations care nothing for geographical lines established by king's charter or acts of congress. They pass underground from one state into another. The geology of southern New York is exactly the same as that of northern Pennsylvania. The geology of northern New Jersey passes on across middle Pennsylvania into Maryland and Virginia. Eastern Ohio and western Pennsylvania share with West Virginia the same beds of coal, limestone and iron ore, the same oil and gas sands. The formations exposed on the Juniata are exposed on the Potomac, and their outcrops extend to Alabama. The Brown sandstone and red shale belt of Bucks, Montgomery, Chester, Lancaster, York and Adams counties is continued to the Dan and Deep rivers of North Carolina in one direction, and up the Connecticut valley into Vermont in the other direction. The Philadelphia gneisses and mica schists pass on without break through Delaware, Maryland and east Virginia as far as Georgia. The South mountains of eastern Pennsylvania are the same as the Highlands of New Jersey and New York ; the South mountains of southern Pennsylvania are the same as the Blue Ridge of Virginia.

These facts are positively known to all geologists now ; but they were only suspected to be possibly or probably true by geologists sixty years ago, when the principal state surveys were set on foot. Hastily to give the same name to a series of rocks in two different states which might turn out on examination to be two distinct series would have made a great embarrassment ; and an example of this is afforded by the employment in our Pennsylvania reports of the name "Potsdam sandstone" borrowed from Dr. Emmons' survey of the Champlain district in northern New York, to designate the "White Spot" rock overlooking Reading, Chicques rock at Columbia, the quartzite beds at Mt. Holly Springs and Mont Alto in Cumberland and Franklin counties, and the North Valley hill rock at Downingtown and Norristown; for it is now doubtful if all or any of these have right to that name.

A still more flagrant instance is afforded by the old and standing controversy over the name Taconic System, a name which may justly be called the Nightmare of American Geology, from which, however, we are happily almost awakened.

For fear of thus hampering their surveys with names that might become popular and yet be absolutely false and worse than useless the state geologists of Pennsylvania and Virginia, the distinguished brothers Henry D. and William B. Rogers, refused to accept the names of the formations adopted for New York by the four principal geologists of that state, Mather, Emmons, Vanuxem and James Hall, and adopted a plan of numbering the great formations according to their order of superposition from below upwards; a series of numbers which of course would never change, and for which distinctive names might be afterwards substituted. These numbers, from I to XIII (after wards increased to XVII) only applied to the rock formations of three-fourths of the state, Silurian, Devonian and Carboniferous. The earlier rocks of the Crystalline region, and the later rocks of the New Red or Brownstone region, all of them in southeastern Pennsylvania, were left unnumbered. This numbering was accomplished in 1836 and 1837.

Between that time and 1858, when the "Geology of Pennsylvania" was published, the brothers Rogers, who were poets as well as geologists, devised a series of names which they proposed to substitute for the series of numbers, and for all other names applied by foreign and domestic geologists to the Palæozoic formations, considered as successive deposits made in one long, great geological day of time; a day divisible into four portions, before and after sunrise, before and after sunset; the day in which the Lower and Upper Silurian, Devonian, Carboniferous systems of the English geologists were deposited. But the Coal Measures belonged to the night and received no name; or, rather, were allowed to retain that popular appellation, being simply Coal Measures.

No. 1, at the base, also, was simply named the *Primal* sandstone; Nos. 2, 3, *Auroral* and *Matinal*; Nos. 4, 5, 6, *Levant* (sunrise), *Scalent* and *Premeridian*; No. 7, *Meri-*

dian or noon; Nos. 8, 9, *Cadent* and *Ponent* (sunset); Nos. 10, 11, 12 *Vespertine*, *Umbral* and *Seral*.

All these names, except three, are long since forgotten. No geologist has accepted them as useful. But, curiously enough, the people of western Pennsylvania, led by the coal prospectors of the Allegheny mountains, adopted the three exceptions, and still speak of the *Vespertine sandstone* No. X, the *Umbral red shale* No. XI, and the *Seral conglomerate* No. XII. Some geologists have, therefore, employed them in local reports; and they will continue to be used occasionally instead of the newer names: *Pocono sandstone*, *Mauch Chunk red shale*, and *Pottsville conglomerate*.

When the geological survey of the state was reorganized in 1874, and county reports began to be published, it was needful to adopt names for the rock deposits. The old numbers were not precise enough; the fanciful names of 1858 had been universally ignored; the New York names had come into universal use. These last therefore were applied to the formations in Pennsylvania, and others of the same geographical character were added at the end of the list where Pennsylvania had higher strata than any in New York.

No. 1 was called *Potsdam sandstone*.

No. 2 included the Calciferous sandstone, Chazy and Trenton limestone.

No. 3 included the Utica and Hudson river slates.

No. 4 included the Oneida conglomerate and Medina sandstone.

No. 5 included the Clinton, Niagara and Salina shales.

No. 6 was the Lower Helderberg limestone.

No. 7 was the Oriskany sandstone and Caudagalli grit.

No. 8 extended from the Corniferous and Marcellus up through the Hamilton, Genessee, Portage and Chemung.

No. 9 was the Catskill or Old Red sandstone.

No. 10, not being named in New York, although it forms the peaks of the Catskill plateau, received the name Pocono gray sandstone.

No. 11, Mauch Chunk red shale.

No. 12, Pottsville conglomerate.
No. 13, Allegheny river coal measures.
No. 14, Pittsburgh (Lower Barren) measures.
No. 15, Monongahela river coal measures.
No. 16, Washington county group.
No. 17, Greene county (Upper Barren) measures, the highest Palæozoic strata to be found in Pennsylvania, and possibly belonging to the last or Permian age of that era in geological time.

Names given by the assistant geologists of the state survey to sub-divisions or important local beds in these formations will appear in the chapters devoted to their description.

The terms Azoic, Eozoic, Palæozoic, Mesozoic, Kainozoic, have been already alluded to as designating the successive grand geological ages of vegetable and animal life on the planet. It is not intended in this book to use the first two with any dogmatic sentiment, in view of the current controversies on what I consider a very unimportant subject, namely, the precise unification of geological nomenclature. One name is quite as good as another provided it be known to what it applies, and provided that it implies no false description of character.

Azoic or No-Life rocks was a good term, first applied by Foster and Whitney to the crystalline and semi-crystalline rocks of the Lake Superior region, to express the fact that no relic of either vegetable or animal life had yet been discovered in them. It was not intended to assert that these rocks never had had fossil seaweeds or shells in them, but merely that none such had ever yet been discovered in them. It is not only probable but proved that fossil bearing sediments crystallize, and in doing so obliterate the fossil forms which before crystallization must have been visible enough. The term Azoic simply tells the fact that no fossils have been found in them. The objection made to it, that rocks of later ages may suffer this change and lose their fossils is not practically a good one, and for this reason, viz: that ninety-nine-hundredths of the Azoic rocks belong to the oldest geological age we know anything about; therefore *Azoic* is a very convenient name for the *oldest* formations, whether they appear at the surface in our southeastern counties, or lie at great depths beneath the rest of the state.

Archæan is however a much better term, invented by Professor Jas. D. Dana, and adopted very generally, almost universally, by the geological craft, because it simply means the *oldest rocks known*, and passes by the question whether they ever contained fossils or not.

Fundamental gneiss was the term preferred at first by English geologists because it expressed the general character of the crystalline consolidated floor on which all other formations have been built up. But Dana's name *Archæan* has been gradually replacing the English name even in England.

Laurentian, Sir W. E. Logan's name for the Azoic, Archæan, Fundamental gneiss floor of the known geological under-world, has been very generally adopted by American geologists, and has been used in many of the reports of the survey of Pennsylvania, especially in Prof. Prime's reports on Northampton and Berks counties, Mr. C. E. Hall's reports on southern Bucks, Montgomery and Delaware counties, and Dr. Persifor Frazer's reports on Chester, Lancaster, York and Adams counties. The mountains of the Lower St. Lawrence, Labrador, Canada, and the Adirondack region of northern New York, show the floor rocks of the world on the grandest scale.

Pre-Cambrian is another term for the same azoic, archæan, fundamental, Laurentian rocks, adopted by conservative geologists who recognize how little we know of them, and how uncertain are the identifications of them in the isolated and far-separated regions where they appear at the present surface of the globe. For this term merely states that they were in existence when the first *Cambrian* or *Eozoic* sediments were deposited upon them in the earliest seas. In this sense *Pre-Cambrian* means all rocks older than or beneath the lowest Cambrian beds which contain fossils. But by other geologists it is used in another sense, namely, to signify formations which show themselves rising to the surface from beneath the Cambrian, and which yet may not be as old as the Laurentian, but intermediate between the Laurentian and the Cambrian. If they contain fossils they should be included in the Cambrian. If they do not, they are Azoic rocks, but yet may not be Laurentian.

The Huronian system, first studied by Murray on the north shore of Lake Huron, and so called by Logan and Hunt, of the Canada survey, was supposed to hold such intermediate place. But Irving and A. Winchell have apparently proved that only the lower portion of it is Pre-Cambrian, and the upper portion may be Cambrian, although no fossils have yet been found in it by which alone its Cambrian age can be established. In Report E of the Pennsylvania survey Dr. T. Sterry Hunt has used this name *Huronian* in describing rocks in Adams county; and Dr. Frazer's sections of the South mountains of Cumberland and Fayette counties give them a *Huronian* aspect. On the other hand, Walcott's *Cambrian* quartzites seem to be well represented in the Mt. Holly (Papertown) gap, and elsewhere between that and the Maryland line. But no fossils (except *Scolithus*) have as yet been found in the South mountains ; probably, or perhaps, for want of observers sufficiently disciplined by the study of Cambrian areas elsewhere to detect them. The Green Mountain rocks of Vermont are called by T. S. Hunt *Huronian*. Of the White Mountain hornblendic gneisses and mica schists he makes his *Montalban system*, and identifies it with the Philadelphia belt; *Montalban* being after and above *Huronian*. See Report E, page 241.

Eozoic rocks are those which show by fossils the *dawn of life* on the planet. It is a convenient phrase which means nothing definite and it is synonymous with the term Cambrian, although the *Eozoon canadense* is called a Laurentian fossil. But C. E. Hall asserts that he can prove that the strata which contains this oldest of all supposed animal remains in the rocks of the earth really belong to post-Laurentian times. At all events, with the possible exception of the Canadian *Eozoon canadense*, the earliest animal remains are the trilobites and shells of the Lower Cambrian (once called *Taconic*) rocks.

Cambrian is Sedgwick's English name for a great series of deposits in Wales, Scandinavia, Bohemia, Spain and elsewhere, which have been admirably studied by Walcott and others in eastern New York, eastern Massachusetts, New Brunswick, Newfoundland, Georgia and the Rocky mountains. Its three divisions of Lower, Middle and Upper are characterized by what are called the *Olenus*, *Paradoxides*, and *Olenellus* faunas, or groups of trilobites mixed in with sea shells of many kinds, sponges, worms, sea weeds, etc. With the old controversy between Sedgwick and Murchison respecting the limits of the Cambrian and Silurian systems, practically settled by the publications of the geological survey of Great Britain, we have nothing to do. And as little now with the equally protracted and ill-natured controversies over Dr. Emmons' *Taconic system*, now happily ended by discoveries which turn that unfortunate system upside down and distribute its members among the Silurian and Cambrian formations. The same fate has befallen Logan's *Quebec group*. Neither of these too famous names appear in the reports of the Pennsylvania survey, as far as I can now recollect, except that certain fossils in P. 4 are quoted as occurring in the latter.

Palæozoic rocks are those which contain the remains of the *ancient living beings* of the world, vegetable and animal, from the Cambrian sea weeds, sponges, worms and trilobites up to the land plants, shells and reptiles of the Coal age. If anyone pleases he may merge the *Eozoic* in the *Palæozoic*, and begin the system at the bottom of the Cambrian sediments, calling the whole *Palæozoic*. *Cambrian* is a more definite term than *Eozoic*, and quite as convenient. The fewer names the better. Until their discovery by Walcott three years ago in the Trenton limestone of the Colorado, fishes were supposed to have come into existence in the Upper Silurian times. New discoveries are constantly carrying back the first appearance of one or another family of living things to remoter and remoter times. No one has a right to say how early in geological history vegetables and animals appeared. "The dawn" of life recedes farther and farther into the past. The word *Eozoic* is becoming useless; the term *Palæozoic* will always be sufficient to embrace it.

Silurian rocks, originally studied by Murchison in Wales, whence their name, and since then in most of the countries of the world, were early recognized in New York, and there classified (in ascending series) as *Potsdam*, *Calciferous*, *Chazy*, *Trenton*, *Utica*, *Hudson river*, *Oneida*, *Medina*, *Clinton*, *Niagara*, *Salina* (at first *Onondaga*) and *Lower Helderberg*, corresponding to the Pennsylvania numbers I to VI.

Devonian rocks, first studied by De la Beche and Murchison in southwest England, and afterwards in Scotland and other parts of the world, received in New York the sub-division names (upwards) *Oriskany*, *Upper Helderberg*, *Marcellus*, *Hamilton*, *Genesee*, *Portage*, *Chemung* and *Catskill*, corresponding to the Pennsylvania Nos. VIII and IX.

The *Carboniferous* formations in Pennsylvania are (in ascending order) *Pocono* (*Waverly* in Ohio), *Mauchchunk*, *Pottsville*, *Allegheny*, *Pittsburgh*, *Monongahela*, *Washton county and Greene county* groups, the last two being awkward names for the highest palæozoic rocks in the state. An unknown additional quantity of beds having been removed by erosion, the original topmost or last deposits of the Carboniferous series are unknown. This is the same as saying that the exact date at which the Appalachian sea was dried by the elevation of the Palæozoic continent into the air is not indicated by any now remaining layer or layers of rock in the region of southwest Pennsylvania, or elsewhere in the state. If the upward movement took place within the limits of the *Permian* age of Europe, then the highest strata of Greene county may be called remnants of the Permian formation. But geologists on both sides of the Atlantic are disposed to classify the Permian strata as the last of Palæozoic age, and to begin the great *Mesozoic age* with the *Trias*.

The *Mesozoic* or *middle life* time of the world's geological history, as we know it on the surface, began with that vast catastrophe which produced the United States as a continental area. He that is best acquainted with the phenomenon will be the best convinced that it was a sudden or rapid movement, a genuine cataclysm. The overthrust faults are of themselves alone sufficient to prove it. A belt of parallel mountains, as high as any that now exist in South America or Asia, rose into the air along a line extending from the St. Lawrence to the Gulf of Mexico, passing through Pennsylvania. The whole Appalachian sea was drained off and became dry land, a continental area of coal measures, much of which has since then been carried away, but much still remains, constituting the extensive coal fields of the present time. The whole rain water drainage was reversed. The Palæozoic river system which came from the east disappeared, and a new Mesozoic river system began to dissolve the raw continent and carry its undried strata piecemeal eastward into the newly-created basin of the present Atlantic ocean.

The *Mesozoic* age has three divisions, during which were successively deposited the *Triassic*, *Jurassic* and *Cretaceous* rocks. These again are subdivided in Europe into *Bunter*, *Middle Trias*, *Keuper*, *Rhætic* and *Lias; Oolite, &c.; Wealden*, *Greensand* and *Chalk*. With most of these names Pennsylvanian geology has nothing to do. Some are local English or German names. And many more names have been invented for use in other countries of Europe, Asia and Africa, where peculiar fossil plants and animals of Mesozoic times have been collected and described; ferns of a new style; trees quite different from those that made the coal forests; crocodilian land reptiles; winged lizards, the prototypes of birds; reptilian sea serpents; superb whorled shellfish (*Ammonites*); small land mammals like kangaroo-rats and ant-eaters; fish with pointed teeth of twisted fibre; the earliest oysters, &c.

The *Mesozoic* age was probably as long as the Palæozoic, judging by the thickness and variety of its sediments, and the succession of its living creatures. In Bucks and Montgomery counties Mr. B. S. Lyman's survey makes out more than 22,000 feet of regularly super-imposed strata, all deposited in its earlier and middle divisions. To this must be added the *Cretaceous* or greensand marl deposits of southern New Jersey, which only appear in Pennsylvania at the bend of the Delaware below Trenton.

New Red was the name (borrowed from the English) at first given to the Mesozoic belt crossing the Delaware, Schuylkill and Susquehanna rivers, and the Maryland state line.

Trias is the name usually given to it in the survey reports; and by this name the system, as studied by the Hitchcocks in Massachusetts, by Cook in New Jersey, and by Fontaine in Virginia, is now commonly known.

Rhœtic is the term adopted by Fontaine (in his U. S. Geological Survey monograph report on the fossil Mesozoic plants of Virginia) by the use of which he wishes to make more precise the sub-division of Mesozoic time in which that vegetation flourished.

Newark formation is the name used by the New Jersey Geological Survey, and adopted by the assistants of the U. S. Geological Survey, for the Trias sandstone formation of Pennsylvania.

The *Lias* and *Oolite* of Europe are not recognized in the Atlantic seaboard region of North America.

The *Cretaceous*, on the contrary, is well represented, but no chalk beds are known this side of the Mississippi river. It contains the lower two of the three greensand marl beds of New Jersey and Delaware, the third or uppermost being placed in the Tertiary. Its lowest member (the English *Wealden*) is called the *Potomac* formation, and its upper or greensand member the *Severn* formation, by the U. S. geologists working in Maryland and Virginia.

The KAINOZOIC (*Cenozoic*) TERTIARY, Third, *New Life* age of geological history, produced an equally vast and varied series of deposits, named by Lyell *Eocene*, *Miocene* and *Pleiocene* (to which was afterwards added *Pleistocene*) to express the fact that the species of plants and animals now living, all of them new, made their *début* upon the scene in the *dawn* of this *new* third great day (*Eo-cene tertiary*); became *more* numerous in *Mio*-cene tertiary times; *most* numerous in *Pleio*-cene; and *most of all* numerous in the *Pleisto*-cene. These names, except the last, are still in common use, but only for purposes of vague and general description, or in references where knowledge is not locally precise enough. They do not much concern Pennsylvania, a region out of water since Mesozoic times, and therefore destitute of those Tertiary sediments which (with the Cretaceous) make the tide water plain of southern New Jersey, Delaware, Maryland and other Atlantic and Gulf states.

Pamunkey (Eocene), *Chesapeake* (Miocene), *Appomatox* (Pliocene?), and *Columbia* (early Pleistocene), are names given to Tertiary sub-divisions in Maryland and Virginia by the U. S. Geologists. The *Pamunkey* represents the uppermost (or third greensand marl) beds of New Jersey. The *Chesapeake* diatom beds at Fort Monroe are 1,000 feet thick. The *Appomattox* gravel loam formation is the same as the Bryn Mawr (400′ level) high gravel of the Delaware county Report C 4. The *Columbian* terraces pass up the river valleys of Pennsylvania and are connected with our glacial deposits, which are usually designated, not Tertiary, but Quarternary.

In the *Tertiary* age appeared shrubs and trees that flower and fruit, and animals of sea and land that suckle their young, herbivorous and carnivorous, man among the number. When first mankind appeared is not known; nor when the dog, the ox, the sheep, the horse, the elephant. It has just become known that Leidy's fossil horse of Carolina was not a modern horse. Mammoths and Mastodons were not the modern elephant. No fossil ape agrees entirely with man. Yet discoveries year by year have been pushing back the proven existence of man into Tertiary times. There is therefore less and less propriety in separating the *age of man* from the Tertiary (or Kainozoic) age and calling it, as is so often done, the QUARTERNARY or Fourth age of the world. Yet this will still be used as a convenient term for expressing the state of things which now exists, and be especially applied to alluvions, or river sands and gravels and clays such as Philadelphia is built upon.

The *Glacial Age*, or *Age of Ice*, is a term which frequently occurs in this and other geological literature of a recent date. Its use began when, half a century ago, the great Swiss explorer of the Alps, Louis Agassiz of Neufchâtel, announced his theory that Europe had been covered with a sheet of ice just previous to the creation of mankind. When he settled as a teacher in Harvard College, Cambridge, Mass., he showed that all New England had been under ice. Since 1847 the phenomena of the glacial epoch have been studied by Upham, Carll, Wright, Lewis, Chamberlin, Dawson, Whitney and a host of other glacialists, over all North America; and the southern edge of the ice sheet, the terminal moraine of the continental glacier, has been traced for over 2,000 miles from Cape Cod to Manitoba. Its course through Pennsylvania is mapped and described with many illustrations in H. C. Lewis' Report of Progress Z. The age seems to have been double, the first ice sheet receding and the second ice sheet advancing, with an interval of vegetation between the two. In California man seems to have been living before the first advance of the ice. In other parts of America man and the mastodon lived together as in Europe and Asia man and the mammoth lived together in glacial times.

The cause of the prevalence of ice in the glacial age is still a matter of contention; but the facts have been verified beyond controversy and are accepted by all. Many of the details are still to be worked out; but the general theory is well established.

Now granting that such physical operations as the evaporation of the sea water and the condensation of snow upon highlands, to form ice in favorable situations, have been regular from the beginning of geological time, it is reasonable to search for evidences of previous and far more ancient glacial epochs; and such evidences, in the shape of moraine blocks and scratched rock surfaces, have been found in England, in India and in South Africa. Prof. Kerr thought he found such in his survey of North Carolina. All these evidences are localized in the last Permian or first Triassic rocks. None have been found in Pennsylvania;

and for good reason. There must have been a glacial age immediately following the rise of the great anticlinal mountains of our state out of the Appalachian sea into the upper regions of the atmosphere to a height of more than five miles above present sea level, and to a height of perhaps eight miles above the bottom of the alternate synclinal valleys. Even if the climate of the 40th parallel of north latitude in the coal age was tropical, the tops of the uplifted anticlinal ridges must have been immediately covered with perpetual snow, like Killimanjaro under the equator in eastern Africa, the volcanoes of Peru, and Mount Whitney overlooking the valley of death in Arizona, where the thermometer stands at 110° F. in the shade. The heads of the synclinal valleys doubtless made good circuses for the manufacture of nevé; and of course glaciers flowed down the synclinal valleys, and produced mountain-meal and moraines. The meal was not white like that made now from Jurassic, Cretaceous and Tertiary slopes of the Alps, but dark grey and red from the Carboniferous and Devonian; and therefore the deposits of Triassic age in Pennsylvania, brought down by the Susquehanna and Delaware from that ancient highland, are mostly red or reddish. But the long continuance of erosion has reduced the highland to its present level of only 1,500 to 2,500 feet above tide level, and swept away every trace of that local glacial state of things.

Alluvial deposits are those river gravels, sands and clays which have been deposited in the now existing valleys, mostly since the retreat of the ice, and up to the present date.

CHAPTER VII.

The Earliest Archæan, Azoic, Highland, Laurentian, Fundamental gneiss or crystalline schists.

In the beginning of time as known by the science of geology, the heavens were as they are to-day; the planets encircling the sun, comets coming and going, the moon a trifle nearer to the earth, the sun a little farther off but shining with somewhat more fervor and brilliancy.

The earth was already in extreme old age, having long before then shrunk almost to its present size and globular shape, by slow condensation, from a gaseous to a liquid state, and got itself encrusted with a rind of solid rock, which no longer shone with a dull red light of its own, but reflected into space the white radiance of the sun.

The surface of the earth was no longer hot enough to keep all the water of the planet in a state of vapor in the surrounding atmosphere; descending in local deluges of sour rain to boil upon the rocks and dissolve apart their mineral elements, sweep them into hollows, and there leave them, while it sprang aloft as steam to rejoin the universal canopy of cloud. All this had taken place before the first age of which we have any geological monuments, and is only known to God and Dr. Sterry Hunt, who has described it magnificently in his Chemical Researches.

When the monumental history of geology commences, the crust of the earth had become as fixed and rigid as the attraction of the sun and moon and Jupiter would permit. It still bent and groaned and quaked indeed, as the globe turned on its axis beneath thier irresistible influence; but now only enough to strain open great volcanic vents, from which flames and smoke and ashes were ejected, to fall in beds of tufa over large areas; and from other apertures great streams of lava poured themselves upon the surface of the lands, or spread themselves upon the bottom of the sea. Earthquakes were then in the common order of events, and changes of sea level rapidly accomplished. The air was moist and murky, the ocean warm, the continent a bare and rocky desert, ridged and rugged, with no sign of future life. No sound disturbed the silence of the air, except the noise of water-falls, of rain, or breaking waves, the roar of a volcano, the crash of a crumbling cliff, or the explosion of a descending meteor. But snow had begun to cover the peaks of Alpine mountain ranges, and old thousand-branched rivers raged through chasms between them, fretting their sides into valleys, and sweeping the rabble-rout of that perpetual destruction into all low places where the waters lay eager to receive and spread it out in beds. There was no more hurry nor appearance of confusion then than now; only a more earnest, rapid and efficient operation of tearing down on land and building up at sea; for Nature was leveling her grounds and getting ready to plant and house her future progeny. Nor can we find out with all our searching and calculation how many centuries or milleniums of human and solar years that first great No-life age of purely physical preparation lasted.

Of that Archæan, oldest, Azoic, or No-life age we know nothing except the kinds of rock which bear its date. These appear at the present surface of the earth only here and there, in limited districts, far apart from one other, in Canada and New England, in the Blue Ridge, in the Rocky mountains, in Brazil, in Scotland and Scandinavia and Bohemia, in the Ural mountains, in Upper Egypt, the peninsula of Mt. Sinai and elsewhere; but so surrounded and overlaid by the deposits of aftercoming ages that no connected account can be given of their origin and general distribution; nor can the geography of that time be mapped out; not even where was land and where sea; nor where the mountains rose, nor where the rivers ran, nor the direction of the great sea currents, nor the location of volcanic vents. So that nearly all that has been printed in geological books respecting these things may be safely regarded as pure speculation, and uncommonly dangerous for any one to believe who wishes to gather only the knowledge that is real, and prefers expectant ignorance to any satisfaction to be drawn from unsubstantial opinions.

What is *certainly* known about the oldest rocks may be set down in a few sentences.

First, that they underlie all the formations in which appear traces of vegetable and animal life, and therefore, that they constitute the underground bottom floor of all countries wherever life-rocks occupy the surface

Secondly, that they differ from the life-deposits of succeeding ages by being *crystalline* instead of granular; as loaf-sugar differs from ground sugar, or wheat from grist or flour, or wood fibre from paper pulp, or a stone-slide at the head of a river from the sand banks at its mouth. For the life-rocks of subsequent times have been made out of the frost-fractured and water-worn no-life rocks of the ground floor of the world; and show this derivation in the fact that the original crystals may still be detected, with their points and edges worn off, and their prisms changed into globules or rounded grains.

Thirdly, that they differ among themselves by the circumstance that some are coarsely crystalline (like the porphyries and graphic granite), while others are so finely crystalline (like many of the quartzites, felsites, diorites, dolomites and micaceous gneisses) that their crystalline constitution must be looked for with a magnifying glass.

Fourthly, that they differ among themselves in another particular, namely, that some are plainly stratified or bedded, others foliated or split into millions of thin leaves, and others subdivided only into masses by occasional cracks; and these three principal varieties seem to represent, 1st, those which were deposited in water and afterwards crystallized; 2d, those which were ejected from volcanoes as dust or ashes and afterwards crystallized; and 3d, those which flowed up from the interior of the earth as lava and crystallized on cooling. But there is such variety in each kind, and so much discussion among microscopical geologists over these different varieties, as to leave the whole subject still in doubt and confusion.

Fifthly, that they may all be broadly grouped under two heads in respect of their chemical constitution. For the crust of the earth is almost entirely made out of three elements, two metals and one gas; the two metals being *silicon* and *aluminium*, and the gas being *oxygen.* The other elements known to chemists play subordinate parts. First, the union of oxygen with silicon makes *silica* (*quartz*, *rock crystal*, *opal*, *&c.*); and the union of oxygen with aluminium makes *alumina* (*corundum.*) Then, the union of silica and alumina makes *glass* (*fe spar*, *porcelain clay*, *&c.*). Therefore, the ball of the earth may be said to have a glass coat or crust, which may be likened to the slag of an iron furnace; not pure transparent glass, but glass mixed with earths and metals of various kinds in smaller proportions, lime, magnesia, soda, potash, iron. manganese. Now in the chemical union of silica with alumina the silica plays the part of an acid, and the alumina plays the part of a base, being the fundamental element or basis of the union. Hence all rocks which have more alumina than the silica can unite with are called *basic rocks;* and these which have too much silica for the amount of alumina present are called *acid rocks.* But as silica unites in the same way with lime, magnesia, soda, potash and iron, which general accompany alumina, a great surplus of silica was required in the creation, and was amply supplied; so that a considerable portion of it remains by itself in the form of *quartz* (rock crystal). This is seen scattered through rock in brilliant transparent crystals; especially in granite. The rest of the silica is united with the alumina in shining waxy crystals (*felspar*) of various colors. When these quartz crystals and these felspar crystals make up the whole of a rock it is called a *syenite.* But when iron is present, then the rock shows millions of glittering spangles, exceedingly thin films of *mica* (white or black), and the rock is called a *granite.* With other combinations the iron forms black prisms of *hornblende*, and the rock is called *hornblendic granite.*

If the silicate of alumina has separated from the quartz by slow cooling into great crystals of felspar, the rock is called a *porphyry*; and when a small mixture of iron, &c. gives the felspar a rose tint, *red poryhyry.* From these few specimens of variation it may be easily seen what infinite variety of grain and color the Azoic rocks present, although they are all mere glass.

Sixthly, that the Azoic formations are enormously thick. But their true thickness has not been accurately measured in any country; nor can it be measured; because, being the oldest known rocks, they have suffered more than all from waving, compressing and overturning movements in the flexible earth crust, both in their own time and in all succeeding ages; so that at no place in any country can they be seen lying flat; but always uptilted, at all angles, and so folded and twisted, so cracked, veined and faulted, as to defy measurement, and make it often impossible to decide which is top and which is bottom to them; so that their order of arrangement is in dispute; and some experienced geologists declare that we must be satisfied to consider them as a whole, without attempting to subdivide them into series of formations, with separate dates and names. This opinion, however, is not shared by most geologists, and various methods of arranging them are in vogue, under such names as *Laurentian*, *Norian*, *Arvonian*, *Huronian*, *Montalban*, *Dimitian*, *Pebidian*, *&c.*, which may be found in text-books and other writings of geology, but which have no real meaning except in the districts where they were first invented, and not in all cases a certain meaning even there. For when the supposed or imagined order of the Azoic rocks in one region or country is applied to another region no one is satisfied with the result, and some other order must be invented to suit each local exhibition. If all the Azoic rocks were truly and certainly stratified, or deposited as successive layers of sand and mud in water, and afterwards crystallized and folded up, there would be some chance of learning their disposition, and getting somewhat near to the real thickness of the whole. But so many lava and volcanic ash beds lie among them, and such huge and numerous outbreakings of fluid rock from the earth's interior through and between them have happened, and whatever bedding they may once had is so obscured by foliation and cleavage planes produced by pressure, that taking all these things together into consideration the wise geologist will be cautious of forming an opinion where Nature seems resolved to leave us in the dark. This much alone is evident, that the Azoic rocks are thick enough to make whole mountain ranges. In New Hampshire and Vermont they are imagined to be 77,000 feet thick.* In the Lake Superior region where six subdivisions of them have been devised, the upper five are thought to measure more than 18,000 feet.† In Pennsylvania, where the Schuylkill cuts through a part of them for twenty miles from Conshohocken to Philadelphia, they seem to measure at least 15,000 feet, with an unknown additional quantity beneath the valley of the Delaware river.

Lastly, that all the great magnetic, specular and titaniferous iron ore beds, beds of plumbago, beds of crystalline phosphate of lime, and beds of red jasper are of azoic age, but not in the oldest series of its rocks. To the same age belong the tin ores of Cornwall, New Hampshire and Dakota, the corundum and beryl beds of North Carolina, the mother rocks of the Brazilian diamonds, and the turquoise rocks of Mt. Sinai. The serpentine beds of the great lakes are of that age; probably those of the Alps and Appenines; perhaps those of southeastern Pennsylvania and Maryland; but those of Northampton county in our state, and others elsewhere may be of later age.‡ The so-called *Eozoon* serpentine-limestone beds of Canada, Massachusetts and Bohemia are in azoic districts; and many groups of crsytalline limestone strata of great thickness were deposited

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*Desc. of Geol. Sect. crossing N. H. and V., by Prof. C. H. Hitchcock, Concord, N. H., 1884, p. 33.

†N. H. Winchell, in Amer. Naturalist, Oct., 1884. R. D. Irving in Presidential address to Wisc. Acad. Sci., Dec. 30, 1884; and Art. 33, Amer. J. of S., March, 1885.

‡Geol. Hist., Serpentiees, T. S. Hunt. Trans. R. S. Canada, Vol. I, Sec. IV, Montreal, 1883. But see T. D. Rand, Proc. Acad, N. S. Phila., March, 1890, page 95.

before the appearance of life upon the planet, unless the theory of their organic origin be adopted, or the old exploded theory of their igneous origin be so dressed up as to be again presentable.

From what has been said above it will appear that our knowledge of the earliest chapter of geological history represented by the Azoic or No-life rocks amounts only to a confused perception of great events taking place at the consolidating surface of the globe through a great length of time, without being able to tell with any certainty what those events exactly were, or how they were brought about. Fire and water were coöperating in the slow preparation of continents and oceans capable of sustaining every form of life which should afterwards appear. The atmosphere was gradually clearing itself. The sun went on contracting its dimensions. Of the moon we know nothing; it may have grown cold and lifeless long before, or not until afterwards.

But when this picture of apparent vast obscurity and confusion is carefully studied, as it has been for many years, and more closely now than ever, by a host of shrewd geologists, provided with three kinds of apparatus for investigation, the pickaxe, the microscope and the retort, innumerable items of positive knowledge come to view, and the geology of the Azoic rocks takes practical shape and may be relied on as a useful guide in the affairs of human business.

Some steps even have been taken towards the solution of theoretical questions of age and order of arrangement. Thus rocks supposed to be sedimentary have been shown by a study of their microscopic crystals to be volcanic ashes, * or by their banded structure to be lava flows, † or by the shape and connection of their atoms to be crystalline masses crushed into the form of laminated schists.‡ On the other hand, iron ore deposits once assuredly

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*The felsites and their associated rocks north of Boston. J. S. Diller, Bull. Mus. C. Z., Harvard College, Cambridge, 1881, Vol. VII, p. 168.

†The Azoic system, J. D. Whitney and M. E. Wadsworth, Bull. Mus. C. Z., Vol. VII, 1884.

‡Prof. Bonney's papers on the rocks of the Alps.

taken to be volcanic, have been found by mining operations to be true sedimentary beds, deposited in water, and probably in a manner similar to the beds of magnetic iron sand now forming on the northern shore of the Gulf of St. Lawrence and along the coast of California.

The study of the Azoic rocks in many countries has been conducting geologists gradually to the conclusion that, however difficult it may be to classify them in regular order of time or superposition, yet that as a whole they separate themselves naturally and broadly into a lower, older, more massive, darker *hornblendic* series, and an upper, younger, more thinly-bedded, lighter-colored *micacious* series, containing the most ancient iron ore, serpentine and marble beds. The older series, if such it be, is known in Europe as the *Fundamental gneiss*, and in America as the *Laurentian system.* The upper series is often called the *Newer gneiss* by those who feel unwilling or unable to subscribe to any universal Huronian theory, or who suspect that the whole or parts of it may possibly turn out to be more recent sediments disguised by recrystallization, an idea once popular, then falling into disfavor, and now struggling to regain its reputation against vehement and powerful protestations.

But just here the Story of the Creation halts to ask itself three questions: 1st, Whether there could have been any serious interruption of events between the Older and the Newer Gneiss; 2d, Whether there could have been a general deposit of the same kind of Newer Gneiss upon the surface of the earth to such an extent as to make it now recognizable in places so far apart as the opposite shores of America, or the opposite sides of the Atlantic; and, 3d, Whether, if life had then commenced upon the planet, all traces of it could have been completely lost, the closest examination failing to detect them. Until these three prime questions are answered a satisfactory history of the Azoic age or ages can by no means be written; nor can Azoic geology be other than an unconnected description, an unclassified catalogue of the rocks (with their included minerals) which occupy isolated areas of the earth's surface, projecting through the sediments of later times.

The terms *Laurentian* and *Huronian* are local and peculiar to the Canada survey. The range of mountainous country which extends from Labrador westward across the Saganay and Ottawa rivers, north of the river St. Lawrence, and Lake Superior, is made up chiefly of massive reddish and grayish hornblendic granite and gneiss rocks, and with great beds of crystalline limestone in the upper part of the series, the whole being called the *Laurentian System.*

To the south of this mountain land, along the north shore of Lake Huron and extending westward through the Marquette iron region into Wisconsin, appear, finely exposed to view, beds of vitreous quartzite, red and white, beds of conglomerate, holding pebbles of jasper, chert and limestone, beds of chloritic slate, beds of reddish limestone, beds of lava of various kinds and volcanic glass, beds of sulphuret of copper ore, and, in the western part, vast beds of jasper and specular iron ore, the whole being called the *Huronian System.*

The Laurentian system is directly connected by the Thousand Island rocks with the great Adirondack mountains of northern New York. The Adirondack rocks are the same as those of the Laurentian mountain belt of Canada ; but no Huronian rocks appear on or around them ; unless the Green mountains of Vermont are Huronian.

No one doubts that the Adirondack rocks when they sink at Lake George rise again a hundred miles further south as the Highland rocks of the Hudson river above and below West Point. The Hudson Highlands range northeast a few miles and then sink out of sight beneath sedimentary formations. But in the other direction, southwest, they range away across New Jersey in an unbroken belt of mountain ridges called the Highlands of New Jersey ; cross the Delaware river into Pennsylvania between Durham and Easton ; cross the Schuylkill river above and below Reading and then sink underground.

In Pennsylvania the New Jersey Highlands are called the Durham and Reading hills ; or the Lehigh hills ; or the South mountains of Northampton and Lehigh counties; or the Highlands of Pennsylvania. This last name is the most convenient. There seems no probable objection to be urged against recognizing in the rocks of the Highlands of New York, New Jersey and Pennsylvania, the rocks of the Adirondack region and of the Laurentian mountains of Canada. Therefore the term *Laurentian gneiss* has been freely used in the Reports of Progress of the Survey to signify the rocks of the Pennsylvania Highlands.

But it is quite otherwise with the *Huronian* rocks of Canada. These are nowhere recognized along the Highland belt from the Hudson to the Schuylkill.

We will see hereafter whether they appear in other parts of Pennsylvania, in the South mountains of Cumberland and York, Fayette and Adams counties.

CHAPTER VIII.

The Archæan Highland belt of Pennsylvania and New Jersey.

In New Jersey the highlands of older or archæan gneisses have been surveyed with instruments, and mapped in contour lines, to bring to view all the features of the surface. Some important facts of geology have been thus revealed. These are given in Prof. Cook's annual report of 1884, pages 61 to 68, in a clear and careful manner; and they are of equal value for understanding the geology of the same Archæan Highland belt in eastern Pennsylvania. They may be briefly stated thus:

1. The Highlands of New Jersey is a belt of country made up of parallel mountains crossing the state in a N. E. and S. W. direction, with heights varying between 1,000 and 2,000 feet above tide.

2. Each mountain is composed of a series of smaller oblique crest-ridges; and the stratification does not follow the general course of the mountain as a whole, but of these oblique crest-ridges. Thus, the strike of the beds and of the crest-ridges of the Ramapo mountain is not N. 38° E. which is the course of the southeast foot of the mountain, but N. 20° E.

3. The same strike is not maintained across the state; for near the New York line it is more N. E. and S. W.; in the middle district more nearly N. N. E. and S. S. W.; and towards Pennsylvania more N. E. and S. W. again.

4. Therefore, while the mountains have been elevated as a parallel series of large arches, they have been subsequently pressed into a much more numerous series of smaller rock-folds by a side pressure which has acted obliquely.

5. The folds are manifested in some places by opposite southeast and northwest dips; rarely less than 45°, in most cases exceeding 60°, and often vertical. Dips towards the northwest are not uncommon; but nevertheless, the prevailing dip is toward the southeast; therefore, it is to be supposed that a large number of the steeper southeast dips are exhibited by strata which have been pushed northwestward beyond the vertical so as to lie now with their undersides uppermost.

6. As this structure characterises the belt of the highlands of northern New Jersey as a whole, it seems impossible to doubt that the azoic gneiss formations are made up of regular beds of sediment, deposited one over the other in some ancient sea, and afterwards crystallized. It is hard to imagine them in any sense volcanic rocks. For all we know of volcanic rocks leads us to believe that *irregularity* is their chief feature. Even when, like the lava beds of the far west, they spread abroad over thousands of square miles, they construct nothing resembling the geology of these highlands.

7. But the regular crest-ridge structure of the highlands is not shown in all parts of the map, nor is the appearance of stratification universal. Dykes and veins of unstratified rock are common in all parts of the highlands. There are also masses of syenite or hornblendic granite of great size, which also may or may not be of the nature of the lava coming up through fissures. One such belt is two miles wide; another has a diameter of three miles, the only sign of bedding noticeable being the parallelism of its minerals in some specimens, and the rock being an almost exclusive mixture of white feldspar and glassy quartz. Wherever the map does not show the regular oblique crest-ridge structure (that is, where the mountain tops are shaped by erosion in various directions) there such unstratified masses may be justly viewed as breaking the stratified system.

8. No contacts of the stratified and unstratified syenite or granite have yet been noticed, and, therefore, their relations to each other are a matter of conjecture. The unstratified masses are of irregular shape and seem to have

nothing to do with the northeast and southwest belting of the stratified gneisses.

9. The stratified rocks of the highlands cannot as yet be grouped in any definite order of superposition; and the same varieties of kind are to be found in all parallel ranges or belts. A representative collection of rock specimens from one belt might pass for that from the next, or any other; and collections made along many lines across the region resemble each other. The varieties of rock in any given area are endless; but on looking over the entire collection from all parts of the highlands, two principal varieties are recognized as predominating.

10. One of these, a light-colored or gray variety, is composed chiefly of white or pinkish-white potash-feldspar (orthoclase) and glassy quartz, but containing usually small brown-black scales of mica. This *feldspathic gneiss* often contains magnetic iron, hornblende, phosphate of lime and sulphide of iron, and perhaps lime-soda feldspar.

11. The other, a greenish-black variety, is made up chiefly of *hornblende*, with dark mica; but when the mica becomes more abundant than the hornblende the rock turns into a dark mica-schist or micaceous gneiss. The feldspar is white and sometimes triclinic. Some quartz is usually present.

12. Chemical analyses show that the *feldspathic gneiss* is largely siliceous, with a comparatively small percentage of alumina, scarcely any iron oxide, still less lime and magnesia, and no excess of potash and soda; and that the *hornblendic gneiss* is deficient in silica, potash and soda, but has the more iron, lime and magnesia. But recent deposits show the same elements in similarly varied mixtures. The azoic rocks of the highlands therefore may have had a sedimentary origin, although they are so highly crystalline; and if so, their original stratification ought to be more or less recognizable in spite of changes wrought by heat and pressure.

The Pennsylvania Highlands.

Such is the lesson taught by the survey of the New Jersey highlands; and it is repeated by the survey of the same belt in its extension in Pennsylvania. All that has been said by Prof. Cook of the New Jersey azoic rocks, is confirmed by Mr. D'Invilliers in his report on the azoic rocks of Berks county, described in his Report of Progress D3, Vol. II, 1883, pages 49 to 57.

These Pennsylvania highlands also have been instrumentally surveyed and mapped in contour curves on a large scale (1,600 feet to one inch) and published (on 16 sheets), in an atlas to accompany Reports D2, D3; with a geologically-colored index map (on one sheet), on a reduced scale (2 miles to an inch) showing:—the ridges of gneiss, both parallel and irregular;—the patches of sedimentary sandstone which once spread in a continuous sheet over the whole of them;—the limestone valleys north and south of them;—and the isolated limestone vales between them, proving that the limestone formation also once spread continuously over the whole region. Of these facts more will be said hereafter in narrating the history of the sedimentary formations. At present we are only concerned with the Azoic mountain ridges themselves, and the nature of the crystalline rocks of which they are composed, concerning which the following statements may be confidently made:

1. The Pennsylvania highlands make an Azoic belt, of irregular width, in a W. S. W. direction from the Delaware to the Schuylkill, south of the Lehigh river. But isolated, short, small ridges rise through the overlying sandstone and limestone strata north of the Lehigh river, showing that the Azoic floor extends underground under middle and northern Pennsylvania, as it does under New York.

2. The sheet maps plainly exhibit an oblique arrangement of N. E. and S. W. bearing subordinate ridges; and the limestone vales of the belt conform rather to this direction than to that of the belt as a whole. This oblique tendency, however, seems to belong to the more ancient folding of the Azoic rocks rather than to the later movements

which folded the overlying sedimentary strata. This is just contrary to what would be expected by a classical geologist. Nor has it all the force that it would have were the apparent stratification of the gneiss not brought into doubt by the abundance of cleavage planes, and were the apparent stratification of the gneiss traceable for long distances in any one fixed direction. But the very reverse of this is true.

3. The apparent stratification of the gneiss rocks varies in dip and strike incessantly, as shown by the arrows on the map sheets and by the detailed description of outcrops in the report, pages 57 to 98. From this it will appear that the rocks dip to all points of the compass, and commonly at high angles, rolling over from south to north and from east to west sometimes in well-defined arches, which often end or die down suddenly. Some of these arches run lengthwise of the belt; others are oblique to it and pass beneath the overlying sandstone. Thus, near Maple Grove the arch of the Gap Hill is marked by a N. 34° W. dip (of 87°) and a S. 60° E dip (of 60°), but at its east end are dips of S. 51° E. (52°), S. 48° E. (45°) and N. 70° W. (47°), and here the arch lies under the sandstone. Some distance from this the gneiss dips S. 70° E. (50°), and further on, S. 75° E. (57°), and S. 80° E. (80°). Along this ridge there is plainly a local general strike very oblique to the general direction of the whole Azoic belt.* On the other hand, groups of exposures show a general strike east by north, or E. N. E., coinciding with the belt.

4. On account of this excessive irregularity which pervades the whole Azoic belt it has been found impossible to classify its rocks into a series of formations, or even to show with any satisfaction the course of the outcrops on the map. All that can be said about them is that they are a badly crumpled-up mass of strata, of unknown thickness, all more or less thoroughly crystallized, of every grade of thick and thin-beddedness, of every tint of gray from nearly white to nearly black, of nearly every possible mixture of quartz, feldspar, hornblende, magnetite and mica, some of

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*Report D3, Vol. 2, p. 63.

them being a syenite, some a granite, some a granulite, some a hornblende-schist, some a mica-schist, some a magnetic iron ore; and all these kinds passing into one another, and overlying one another, as if the original sediments (if sediments they were) were of the most mixed and varied character, yet all derived from essentially one source and belonging to one age, an age moreover not overrich in lime and magnesia, if we may judge of it by the absence of crystalline limestone beds and beds of talc or serpentine.

5. The same broad distinction between a prevalence of dark *hornblendic gneiss* (*syenite*) carrying beds of magnetic iron ore and destitute of quartz, and a prevalence of light-colored, thick-bedded *granular quartz-feldspar gneiss* (*granulite*), destitute of mica, is noticeable all through the belt of highlands.

6. The *hornblendic rock* is full of grains of magnetic oxide of iron; and a good deal of what appears on first glance to be hornblende is in reality magnetic oxide of iron. The quantity of iron held by these strata must be immense; and, therefore, it excites no wonder to see many of the beds rich enough in iron to be mined as beds of magnetic iron ore. Where all this disseminated iron came from is a mystery; but is no greater mystery than where the grains of quartz sand came from which make up so large a part of the granulite variety. Both these constituent elements of azoic strata furnish very strong evidence in favor of their sedimentary origin. But if this be granted it still remains an unanswered question where were the more ancient land areas from which these quartz and iron sands were washed down into the azoic sea; and what kind of country could that have been to furnish such stupendous quantities of iron?

7. The *granulite strata* consist of grains of quartz, mixed with pinkish-white feldspar, and also with some grains of magnetic oxide of iron. The amount of quartz, however, is seldom in excess of the feldspar; that is, the quartz usually occurs in small glassy grains, and not in chunks. The rock is therefore, usually, as fine-grained as it is massive, and in this respect reminds one of the massive

sandstone strata of later ages and undeniable sedimentary origin. The feldspar varies in color between dull white and flesh-pink, greenish and bluish tints being rarely seen. The feldspar also varies in its relative percentages of potash, lime and soda. The strata in which the potash feldspar abounds are hard, resist the weather and show their stratification plainly; but those in which the soda feldspar, the soda-lime feldspar and the lime feldspar abound are softer, weather into rounded bowlders, and get so covered with the soil which they make in mouldering as to conceal their stratification, and this give a soft and rounded aspect to the hill slopes.

8. On the whole, the ridges which are made chiefly by the *hornblende gneiss* are higher and rougher, and their crests are rocky; but the ridges which are made chiefly by *granulite rocks* have rounded summits. The ridges on the northern side of the belt, where the iron mines are, show the hornblende character of topography more plainly than the southern side of the belt; and this geographical fact may have an important geological significance. The soils also indicate the difference; for the *hornblende* districts are covered with earth stained by the decomposition of the iron element to a deep brownish red; whereas, the *granulite* districts are covered with light-colored, sparkling, sandy earth.

9. That the *iron ore beds* are original parts of the stratification and not ejections from below is plainly shown in these highlands; for they lie in lens-shaped plates between the gneiss rocks; fining off to an edge all round; or rather fading away into gneiss rocks so gradually that one cannot say where the bed ceases to be an ore and becomes an unprofitable rock.* It seems conclusive logic that if the magnetic ore beds lie thus between the gneiss rocks, the whole azoic mass must be a sedimentary formation.

10. The absence of any noteworthy mica schist forma-

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*Report D3, Vol. II, page 239. Along the southern edge of the azoic belt some limestone has been deposited with the magnetic ore; and there is a hand specimen in the Pennsylvania collection, which shows three parallel layers of ore averaging an inch in thickness, separated by two layers of limestone each three or four inches in thickness.

mation,* of any remarkable crystalline limestone beds,† and especially of any magnesian formation (chlorite, talc, serpentine,‡ &c.), in the Pennsylvania highlands between the Schuylkill and Delaware rivers, shut in as they are on both the north and south sides by sedimentary fossiliferous sandstone and limestone formation, patches of which lie upon the very summits or are preserved between the ridges, makes it useless for us to seek for a Huronian formation here. To imagine that it once existed, but has been swept away, or that it lies buried many thousands of feet deep to the north and south of the highland belt, is a mere conjecture, worthless because unsupported by any known facts.

The Archæan rocks of the highlands of New Jersey pass across the Delaware river into Northampton county, Pa. and extend in parallel ridges through southern Lehigh and Berks as far as the Schuylkill river at Reading, where they sink (westward) beneath the Great Valley limestone, not to rise to the surface again (as a mountain range) short of York and Adams counties.§

The South mountains of York and Cumberland, Adams and Fayette were formerly supposed to be a geological continuation (or revival, geographically, going southwest) of the highlands of New Jersey and the Easton-Reading, or Durham hills; but it is nearly certain that the South mountains are for the most part composed not of Archæan (Laurentian) but Cambrian (Huronian?) strata.

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*Both muscovite and biotite mica has been found in fine scales and in large plates in several places. See D3, Vol. II, page 53.

†The crystalline limestone bed in the report of the first survey, as running through Colebrookdale, was sought for carefully but not found by the second survey. D3, Vol. II, page 56.

‡Greenish talcose slates appear along the southern edge of the belt at one or two places and will be described in another place.

§A narrow outcrop crosses the Schuylkill below Reading and runs a mile or two west. A few miles further west they appear again in Mulbaugh hill. But with these exceptions there is a gap of about sixty miles in the direct Highland-Blue Ridge range which may be said to extend from Massachusetts to Georgia. But in northern Chester, south of the direct line, they occupy the surface in the Welsh mountain region, and still further south there is a Philadelphia-Baltimore belt of them to be described further on.

Archæan types in New Jersey.

The Archæan (Laurentian) rocks of Pennsylvania have been studied as closely, but in some respects under less favorable circumstances than those of New Jersey, where they have been subjected to repeated examinations and are exposed in a bolder manner and in connection with mining operations at many places. The New Jer3ey report of 1889 is of special value.

It distinguishes four types or characteristic masses of highland strata, without positively affirming what their respective ages are, how they underlie or overlie each other, or what their mutual geological relationships may really be, but very particularly describing their geographical ranges and their mineral constituents.*

I. The *Mount Hope type* (*Feldspathic gneiss* of Smock; in part the *Hornblendic gneiss* of Britton) is a quartz-feldspar-magnetite rock, varying from massive to coarse and to fine-grained and beautifully foliated, often obscurely foliated on a fresh unweathered surface; the quartz generally in shot-like grains pressed into the cleavage face of the feldspar, which, under the pocket lens, gives a characteristic unmistakable spotted (*poicilitic*) appearance to a broken specimen; the feldspar both orthoclase and plagioclase; the magnetite usually in rough, irregular little grains, occasionally in octrohedral crystals, and sometimes largely replaced by hornblende and scattering flakes of black mica (*biotite*). These massively-bedded and usually well-foliated strata have numerous interstratified layers of hornblende-feldspar rock without quartz, some of them only a few inches thick, others many feet thick, and usually quite destitute of magnetite.—The typical Mount Hope rocks usually occupy the highest ground or summits of the ridges flanked by the Second or Oxford type of rocks; which would make them older than or underlying the Oxford; but there are important exceptions to this general

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*New Jersey An. Rt. 1889, part 2, page 12, Geological Studies of the Archæan Rocks, by Frank L. Nason. See Geol. Rts. of Pa., by Persifor Frazer, Fred. Prime, C. E. Hall and E. V. d'Invilliers, C, C2, C3, C4, C5, D, D2, D3, Vol. 1 and 2.

statement which perhaps weaken somewhat the correctness of that conclusion.

The Mount Hope type rocks may be separated into three classes: 1, Light-colored quartz and feldspar rock. 2, The same, darkened with magnetite. 3, The same, darkened with hornblende, or biotite, or both. Texture and general appearance the same in all. Dark (non-eruptive diorite-looking) feldspar-hornblende layers are often interstratified with them, and beds of solid iron ore occur in all three.

II. The *Oxford type* (*Syenite gneiss* of Smock; in part *Hornblendic gneiss* of Britton), always well foliated (even in fresh broke specimens) and not so heavy-bedded as the Mount Hope type, consists of feldspar (both kinds) and hornblende, with grains of quartz frequently rounded and imbedded in the feldspar; always only a small proportion of magnetite (sometimes octohedral); the hornblende usually distributed in strings so as to give the rock a striped appearance; and the longer axes of feldspar often oblique to foliation. The railroad tunnel at Oxford tunnel shows all the various phases of this type; but no contact with the other type can be seen; the change however seems abrupt and radical. The Oxford rocks are, however, almost everywhere seen on the flanks of those ridges the central mass of which is of the Mount Hope type. The Mount Scott range which reaches the Delaware is a sufficient example and introduces the distinction of types into Pennsylvania.

III. The *Franklin type* (probably the *Biotite gneiss* of Smock and Britton); foliation less distinct; texture more uneven; crystals of biotite, &c. at angles to each other; eyes of quartz and feldspar singly or mixed frequent (*augenstructur*); rocks rather thin bedded; frequent interstrata of biotite and hornblende schist; essentially a quartz-orthoclase-biotite rock (plagioclase rare); quartz and feldspar grains usually sharply angular, in striking contrast with other types.

IV. The *Montville limestone type;* not certainly known to belong to the Archæan; possibly of later age. Southeast belt (A); bluish gray, rarely white; crystalline; holding great quantities of *serpentine*, more or less *chrysotile;* also *diopside*, in some places small crystals of *muscovite* mica; never *tourmaline*, no *zinc*, no *iron*. Northwest belt (B) sparkling white; holding *graphite*, *tremolite*, *tourmaline*, *pyrite*, great quantities of *zinc*, and also beds of *iron*.

CHAPTER IX.

The Archæan rocks of Pennsylvania.

1. In the Reading and Durham hills.

Prof. Prime and Mr. C. E. Hall have described the highland rocks in Lehigh and Northampton counties in the same general terms;* but there is mention made not only of hornblendic and feldspathic gneisses, but occasionally of mica-schists, rocks composed of white mica and decomposed white feldspar.† Mr. Hall says, that the crystalline rocks are composed chiefly of quartz and feldspar; that magnetite is disseminated throughout the rock in all parts of the region, and that the magnetic iron beds are distinctly interstratified; that in some places the rock contains small amounts of dark mica and pyroxene (hornblende) and that occasionally particles of mica and magnetite are found together; but that many rocks are wholly of quartz and feldspar. One vein (?) of corundum has been found.‡

The Delaware river cuts through five ridges of these rocks, separated by valleys filled with sedimentary limestone. Some of these ridges seem to be rock arches pressed over northwards. In the third ridge at least 800 and perhaps 1,200 feet of strata show themselves.§

This anticlinal structure, however, cannot be made out in the ridges of the belt as a whole. Some of the ridges seem to be monoclinal and others synclinal. It is quite impossible to be sure of the correctness of any kind of structure anywhere. Nevertheless, there are places where plenty of opposing dips can be observed, although it can seldom be decided that they lie on two sides of an arch, or

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*Reports D, D2, D3, Vol. I.

†D2, page 7.

‡D3, Vol. I, pages 254-255.

§The difference being due to the possible existence of a roll.

on two sides of a basin. One example will be sufficient to illustrate the difficulties.

The Hexenkopf (*Witch's head*) is the highest point of land southwest of Easton where two of the azoic ridges converge. On its north slope gneiss rocks dip to the S. E. 54°; at its south brow 29°; on the south slope they dip to the N. W. 36°, 60° and 50°. There is certainly a basin on the south slope, even if there be an overturned arch at the crest; if there be no such arch then the whole mountain is a basin with at least 1,200 and possibly 2,000 feet of azoic strata visible on each of its sides.*

2. *In northern Chester county.*

The Welsh mountain azoic district of northern Chester county is nowhere more than 500 feet above present sea level; is surrounded by sedimentary sandstone and limestone (although the northeastern rim is concealed by still later deposits); and was once covered by them, as is shown by the patches of sandstone left upon it. It does not lie in the W. S. W. prolongation of the highland belt of Berks county, but to the south of it; the present interval between their edges being ten miles. This interval represents an ancient valley, of great but unknown depth, now filled up with Palæozoic white sandstone and limestone, covered in turn by a thick mass of Mesozoic brown sandstone and shale. The azoic rocks of both districts undoubtedly meet beneath this valley and form its floor, covered entirely by the white sandstone and limestone which rise to the present surface on both sides of it; the sandstone being about 100, and the limestone about 2,000 feet thick, and perhaps covered in places by a third deposit of slate; but of this we know nothing; only, it is certain that the limestone in the valley suffered erosion before the Trias sand and shale was deposited upon it in much later times. The thickness of these later brown sands and shales is also unknown; but, judging by the dips and distances, they must be nearly

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*See the accompany page plate, showing both alternative constructions: also the description of the locality and its rocks on pages 75 and 251, of Report D3, Vol. 1, 1883.

4,000 feet thick along their northern edge. The ancient buried valley, then, must be about as deep beneath the present mountain surfaces to the north and south of it as the valley of the Rhone between the two enclosing ranges of the Alps. Originally this could not have been the case; for the brown sandstone strata all dip northward at the rate of at least 500 feet to the mile; so that if they were deposited horizontally, either the Highlands were 5,000 feet higher than they are now, or the Welsh mountain district has been elevated 4,000 feet.

The Welsh mountain azoic rocks are, as we might suppose from their underground connection with the Highlands, the same dark hornblendic and light gray feldspathic gneisses which have been described in the foregoing pages. Being more easily destroyed by the weather than the white sandstone which was afterwards deposited upon them, their outcrops lie in shallow vales between ridges of white sandstone;* but this is owing to the fact that the softer white feldspathic gneisses, interbedded with the harder dark hornblendic gneisses, make up the greater part of the formation as it appears at the present surface. By far the most prevalent variety is a feldspar-quartz rock (*granulite*) of a grayish-white color, holding only a subordinate amount of mica, and deposited in comparatively massive beds. Some of the finer-grained kinds can hardly be distinguished from the white sandstone afterwards deposited upon the azoic rocks.† Micaceous gneiss strata, however, are also sometimes seen; but nowhere in outcrops of considerable breadth; and true mica slate only in thin interstratified layers.

It is very noteworthy that in this Welsh mountain azoic field, as in the Highland belt, the hornblendic rocks prevail along its northern portions, and the feldspathic rocks along the middle and southern portions.‡ No reason for this can, in our present knowledge of the azoic formations, be given. Eor even if it be true that two grand rock waves and

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*Dr. Frazer's Report C4, page 163.

†Pages 164–165.

‡C4, p. 165.

several smaller ones traverse the district from east to west, it cannot be proved that the hornblendic gneisses are lower in the series than the feldspathic gneisses; or, that they are brought up only by the northern arch. Such a supposition is merely a tempting conjecture.

Plumbago beds have been found in at least three places in the district. One 3 feet thick lies between gneiss strata dipping 45° to the S. E.* Another is a gneissoid stratum 12 to 15 feet thick containing about 4 per cent. of disseminated graphite, which is shown to be merely an element in the rock by the fact that the stratum includes horses of whitish rock without graphite.† An outcrop, traceable for a long distance, is that of a curious *conglomerate* (so-called) containing graphite; but, although the rock looks like a conglomerate, it is more likely to be a decomposed porphyritic crystalline rock if judged by the fresh character of its feldspar, the unworn angles of its quartz crystals, and the even distribution of the graphite through it.‡

Although exhibitions of plumbago in these azoic rocks suggest a relationship to the Canadian azoic rocks, they can have no time value for settling the order of the series, even were the relative age of the Canadian plumbago beds established; for the origin of the graphite is wholly unknown. For, while it is looked upon by some as a proof of fusion, like the graphite in cast iron, others rely on it as a confirmation of the sedimentary character of the rocks which hold it, as if it represented the consolidated and recrystallized remains of living creatures, the first and lowest kinds of plants or animals. And, in fact, graphite is found both in lava and in limestone.

Porphyries occur with the hornblende syenite; and these consist of a mixture of large crystals of potash feldspar and white (sometimes amethyst-colored) quartz, sometimes enough mica being present to make the rock a coarse porphyritic granite. The syenite layers are a dark compound of hornblende and white feldspar, and weather into round boulders and clay, and show iron stains.§

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*C4, p. 222. †C4, p. 251. ‡C4, p. 254.

§Dr. Frazer, C4, p. 215. Dr. Genth's analysis of such syenites exhibits labradorite and andesite with pyroxene.

The absence of *limestone* and *serpentine* beds from the azoic district of northern Chester is as noteworthy as their absence from the Highlands of Berks, Lehigh and Northampton counties.

The Welsh mountain proper is the westward extension of the northern part of the district into Lancaster county; a prong of gneiss, covered partially with sedimentary white sandstone, sinking beneath the great limestone plain of Lancaster, and not rising again to the surface, although the sandstone reappears on the Susquehanna river, above Columbia, and again in the Pigeon hills, on the Adams county line. (Chiques or Hellam quartzite.)

A southern prong of gneiss, covered with sandstone, and known as the Gap hills and Mine ridge, extending much further through Sadsbury and Bart townships, sinks beneath the limestone, and does not rise again to the present surface. At one point on the Susquehanna river, at the mouth of Tocquan creek, in the center of a flat arch of great breadth, the gneisses which have been described in the Highlands and in the Welsh mountain region,* should make their appearance; but they do not—neither the hornblendic nor feldspathic gneisses—but the vast arch is made up of micaceous gneisses and mica schists, apparently many thousands of feet in thickness, as will appear hereafter in the course of this history.

West of the Susquehanna river, in Pennsylvania, the highland rocks nowhere reach the present surface, for the rocks of the South-Mountain-Blue-Ridge range belong to a different system, as will be described further on. We will therefore turn back here and describe them as they appear along the Philadelphia belt in southern Bucks, Montgomery, in Delaware and in southern Chester counties, where we will find them supporting the white sandstone and limestone sedimentary formations, but also in contact with another great azoic system of an entirely different character and of as yet unsettled age.

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*Prof. Frazer's report on Lancaster county, C3, p. 71, 128. See, also, the third line of the Susquehanna river section, sheet 3, in the Atlas to C3.

3. In Bucks, Montgomery and Delaware counties.

At the Delaware river, opposite to the city of Trenton, a low range of old azoic gneiss is seen rising from beneath the mesozoic brown sand and shale formation and running in a straight course west southwestward thirty miles to the Schuylkill river above Philadelphia. For the first few miles it is more or less concealed by the earliest Delaware river gravels. From the gorge of the Neshaminy to the gorge of the Pennypack, it makes what is locally known as *the Buck ridge*, with a constant width of 2½ miles.* At Willow Grove, in Montgomery county, it splits—the northern fork soon disappearing beneath the edge of the mesozoic country to make its underground connections with the Welsh mountain region of northern Chester—its southern fork keeping on, as a narrow thread, into Delaware county, where it spreads out into three separated areas, the northern one passing on into southern Chester and the southern one into the State of Delaware.

Between the two forks commences the range of white sandstone and overlying limestone, of the Chester county valley, which runs straight W. S. W. for sixty miles, past Conshohocken, Downingtown and Coatesville, into Lancaster county. The valley is evidently a long and narrow basin, at least towards its eastern end, where the limestone is seen lying in a spoon of sandstone, and the sandstone lies in the spoon-shaped depression which splits the ridge of gneiss.

There can be no mistaking the fact that here the Chiques sandstone reposes directly upon the old azoic gneiss floor of Pennsylvania, without the intervention of any other azoic rocks, just at it rests upon the old azoic gneiss of the Reading hills. So also, for miles along the North Valley Hill in Chester county, this "North Valley Hill sandstone" or quartzite is seen lying directly upon the older azoic gneiss of the Welsh Monntain country

But it is equally evident that the age of the older gneiss and the age of the sandstone were separated by some great interval of time, for the sandstone lies comparatively flat

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*See map on page 39 of Report C6, and large sheet map in C6.

upon the nearly vertically upturned edges of the gneiss. The sandstone basin is real; the basin of gneiss is false—a mere valley worn out of a much older surface of uplifted, compressed and complicated rocks. How many ages were required for working down the ancient range of gneiss into hills and hollows before the sand of the sandstone was drifted into the water around the gneiss spurs is the most important question to be asked of our geology, and the most difficult to be fitted with a proper and probable answer. For during those intermediate ages the rain had been always falling, and the rivers running to the seas, and the seas adjusting their deposits. But where were the lands overhung with clouds and traversed by streams? And where were the seashores along which the tides were rolling gravel and spreading out the new formations of sand and mud? And where shall we seek for the rocks which represent those gravels, sands and muds? And in what condition should we expect to find them, crystalline or uncrystalline, fossiliferous or non-fossiliferous?

The Buck ridge gneiss (always called *syenite* in Mr. Hall's reports C5 and C6) has the character of the prevailing rocks of the Highlands and Welsh mountain district. The rocks are composed chiefly of quartz, feldspar and hornblende. The beds are often massive, but usually have thin bands of black mica or of hornblende. They are syenites, gneissic granites, or granite gneisses. A *peculiar bluish quartz* is a remarkable feature of the formation.* Small particles of *magnetite* are in some places scattered through the rock; but nowhere in sufficient abundance to make a magnetite iron ore bed. *Graphite* occurs; and in one place enough of it in the rock to warrant an attempt at mining, which however was abandoned.† *Crystalline limestone* occurs near Rockville, at Van Artsdalen quarry, so well-known to mineralogists.‡ A gray and red granite appears between Somerton and Feasterville.

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*Report C6, page 4.

†The old mine on A. Johnson's farm, near Feasterville, Bucks county. See C6, page 57.

‡C6, page 47.—NOTE. After his long survey of the Philadelphia belt Mr. Hall made a careful re-survey of the Highlands. See D2.

Now the rock which lies upon it is usually a fine-grained, thinly-laminated, whitish sandstone, changed by infiltration of silica into a quartzite, and full of small scales of light-colored mica; but some of the beds are occasionally coarse enough to be called a fine conglomerate; and east of Willow grove there are massive beds of conglomerate made up of rolled pieces of the Buck ridge syenite gneiss and the blue quartz, overlaid by finer sandstone beds and beds of sandy slate.* This shows that the old azoic (syenite) land was not very far off, and was bare of any newer azoic formations, mica-schists, micaceous gneiss, &c.; for not a fragment of any such rocks can be found in the sandy conglomerate.†

Furthermore, in places where the sandstone was not deposited, and where the limestone strata therefore rest directly upon the old azoic gneiss (as at the furnace quarries at West Conshohocken on the Schuylkill) the limestone beds contain similar fragments of syenite which shows the neighborhood of an old azoic seashore.‡ But how far the land extended back from the shore (towards the present Atlantic ocean), or how high into the air it rose, must be left to the imagination, unguided except by a single fact, namely, that in a long subsequent time in the history of the earth, at the end of the Palæozoic ages and the beginning of the Mesozoic ages, the azoic syenite land was out of water just as it was out of water at the beginning of the Palæozoic ages when the white sand and limestone were deposited. For, at the southern edge of the Mesozoic brown sand and slate country in Bucks and Montgomery counties the bottom beds not only lie directly upon the azoic range of Buck ridge, but are conglomerates largely made up of rolled syenite rock fragments. But whether this particular belt of azoic land remained exposed to the air through all those Palæozoic ages, during which 40,000 feet of strata of all sorts were deposited to the northwest of it, is a question to be discussed more in detail here-

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*Exposed in the N. E. Penn. R. R. cut below Willow Grove. C6, page 45.

†C6, page 5.

‡C6, page 36.

after. But surely Buck ridge could not have remained through all those ages exposed to aerial destruction unless it had been at the outset of them a high mountain range.

On the other hand, it could not have been an Alpine mountain range facing the Palæozoic sea through all those ages without doing *more* than dropping a little gravel into the white sand-beds here and there, into the lowest beds of Palæozoic limestone, and into the lowest beds of the Mesozoic sand and shale. Were it the mountainous northwest edge of an Atlantic continent it must have been somewhere or other broken by mighty rivers draining such a continent. Where are the deposits which such rivers must have made in all that lapse of ages? We will see in due time. But surely no such rivers opened their mouths in Bucks or Montgomery counties; for the sandstone (which is indeed a vast delta deposit, extending far and wide in the United States, as we shall see hereafter) is so thin in eastern Pennsylvania that it can stand for but a transitory operation at an early period of the Palæozoic age; being immediately followed by the great oceanic magnesian limestone formation (at least 2,000 feet thick in the azoic regions, but more than 6000 feet thick in middle Pennsylvania) representing a totally different relationship of continental and oceanic circumstances.

In the face of all these difficulties we might assume that the Buck ridge azoic district was a long narrow island at the time when the sandstone was deposited around it. But if so, this island must have been the crest of a mountain ridge belonging to a much larger extent of azoic land which had sunk and become submerged—at least 50 miles broad—namely, from Trenton up the river Delaware to the gap in Chestnut ridge above Easton; for over the whole of this breadth, as we have seen, the sandstone and limestone were deposited. And it looks as if the Buck ridge was the only azoic island at that time. For the sandstone patches on the Welsh mountain region and on the tops of the Berks county highlands remain in evidence that these were all submerged. Yet this seems a very strange fact on noticing that the Highland summits now stand 1,000 feet above the present sea level, and Buck ridge only about 400 feet.

We should be obliged then to suppose one of three things, either that Buck ridge has sunk additionally since then; or that the Highlands have been lifted additionally since then; or that the whole azoic underground country on which they both stand has been tilted or warped to produce the difference of height.

How idle are all such conjectures to account for the imaginary fact that Buck ridge remained an island, while the higher Highlands were beneath the sea level, when the only reason for supposing it an island is furnished by syenite pebbles in the sandstone and limestone beds, which pebbles may have come from some more distant azoic land no longer to be seen?

The impotence of the structural geologist to encounter such a problem with success becomes more and more apparent as new facts present themselves to be adjusted into place. Since those remote days in the history of the planet movements of many kinds, in shape, direction and degree, have followed each other at shorter or longer intervals, disguising and distorting or obliterating each others' traces; while the perpetual shifting of the ocean level up and down in all ages, often produced by foreign catastrophes, and originating even on the opposite side of the globe, takes from us the only index and measure of movement which might otherwise be at our command.

We know not when the excessive plication of the Buck ridge gneisses took place, whether wholly before or partly after the deposit of the sandstone. As we see them now. the old azoic strata stand nearly vertical. But it looks as if two principal folds, both tightly compressed, run along the ridge, one producing the short north spur at Willow Grove, the other following the narrow belt or thread, scarcely a mile wide, past Chestnut Hill to the Schuylkill just below Conshohocken. Whether or not these are true rock arches is much more than doubtful. But if they be, it is plain to see that two such arches in a breadth of two miles, if restored by ideal projection upward, compels us to believe that Buck ridge was once a mountain 10,000 feet high; and that it has been torn and worn and washed away down to its present lowness. There is no difficulty in believing the fact of its great height, seeing that we have absolute proof of the former existence of mountains 20,000 feet high in middle Pennsylvania, where now in the place of them spread smiling limestone valleys not 800 feet above the level of the sea. The difficulty lies in finding reasons for deciding whether the elevation of this mountain range took place before or after the deposit of the sandstone and limestone of the Chester county valley. For, in the first case, they should lie more horizontally around it and be mixed with its *débris* to a vastly greater extent than they are: and in the second case, they must have covered the mountain, been pushed up to an almost vertical posture, been eroded away along with it, and their eroded outcrops be found now on both sides of it.

To test the question let us look at their present attitude.

On the *north* side of the Buck ridge proper from Trenton to Willow Grove, and on the north side of the short northern prong west of Willow Grove, the sandstone and limestone cannot be found; their edges lie concealed underground beneath the Mesozoic brown sands and shales. But that they are there we know by an accident. Among the many probable faults in the mesozoic, one is so great in its vertical displacement—the one that runs from the Delaware river at Centre bridge (15 miles above Trenton) southwestward to Forestville near Doylestown—as to bring the ground-floor of sandstone and limestone up through the mesozoic to the present surface. This happy accident, taken in connection with their appearance again, 15 miles further north, along the south flank of the Highlands is quite sufficient to justify us in asserting that they extend beneath the mesozoic the whole distance (30 miles) between Buck ridge and the Highlands; ofcourse everywhere lying upon the azoic ground floor; but whether flat and undisturbed, or compressed into folds, or simply shifted by faults, we cannot tell.

From Willow Grove westward to the Schuylkill, along the *northern side of the south prong* of the Buck ridge, there is a continuous outcrop of sandstone and limestone (as has been already said) turned up at various steep angles from 60° to 90°.* These are the north dips on the southern side of the Chester county valley basin east of the Schuylkill; and if the curves of the basin be properly drawn they show that the bottom sandstone beds must descend to depths of many thousand feet beneath the present surface. But if the argument from structure be good for depth, it is equally good for height; and we are compelled to believe that these beds once ascended into the air with these steep dips to an unknown elevation above the present surface. What is the limit of this their uprise into the air? What is to prevent us from believing that they ascended upon the northern flank of the azoic mountain to its top, and descended its southern flank to an equal depth beneath the present surface? In fact, if they can be found along the *southern* edge of the azoic ridge, and in a nearly vertical posture (descending southward beneath the present surface) must not this be accepted as proof that they arched entirely over the azoic mountain when it was at its highest? No, not quite; for it will still remain a possibility that the azoic arch in rising and pushing up a still higher arch of overlying sandstone and limestone, broke the upper arch and left two edges separately projecting (at any supposable height) between which its own arch (broken or unbroken) rose still higher naked in the sky.†

But the main point is, are such outcrops of sandstone and limestone to be found on the *south* side of the azoic ridge? And, if found, can we be sure that they are the very sandstone and limestone of the north side? Does the sandstone lie upon or next to the azoic, and the limestone upon or outside of the sandstone? In answering these questions the following statements can be made:

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*As shown in Mr. Hall's cross sections, Figs. 18, 19, 20, 21 and 22, on page 43 of Report C6.

†In discussing the Mesozoic belt of Bucks and Montgomery counties, the elevation of the Asoic mountains of the Philadelphia belt will be offered as explanation of the northward dip of the 22,000 feet of Mesozoic sediments. It is evident that the Buck Ridge syenite was once 22,000 feet or more beneath its present position.

1. There is no sandstone, no limestone to be found in the Atlantic coast country southeast of the Buck ridge gneiss except just at its southern edge. The country between it and the Delaware river is occupied by a great series of azoic rocks, (which will come under discussion in due time) among which not a single stratum of sandstone or limestone can be found. And beyond the Delaware river the whole breadth of New Jersey is made of quite recent formations, lying upon a mesozoic floor. If Palæozoic sandstones and limestones exist beneath the mesozoic floor we must be content to remain ignorant of the fact for many years—at least until the legislature of New Jersey shall order borings profound enough to reach them to be made, and for such purely scientific knowledge only.

2. An outcrop of steep sandstone beds actually does run along the south side of Buck ridge, in an unbroken line from the Trenton city bridge, 16 miles, to Huntingdon valley (the Pennypack creek) in Montgomery county. For the next 6 miles, as far as Abington station on the N. Penn. R. R. it makes no show. Then (at Waverly Heights) it reappears and runs for 3 miles to near Chestnut Hill, beyond which it is no more seen.* It forms a low ridge, and is known as the *Edge Hill sandstone* (*eurite*, *quartzite*, *itacolumite*); many yards in thickness;† standing vertical; with the surface edges of the beds often pressed, crushed or "creeped" over at an angle always towards the south, (as seen in fig. 17, C6, page 41); so that the surface exposure has given the false impression that the formation dipped northward *under* the azoic ridge; but it is the same formation as the sandstone on the north side of the ridge.

3. An outcrop of vertical beds of limestone also runs for some distance along the south side of the sandstone east of the Pennypack, making the little valley or gentle vale of Huntingdon creek. West of the Pennypack, where there appears no sandstone, the limestone is seen running on alongside of the gneiss.

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*See the sheet maps of C6, and the small map, Fig. 14, on page 39, C6.

†It is impossible to find its southern edge anywhere, see C6, page 41, therefore it cannot be accurately measured.

‡See fig. 25, C6, page 45.

4. The west end of the sandstone outcrop at the Pennypack seems (from the strike of the beds) to be sharpened to a point. The same is noticeable at the east end of the sandstone outcrop at Waverly Heights. Some would account for the non-appearance of the sandstone in the interval, by suggesting that the sandstone had not here been deposited on the gneiss, which would account for the limestone resting against the gneiss. But an irregular line of crush faulting would afford an equally good explanation; and such a line of faulting seems called for by the thinness of this belt of limestone, and by its shortness also; for otherwise why should not the limestone run as far as the sandstone does? And, as the limestone is, say, 2,000 feet thick in the Chester valley, why should it not make a much greater show on the south side of Buck ridge? Other considerations (hereafter to be presented) add testimony to the existence of a great fault.

The Buck ridge range of syenite gneiss, then, has been pushed up since the deposits of the sandstone and limestone were made; and through them as overlying deposits. The syenite gneiss strata were, of course, under water when the deposits upon them were made. It follows, then, that any syenite fragments in those deposits could not have come down from the Buck ridge strata, but must have been brought from some syenite land at that time out of water. Where, we know not; certainly not the Welsh mountain district, nor the range of the Highlands, for they also were under water. Perhaps from Delaware county, where the syenite areas are large and we have no positive testimony to the fact of their being then submerged, although it is hard to imagine them otherwise. It is idle to look far afield elsewhere.

The Buck ridge range of syenite gneiss, however, could hardly have been pushed up thus in a quiet manner, by simply sharing in the general elevation of a 50 or 100 mile broad region of which it was one of the mountain ridges. For, in that case, the sandstone and limestone deposits would have been lifted also in a quiet manner upon it with their horzontality or seabottom-slope-dips preserved. The steepness of their present dips and their frequently vertical posture shows that the Buck ridge was not lifted but *squeezed* up; squeezing also the sandstone and limestone beds in its own folds. Therefore, we must suppose that to some extent its own folds correspond to their folds; or, in geological terms, that they lie to that extent *conformably* upon the gneiss strata.

This, however, a long and elaborate study of the whole ground (represented by the arrows, &c. on Mr. Hall's sheet map) shows plainly enough that they do not. The sandstone and limestone folds sometimes correspond to folds in the gneiss, and sometimes they do not; and many of the strike and dip details in the gneiss are evidently inconsistent with the folds in the sandstone and limestone.

We must conclude, therefore, that the azoic country had been subjected to movements *previous* to the age of the sandstone deposits, folded, elevated and depressed, weather-beaten and eroded by streams, and sculptured into a region of hills and valleys, which had to be resubmerged in order to receive the sandstone and limestone deposits upon its worn and irregular surface.

The eastern portion of the Buck ridge, *i. e.* in Bucks county, shows no sign of an anticlinal arch structure. All the dips are towards the south, at high angles (75°, 78°, 80°) all across from the sandstone on its southern edge to the border of overlapping mesozoic at its northen edge. On the Neshaminy, however, the belt (two miles wide) is a regular arch, with steep south dips at its southern edge, a 25° south dip near its middle, and vertical north dips at its northern edge. Three miles further west, a section through Feasterville shows *just the reverse*, 63° and 65° N. dips on its southern edge and 75° S. dips on its northern edge; so that one would think that Buck ridge was here an azoic *basin*. Four miles further west, along the Pennypack, where the belt is 2½ miles wide, the gneiss is vertical or (overturned?) 80° N. at its south edge, and then has 56°, 70° and 65° S. dips for 1½ miles, with nothing visible along its northern edge; and this is within half a mile of the end of the sandstone basin; so that we have south dips in the gneiss in direct prolongation of the north dips in the sandstone.

It is needless to illustrate further the fact that the sandstone does *not* lie conformably upon the gneiss, in the sense of the earliest history, but only in the sense of the later history. And here it is necessary to point out a geographical fact which seems to remove the movements of this later history far away from the azoic ages and bring them down to the very end of Palæozoic time, to the close of the Carboniferous age, the date as we know of that general movement which produced all the folds of middle and western Pennsylvania and the whole belt of Appalachian country from New York State to Alabama. This geographical fact is the extraordinary straightness and peculiar direction of the south edge of the Buck ridge belt from the Delaware river at Trenton to the Delaware county line, as shown on Mr. Hall's sheet map.

The south edge of the Buck ridge (marked by the vertical or steep south-dipping sandstone and limestone, and further west at the Schuylkill by serpentine beds) runs first S. 80° W. 2½ miles, then S. 62° W. 6 miles, then S. 79° W. 18½ miles (to within one mile of the Schuylkill), then S. 61°, W. 5 miles (to the Delaware county line).

Nothing in Pennsylvania is more remarkable than this long line of 33 miles, divided into four parts, two of which have a common strike of 61°, 62°, and the other two a common strike of 79°, 80°, especially when we consider that it represents a sudden plunge *vertically downward and southward* (with or without fault) of one great system of rocks beneath another; for one of these strikes is almost exactly parallel with that of the great plunge of the whole Palæozoic system of formations *vertically downward and northward* into the Pottsville coal basin, sixty miles distant to the north, along a line (of even greater length) in a direction S. 62½° W.

The significance of this line is intensified by another, which is undoubtedly in some way connected with it, viz: The long straight line of the vertically-plunging limestone (marble) beds at the south edge of the Chester county valley, the strike of which is S. 74° W. for 45 miles west of the Schuylkill river.

Generalizations become more dangerous as they become larger; but it is impossible to shut the eyes to the fact of a grand parallelism of the anticlinal and synclinal folds throughout Eastern Pennsylvania, produced by a horizontal movement from the southeast; or to the fact that the system of parallel folds as a whole is itself parallel to the special uplift of the azoic belt of Buck ridge which we have been describing in the detailed manner which its importance justified.

The historical azoic question raised by all this parallelism is this:—Were the Palæozoic sediments shoved northwestward on the Azoic floor, adjusting their gigantic plications upon it without regard to its own previously plicated condition;—or, did this azoic floor consist of a system of parallel mountain ridges which decided the parallel direction of and located and increased the Palæozoic folds;—or, was the real folding accomplished in the azoic floor itself, the Palæozoic formations merely sharing in the movement;—or, was the whole movement a complication of *additional azoic* crumplings below, with *new palæzoic* foldings above? These alternative hypotheses must be discussed more fully when we come to the history of the palæozoic ages; but it was necessary to allude to them in advance in drawing attention to the remarkable line of the Edge Hill or south border of the Buck ridge azoic belt, and especially the most remarkable part of it, viz: the 16½-mile straight S. 80° W. line, against which abuts *diagonally* the Philadelphia gneisses.

The Buck ridge old azoic (syenite) belt crosses the Wissahickon at the complicated bend of the creek a mile west of Chestnut Hill; not as a ridge, but mouldered away to the level of the stream, and only 400 hundred yards wide. Thus it runs on a mile and a half further west to Barren Hill; then a mile and a half further west to the Schuylkill river at Spring Mill, where it is just one mile wide. The river after crossing the limestone valley strikes the hill belt of syenite, turns east and flows for a mile at its foot to Spring Mill, and then turning at a right angle southward cuts through it between bluffs of nearly vertical syenite rocks for a mile.

Here the dark hornblendic rocks are pretty plainly arched, although most of them are vertical, or dip very steeply northward (as the sandstone and limestone strata do which face the north side of the ridge); but obscure south dips are seen on the southern side of the belt, where the Philadelphia system abuts against it along a line of fault, at the first brook above Lafayette station. All the exposures from here down the river past Manuyunk and Philadelphia belong to the *Newer Azoic system* of mica-schists and micaceous gneisses to be described in the next chapter.

In Delaware and southern Chester counties the old syenite azoic areas are so irregular in shape that they can only be described by reference to the geological colored county map.* As defined by Mr. Hall they appear as on the accompanying sketch map, by which it will be seen that their irregular outlines are produced by the partial removal of the overlaying Philadelphia system of micaceous gneiss. The whole district is a low rolling hill country nowhere more than about 500 feet above tide level; and the older gneisses being more easily decomposed, their areas are somewhat sunk beneath the general surface, and surrounded by the indefinite, gently sloping escarpments of the borders of the micaceous gneiss areas. Only one syenite area has a well determined east and west extension, between Bryn Mawr and West Chester, with an outlying area further on, crossing the Brandywine. Chester creek makes long exposures of the syenite, which appears also on the Delaware state line and in the northernmost county of that state.

4. *On the Schuylkill River.*

Prof. Rogers' description of the syenite belt where it crosses the Schuylkill river is given on page 76 of his geology of Pennsylvania, 1858.

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*See them represented, as defined by Mr. Hall, in a plate on page vii of the preface to Report C4, on Chester Co., 1883.

The "harder feldspathic gneiss" is first seen (ascending the Schuylkill) north of the soapstone quarries, dipping *southward* 70° and even steeper; and then *northward* 45° to 55°, making a sharp anticlinal arch, up through the broken center line of which has flowed a strong dyke of syenite gneiss. Passing the blue prophyroidal gneiss quarries the strata are lying nearly flat for say 1,500 feet, and then turn up and stand nearly vertical, being closely compressed into numerous narrow folds, all the way past the Wm. Penn iron furnaces, nearly to Spring Mill, at the sharp bend of the river, where the valley limestone appears.

He describes in detail (on page 75) the character of the strata from the dyke northward; commencing at a small dyke, 100 feet south of the end of the long tangent of the Norristown railroad, which follows the east bank of the river. His description may be divided into the following parts:

(*a*) Dyke of syenite, small, composed of pinkish feldspar and quartz; next north of which come

(*b*) Gneiss rocks, dipping 80°> N. 20° W., composed of feldspar, quartz and hornblende (with some mica), coarsely crystalline, evenly bedded with parallel lamination (not minute or very continuous) dipping 80°> N. 20° W. (Some beds have feldspar in excess and may be called porphyries.) Similar massive gneiss cut by the Reading railroad on opposite river bank. Distance along railroad 160 feet.

(*c*) Dyke of syenite (about 100′ north of first dyke), coarsely crystallized pinkish and white feldspar, with a much less proportion of quartz, and a considerable amount of large specks of finely granular (imperfectly crystallized) hornblende. Dyke 10′ thick. Contact with gneiss makes a plane dipping 70°.

(*d*) Gneiss, massively bedded, bluish gray (feldspar, quartz, mica, occasionally some hornblende), many beds prophyroidal, feldspar appearing in large insulated blotches. Granite injections in gneiss near the syenite dyke.

Extensive quarries. Bold nose of hill at bend of river.

Dip of gneiss for the first 250′ regular, 45° to 50° > N. 20° W. Then rather suddenly flattens to a small angle.

Dip of gneiss at 900′ from the quarry, gently *south.*

(*e*) Interval between "the small quarry" and the south end of Wm. Penn furnace No. 2, 387′. Here

(*f*) Gneiss massive, dark-blue, streaked and spotted (with lens-shaped white blotches); composed of feldspar and dark blue mica, in alternate slightly wavy laminæ, with lens-shaped concretions of pinkish feldspar. In some of the bands these lumps are so abundant as to make the rock porphyroid. Other bands finely laminated, the laminæ being in delicate, parallel, slightly wavy, bluish black and pinkish white streaks, according to the relative proportions of the dark mica and pink feldspar. The rock contains some quartz, and occasionally some hornblende. Dip (under furnace) 90°.

(*g*) Gneiss (at N. end of furnace No. 2) feldspar mica; some of it minutely banded; no feldspar lumps.

(*h*) Trap dyke (266′ north of north end of furnace No. 2), very hornblendic; thickness, 8′.

(*i*) Gneiss (421′ north of north end of furnace No. 2) same as (*f*); some beds with feldspar lumps, but fewer and smaller than in (*f*); all more minutely and evenly laminated than (*f*); a real gneiss, but more like altered clay-sandstone. The feldspar weathers mealy, chalky.

(*j*) Dip at north end of *Old furnace No. 1.* 60° >.

(*k*) Gneiss (100′ north of north end of *Old furnace No. 1*), feldspar-mica; exposed for 170′; dip at south end of exposure, 80° >.

(*l*) Gneiss (?) (330′ north of north end of *Old furnace No. 1;* with feldspar lumps and specks rounder than those of (*f*); finely streaked; looks less gneissic and more sedimentary; strike S. 70° W. (pointing across the river to the ferry house opposite Spring Mill); dip, 90° >; visible thickness (in exposure) 100′; ranges along the base of the hill slope from ferry house up the river bank to Merion furnace opposite Conshohocken.

The rock mass (*l*) conforms to the vertical gneiss (*k*) in strike and dip, but is more earthy and less crystalline, and, in fact, looks so different that Prof. Rogers feels authorized to place it at the base of the palæozoic system, lying immediately upon the gneisses (*k*) all in vertical posture.

The difficulties of structure are great, perhaps insuperable. If the gneisses be closely folded and the folds pressed together, so as to make one dip, and there be no clue to the character of the last or northernmost fold, it becomes impossible to tell whether (*l*) lies upon or beneath (*k*); for, if the last beds of (*k*) are rising northwards, then (*l*) underlies; if *falling*, then (*l*) overlies. Mr. Rogers regards the horizontal middle part of the belt as a basin, but it may be the flattened top of a grand arch; in which case, all the vertical gneisses of the northern side of the belt are going down together, and this is the only view to be taken of them in harmony with their extension eastward and their encircling at Willow Grove the sandstone and the limestone of the valley.

Another difficulty arises from the abundance of mica in the masses (*f*) (*g*) (*i*) and (*k*) and especially (*d*) in which hornblende is only an occasional element. In fact, only division (*b*) of the whole belt is distinctively a hornblende-syenite. This difficulty will be felt when we come to describe the Philadelphia azoic belt lying alongside and south of this Buck ridge belt and supposed to be a different system, chiefly if not exclusively on the ground of its exceptionally micaceous character.

As for the two "dykes" of syenite (*a*) and (*c*) containing little or no hornblende, they may be integral members of the series. But if they be true igneous dykes they are merely additional examples of what we meet with in the Highlands and Welsh mountain regions.

The trap dyke (*h*), very hornblendic, belongs to a very late time of disturbance during and at the close of the deposit of the Mesozoic brown sand and shale, when all our largest trap dykes were ejected from the interior as black lavas, and the whole region of middle New Jersey and southeastern and southern Pennsylvania, in fact the whole wide belt of the Atlantic seaboard, was shattered and rifted by continental earthquakes on the grandest scale.

CHAPTER X.

Are the Archæan rocks sedimentary?

The alternations of feldspar-gneiss beds with hornblende-gneiss beds is as easily explained as the alternation of hard sand-rock beds and shale beds among the sedimentary rocks; or as the alternation of limestone and magnesian-limestone beds in great limestone formations.

The feldspars are combinations of the silicate of alumina, with silicates of lime, soda and potash, and a little magnesia and iron.

The hornblendes are combinations of the silicates of magnesia, lime and iron, with more or less silicate of alumina, and little or no soda.

The chemical analyses of both the feldspars and hornblendes show an infinite variety of these combinations; which means an infinitely various mixture of the six silicates of alumina, lime, soda, potash, magnesia and iron; as might be expected when rivers bring down sand and mud from a country of all sorts of rock, mixing them on the way in all possible proportions, and laying them down in beds of all possible thicknesses, shapes and order of superposition.

Where the pure quartz sand was in great excess, the rock became a quartzite. Where the alumina was in excess, a massive feldspar rock was afterwards produced. Where the quartz was simply in excess of the alumina, a quartz-feldspar syenite gneiss was the consequence. Where there was a considerable charge of potash and a small charge of iron, the deposit became a quartz-feldspar-mica granitic gneiss. Where magnesia and lime were abundant, hornblende crystals were formed, if the deposit did not originally consist of rolled hornblende crystals, obtained from some weathered country composed largely of hornblendic rocks.

In a word, given sediments of sand and mud, composed of coarse and fine particles of quartz and feldspar, some of them from a country poor in magnesia, others from a country rich in magnesia, there must result alternations of felsitic, micaceous and hornblendic gneisses, in beds of every thickness and thinness, and in every variety of grouping.

If, in the upper part of a great formation feldspathic gneiss beds predominate, while in its lower part hornblendic gneiss beds predominate, such an arrangement ought to indicate that the drainage of the country which supplied the materials was at first more magnesian or dolomitic, and became less so afterwards. And if a great formation with few micaceous beds be succeeded by a great formation of mica schists, such an arrangement ought to indicate another change in the drainage system, viz., an increase in the quantity of potash with iron in the river waters.

Throughout the Cambrian, Silurian, Devonian and Carboniferous ages such changes in the drainage system of the continent which furnish the numerous palæozoic sediments of middle and western Pennsylvania certainly took place, or else we should not now have that remarkable pile of dissimiliar formations, arranged in no assignable logical order, and composed of an infinite variety of combinations of coarse and fine grains of quartz, of the different feldspars, and of limestones with more or less magnesia and iron. We have a right, therefore, to suppose such changes of drainage to have occurred in pre-Cambrian time. On this supposition, and granting the possibility of the partial or complete re-crystallization of sediments with a total destruction of all traces of organic life (if such existed), it becomes an easy matter to explain the alternations of syenitic, hornblendic, granitic, micaceous and garnetiferous gneisses and schists, with clay slates, mica slates, talc slates and even with such serpentine beds (hydrated silicates of magnesia and iron) as cannot be proved to have had a volcanic origin.*

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*Even Professor Bonney admits this distinction.

The argument from the microscope.

There is a new school of geologists who trust to the microscope for deciding whether an apparently bedded mass of crystalline rocks were originally sedimentary strata, or whether they were ancient outbursts or outflows or overflows of molten rock-glass taking on the appearance of stratification in the course of their lava-like movement.* Such geologists take a totally different view of the order of the old gneiss system rocks, and reject its chronological subdivisions into Lower, Middle and Upper Laurentian. Their point of view is strengthened by the acknowledged fact, that the whole Laurentian country from Lake Superior to the shores of Labrador, northern New York and much of New England is traversed by vast dykes of massive (unstratified) syenite and granite cutting the bedded rocks and each other in all directions both vertical and horizontal. Such masses or dykes of unstratified rock in the highlands of New Jersey have already been referred to.†

At Kennedy's granite quarry, in Delaware county, Radnor township, near Wayne station (a good photographic view of which is given on plate XXXVIII of Report of Progress C5), no stratification can be made out by the eye, and the syenite mass looks like an eruption from below.

In strong contrast to this is the fact that at the Leiper "granite" quarries, so called, in Ridley township (shown in plates 16 to 22 of the same report) the original sedimentary stratification is unmistakable. But here we are in another system of rocks which has no certain connection with the Laurentian, as will be seen hereafter.

How much of the Laurentian system is sedimentary and how much of it volcanic may never be exactly defined; but the mere fact that one kind of rock can be seen cutting or penetrating the other is the strongest argument for the genuiness of both, in spite of opposite theories of the general

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*Rhyolitic, from the Greek verb *rhein*, to flow.

†The granite of Richmond, Va., is of this kind.

origin of the whole, and in spite of any revelations which have been or may hereafter be made by the microscope; with regard to which last, it may be also said, that the microscopic examination of a transparent slice of azoic rock may lead two observers to opposite conclusions under the influence of two opposite prejudices, the one believing at the outset that his specimen comes from a volcanic rock, the other that it is from an original sediment subsequently metamorphosed.

The argument from olivine.

A case in point occurs in Mr. F. D. Adams' report to the Canada survey (in 1885) on microscopic inspection of thin sections of a labradorite rock from the Upper Saguenay river, flowing through the typical Norian region. In the sections he could see grains of *olivine*, each having two skins, an inner of *pyroxene* (?) and an outer of *actinolite* (or *hornblende*), the whole being encased in a matrix of *lime-soda feldspar*. The rock at large, from which the sections were made, was composed of lime-soda feldspar, olivine and some scattered grains of titaniferous (?) iron ore. Now since *olivine** is one of the universally recognized volcanic glasses, abundantly expelled from modern volcanoes†; and since it is of frequent occurrence also in older lavas, basalts and trap dykes, both in the form of grains and small masses, long crystals and balls; and since its golden-colored *transparent* crystals (*chrysolite*) also is found in modern and recent lavas,‡ the conclusion has been drawn that the Saguenay rock formations taken as a whole have been originally in a molten condition, and that the olivine grains were the first to solidify while the enveloping feldspar mass was still in the condition of molten glass; in other words, that the silicate of magnesia solidified in

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*A pale olive green opaque silicate of magnesia and iron ($\frac{4}{10}$ sil., $\frac{5}{10}$ mag. and $\frac{1}{10}$ iron.

†See especially accounts of the Hawaiian islands, and of the Challenger dredgings in the Pacific.

‡Those found in sand at Expailly in France (Dana) probably came from the Auvergnese basaltic beds.

grains first, and the silicates of lime and soda as the surrounding rock afterwards. The enveloping zones or skins of each olivine grain seen under the microscope would then be the products of a slow subsequent process, by which the surface of each grain (silicate of magnesia and lime) lost some magnesia and became a *pyroxene* or augite ; while the surface of the enveloping feldspar gained some magnesia and became an *actinolite* or hornblende (silicate of magnesia, lime and iron); both the inner zones of pyroxene and the outer zone of actinolite being minutely crystallized in fibers crosswise. Similar grains with double skins (the outer hornblende) were described by Tornebohm,* as seen in Swedish *gabbro* rock (an ancient crystalline, granite-like, magnesia-lime-soda lava) the feldspar of which is usually taken to be labradorite, and some varieties of which contain an abundance of olivine.†

It is easy enough to see how a grain of strongly magnesian silicate might act on and be affected by its envelope of lime-soda silicate to produce in time intermediate skins or shells of magnesia-lime-soda silicate by the gradual mixing of the three elements along the contact surfaces. But it is a risky thing to dogmatise an opinion, 1, as to how the grains were first formed, and 2, as to the nature of the action and reaction between the grain and its envelope. While it may be safely accounted probable that the magnesia was concentrated by the *fiery* fusions of the mass; and while it seems almost positively certain that the fibrous zones could not have been cross crystallized around the grains until after they had been fully formed; we know too much of cold aqueous concretionary structure in sedimentary rocks (*e. g.* oolites in the magnesian limestones of No. II‡) not to make the *aqueous* formation of the olivine grains a possibility. And then, the aqueous alterations of minerals seen going on at a low temperature in the hardest crystalline rocks, at all depths of permeation, suggests the possibility of the cold aqueous formation of the skins of the olivine grains.

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*Neu. Lehr. für Min., 1877, page 303, Adams.

†A. Geikie's Text Book of Geol., page 150, 1882.

‡Cambro Silurian.

The granular condensation of the overcharge of magnesia in a magnesian silicate mass is illustrated by Dr. F. A. Genth's discovery in 1874 that grains of *chrysolite* are disseminated throughout the whole mass of *bronzite* (iron-bearing *enstatite*) forming Castle Rock in Delaware county.* The *bronzite* mass is a silicate of magnesia and iron (57, 36, 6). But the grains of chrysolite have twice as much magnesia and iron to the silica as the rock has which envelops them. In studying Castle Rock repeatedly I could not quite convince myself that it is stratified, and therefore do not deny that it may be a volcanic dyke. But on the other hand it is an integral part of the long belt of serpentine strata which crosses the county; therefore it ought to be sedimentary. But this belt of Delaware county serpentine rocks does not belong to the older gneisses; it belongs to the mica schist series to be discussed hereafter; therefore, the question of the volcanic origin of Castle Rock does not directly affect any question respecting the stratification of the older syenite belt which passes just north of it.

The point to keep in view is this, that the genuineness of the stratification of the older gneiss rocks is not impugned by any amount of volcanic disturbance and intrusion to which they may have been subjected; nor by any number of massive granite dykes, bosses or layers of gabbro;† nor by any amount of olivine discoverable in the area of country which they occupy.

The scarcity of olivine in the older gneisses can be appreciated from the fact that in the long course of the history of the geological survey of Canada its accomplished chemist and mineralogist, Dr. Hunt, never saw (or at least never reported finding) olivine in the Norian gneisses, although he found it in some (Norian ?) boulders in New Hampshire which were supposed to have come from Canada in the ice age.‡ When Mr. Adams says that it "occurs abundantly

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*Report of Progress B, page 163.

†Such as the Gabbro formation of Lake Superior, which, however, is placed above the gneiss by western geologists.

‡Adams, Am. Nat., Nov., 1885, page 1088.

in the anorthosite of many parts of the Saguenay area," and that he has found it also in a hand specimen from old rocks near Dolin's lake in New Brunswick, such discoveries leave the question of the aqueous or igneous origin of the great gneiss formation as a whole still unanswered; for it is supposable, and will be to many minds probable, that the observed occurrences of olivine are referrable in all cases to dykes or layers or bosses of igneous rock ejected through and between the recrystallized sedimentary gneiss beds, and not to the constitution of the gneiss itself.

The argument from serpentine.

It is needless to discuss the vexed question of the origin of serpentinous rocks if we recognize the fact that they may be of various kinds and have more than one origin; some of them being sedimentary, others volcanic, and yet imitating each other in the same way as the granite gneisses and granites imitate each other.

In Pennsylvania we have no notable serpentine beds in the Highland, Welsh mountain, Buck ridge, Delaware county older gneisses. A discussion of the serpentine beds of the mica schist series on the Schuylkill and west of it would properly find its place in describing that series. But as Mr. T. D. Rand has argued in the most forcible manner for the assignment of these serpentines to a place in the older gneiss series, not only in Delaware county, but also in Northampton county, it is better to give the facts here. In the proceedings of the Academy of Natural Sciences of Philadelphia, November 24, 1886, pages 393, 407, and in the annual report of the geological survey of Pennsylvania for 1887, Mr. Rand's views may be found with illustrative maps and sections.

Of the two parallel *serpentine* belts that cross the Schuylkill river (1) *above* and (2) *below* Lafayette station, the (2) belt (with *steatite*) cannot be traced (west) beyond a bend in the Black Rock road (one-half mile north of the P. R. R.) The first belt is conspicuous at Rosemont station (P. R. R.), but no farther. A (3) belt commences on Meadow brook ¾ mile east of Darby creek and runs on westward. It was always doubtful to which belt (1) or (2) this should be assigned. In 1885 Mr. T. D. Rand* "found a distinct outcrop on the Roberts road, on the property of Colonel Joseph F. Tobias, or of Dr. E. H. Williams, with fragments in the soil of the former to the northeast. The belt is very narrow, and the valley of a small creek seems to occupy nearly the same line." The outcrop is about half-way between the Rosemont (1) exposure and the Meadow brook (3) exposure and seems to settle the question.†

The *Edgehill* (*eurite*) *rock* seems to outcrop 100′ to 200′ from the *serpentine* on the Roberts road. The two occupy here the same relations as they do near Radnor station, on the other (N.) side of the Laurentian axis.

The Delaware county serpentines.

Castle rock, four miles north of Media, in Delaware county, is a confused mass of plates of that species of *enstatite* rock‡ which contains iron (*bronzite*) and which, after imbibing water (chemically) turns into *serpentine* rock (composed chiefly of silica and magnesia.)§ On the eastern side of a brook flowing south there are outcrops of serpentine which indicate the continuance of the mineral towards the Schuylkill; but at the west end of the Castle

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*Strike N. 30° E., dip 50° S. 60° E.: mica schist, adjacent, strikes N. 40° E., dip 65° S. 50° E.

†This outcrop is somewhat south of the Rosemont outcrop line and indicates some change in strike, or a throw, or an echelon structure.

‡In Bucks county, near the Neshaminy, between Scottsville and Rockville, at Vanarsdalen's quarry of crystalline limestone (interbedded with hornblendic gneiss and charged with plumbago) among the numerous species of crystals some contain percentages of magnesia, but none come under the head of magnesian silicates proper. (Report B). Near the mouth of the creek, at Flushing is an outcrop of enstatite rock, bedded and dipping 10°, the relations of which are not understood. (Report C6, p. 60.)

§Mr. Salom, when Dr. Genth's pupil, found that between 5 and 10 per cent of the Castle rock was soluble in dilute chlorhydric acid, and composed of silica, 45; mag., 31.5; ferrous oxide, 19.4; lime, 3.9, representing disseminated grains of *chrysolite;* the insoluble 90 to 95 per cent was composed of silica, 56; mag., 29; ferrous ox., 12; lime, 1.2, closely agreeing with the composition of *bronzite*. Genth's Rep. B, 1875, p. 64.

rocks a cultivated outspread of gneiss land soil shrouds the geology of this singular place in mystery.*

There is a range of abandoned quarries extending from Media W. S. W. past Lenni for miles.† Other ranges traverse the county. C. E. Hall's sketch map in C4, preface page v, shows more than 50 spots marked serpentine. It is noteworthy that none of them are in the *Older* (syenitic, hornblendic) *gneiss* regions. All of them are in the interval regions of *Newer* (micaceous) gneiss, the equivalent of the Philadelphia belt. Nor are any of them in the South Valley Hill belt of mica slate.‡

The Chester county serpentines.

Serpentine outcrops are very numerous in Chester county. Thirteen are enumerated in Report C4, pages 62, 63. Brinton's quarry is a grand exhibition of serpentine, and from this quarry 500,000 cubic yards of the rock had been taken before 1880, the largest being 3 feet square and 16 feet long. In 1880 6,000 cubic feet of rock were moved, valued at $10,000.

Dr. Frazer makes the general remark that "the serpentine under no consideration has any direct connection with the series of hypozoic and palæozoic strata, or strata of primary origin.§

The serpentines near Baltimore are said to furnish under the microscope ample evidence that originally they were

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*Mr. E. B. Harden has made for me photographic pictures of the mass as it appears on all sides and in various lights. I have myself made a careful contour line map of it, with pencil sketches; but I could come to no certain conclusion whether its apparrent bed-plates were or were not cleavage planes. It may be synclinal, or it may be a dyke.

†See also notes on the minerals of the county by Col. Joseph Willcox, in C4, p. 346.

‡Mr. Hall and Mr. Rand are thus directly opposed in their structural views respecting the Serpentine. Dr. Frazer agrees with Mr. Hall in isolating the Serpentine from the Archæan, but he advocates its connection with the hydromica and chlorite series.

§Report C4, page 289. Prof. Rogers notes serpentinous geodes in the Welsh mountain gneiss, at Warwick mines, Report C4, page 238. Fine specimens of serpentine have been found in the mines on Fritz's island near Reading, at Topton, and at the Wheatfield, Boyerstown, Ruth and Jones mines in Berks county; but no serpentine beds. See Reports D2 and D3.

trap dykes, holding a rhombic pyroxene, with or without olivine.*

A similar conclusion was reached by Prof. F. D. Chester, of Dover, Delaware, in studying the large belt of serpentine on the state line in Chester county;† and he was led to regard all the serpentines of Chester county as alterations of rocks containing a rhombic pyroxene, either *enstatite* or *bronzite.* The great mass of Castle rock, unchanged enstatite rock in Delaware county can be seen passing on eastward as a serpentine outcrop.

The Lancaster county serpentine.

The two remarkable belts of serpentine in southern Lancaster, passing over into Maryland, are described in detail by Dr. Frazer in his Report C3, pages 26, 89, 177, 190. Wood's celebrated chrome mine is in the southern belt in an oxbow of Octoraro creek just within Little Britain township. In Fulton township the serpentine ridges are called "barrens." Up to 1877 about 90,000 tons of chrome-iron ore had been taken. The mine was then 720 feet deep and yielded 500 or 600 tons of the ore annually. The serpentine country through which the ore vein runs is unstratified and about three quarters of a mile in breadth. The ore strikes S. 78° W. The sandy chlorite slates to the north of the mine dip S. 50°. The rocks southeast of the mine are hornblendic, and "a region of syenite commences on that side"(Glenn). The same kind of difficulty here encounters the geologist as in Northampton county, whether he is disposed to connect the serpentine structurally with the older hornblendic gneiss (syenite) system, or with the newer gneiss (mica schist) system, or with the still later chloritic (phyllite) system.

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*Dr. G. H. Williams, of the Johns Hopkins University, on the Peritodites and Serpentines of Baltimore.

†Letter, Oct. 23, 1886. The mother rock of this belt appears to consist of a rhombic pyroxene, probably *bronzite*, associated with a variable amount of *diallage*, both minerals largely altered into light amphibole aggregates, generally *tremolite*, partly *actinolite ;* and these are found in all stages of alter_ nation into a true *chrome-serpentine*, the direct product of alteration of pyroxene, as described by Drasche in the Tyrol.

The Northampton county serpentine.

The *serpentine* of the old Wolf quarry of Chestnut Hill, Northampton county, seems to be not an originally bedded deposit, like limestone, but an alteration product in the white *tremolite** quarry-rock (belonging to the hornblendic or amphibole gneiss series), composed chiefly of silicate of magnesia and lime. The *silicate of magnesia* after imbibing water has separated from the mass into veins and lumps and scattered pseudomorph crystals of pure *serpentine*. The lime has also separated in the form of veins and masses of snow-white crystalline carbonate of lime (*calcite*). It is possible to trace on the face of the quarry, in the space of a few inches, the gradual transformation of the pure white tremolite rock into a mixed stone composed mainly of *serpentine*, *tremolite* and *calcite*. The steps of the process is observable in the thin slices under the microscope, the *tremolite* crystals being broken up into bundles of fibres traversed by irregular canals of *serpentine.*†

It was always an interesting question whether the serpentine beds of Chestnut hill belonged to the Highland gneiss or to the limestone of the valley;‡ but Mr. Rand seems to have set the matter at rest by his observations in the gap of the Delaware above Easton and in the gap of the Bushkill west of the river.§

Five soapstone (*steatite*) outcrops are exposed and four of them have been quarried, all dipping steeply southward enclosed between solid ribs of gneiss one or two hundred feet thick.‖

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*See Genth's Report B, 1874, page 67. On page 64 he notes that the "*Wallastonite*" of Easton is *tremolite*.

†G. P. Merrill, in Proc. U. S. National Musenm, Vol. VII, 1890, page 600, where an analysis of the tremolite by Eakins is given: Sil. 58; Mag. 26; Lime 12; Alum., Potash, Sod 4.

‡See Rogers' Geol. Penn., 1858, Vol. 1, p. 94, and Report D3, Vol. 1, 1883, p. 79.

§T. D. Rand. Notes on the genesis and horizons of the Serpentines of S. E. Pa. in Proc. Acad. Nat. Sci., Phila., March 25, 1890, page 95.

‖South-dipping magnesian limestone outcrops border the river for a mile above Easton to within 200 feet of the first exposed *steatite* or talc-slate bed, which is not thick, has no visible hanging wall, but a foot-wall of gneiss. The second one is immediately below the first and in the gneiss; one mass

Chestnut hill is the western end of one of the Highland ranges of New Jersey, severed by a steep and picturesque gap cut through it by the river. Its beds of gneiss dip all one way, southward, as the limestone beds do to the south of it. There is no appearance of anticlinal structure in the ridge.[*] Its crest, straight and sharp, is made by a massive rib of gneiss, dipping at the river 31°; at its highest point (700′ A. T.) 59°, on the road 30°, at the Bushkill gap 40°, 43°, 48°, 60°, further west 28°, all southeast; no northwest dips anywhere, until its western point sinks beneath the around-lapping limestone country, the nearest outcrop of which dips 12° S. W. That the whole ridge is a monoclinal uplift is confirmed by the first limestone dip (28°, N.) seen at the Bushkill gap abutting against the lowest visible gneiss dipping 48°, S. E.[†] The talc-schist or soapstone beds, and the serpentine (picrolite) beds are not of the age of valley limestones (magnesian though many of these be) but belong to the more ancient gneiss formation of the South

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of it among many (5′–6′ long) nearly pure talc schist at one end, at the other apparently unaltered qartzose gneiss. Two hundred feet north of the second appears the third, quarried for 100′ up the slope; both walls gneiss, fallen blocks of the hanging wall showing change from granulite to steatite. The fourth and much larger one is 300′-400′ further north; interval, all (?) gneiss. The fifth 200′-300′ further north; interval all gneiss, (one rib very massive, making overhanging cliffs, has been much quarried). Beyond this, more gneiss; dips obscure, but nearly vertical; hill crest more than 400 above the river. Incredible that these four outcrops should be tightly-compressed synclinal folds of a talc schist formation overlying the gneiss. They must be conformably interbedded layers in the (Laurentian) gneiss. (Rand.)

[*] All this is noted on Prime's admirable contour-line map of Northampton county in Atlas to D3, Vol. 1, 1883, sheets 1 and 2.

[†] It is not absolutely necessary to suppose an upthrow fault along the northern base of the ridge, for a 28° dip would shoot the limestone high over the ridge. Nor is it a mere "brushed up" dip, for all the observed limestone dips along the Bushkill for a mile up (and along the Delaware as far) are in the same N. W. direction, towards a synclinal axis of considerable length. Although the ridge itself is a very ancient eroded monoclinal, it became the core of a subsequent overarching limestone anticlinal, which included all the Lower Silurian formations, probably the Upper Silurian series also, and possibly the whole Palæozoic system to the top of the Coal Measures. There has been time enough since the Coal Age to remove it all, and exhibit once more the original pre-Silurian or pre-Cambrian topography.

mountain highlands whatever it may be.* And this agrees with all Mr. Rand's observations of the serpentines of Delaware and Chester counties, which he shows pretty clearly to be interbedded among the ancient gneisses of that region.

On the other hand, the serpentine belts of Lancaster county and Maryland are assigned both by Frazer and Keyes to the phyllite system of rocks, which belong to the Philadelphia belt of newer gneiss; and the serpentine and steatite of the Schuylkill are placed by Rogers and C. E. Hall at the top of that newer gneiss system.

In Newfoundland, as in Pennsylvania, no extensive display of *serpentine* is known in the Laurentian system, nor is *crystalline limestone* found. Lime, magnesian minerals, and mica are remarkably absent from the great overlying formation (Huronian); lime showing only in cross veins, and magnesia only at one place, as *steatite* and *asbestos*, in seams. Guided by the fossils Mr. Murray came to the conclusion that the *serpentine formation* overlaid the Levis (Quebec group) and were overlaid by the *Hudson river group*, etc. *unconformably*, so that they were even overlaid in places by Devonian. This possible identity of the Newfoundland serpentine formation with our great magnesian limestones (No. II. Chazy?) would bring it into the neighborhood of the Northampton county serpentine beds, north of Easton.†

Genthite has been found at the Lafayette soapstone quarries, in small, bright, emerald green crusts, showing its characteristic stalactitic structure. This proves the presence of *nickel* in our serpentines.‡

The argument from labradorite.

Labradorite rocks are unknown among our older gneisses

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*Another good argument both for this and also for the monoclinal structure of Chestnut ridge, is the fact that no serpentine or talcschist or steatite is to be seen anywhere along the northern side of theridge, or at its northern base.

†Alex Murray, Canada survey, in Geol. Mag., March, 1879, p. 139.

‡H. C. Lewis, May 12, 1885, in report of Acad. N. S. Philada. meeting in Amer. Nat., Sept., page 929.

in Pennsylvania; and about this it is necessary to say something.

The eastern range of the Canadian mountains, through Labrador to the ocean shore, is a country of massive and schistose gneisses, many of which are made up of quartz and *labradorite* feldspar.* This feldspar is essentially a silicate of alumina, lime and soda (53 : 30 : 12 : 5), and might be formed in a metamorphosed sediment just as well as any other feldspar, provided the drainage of that sediment was from a limestone region. It is a frequent constituent of modern volcanic lavas, and is found also in some ancient trap-dykes and porphyries; but so are several other feldspars. It is in itself no proof of the plutonic origin of the East Canada gneisses.

It is still a question what relation in time the great Labradorian (Norwegian or Norian) system of gneisses holds to the West Canada Laurentian (Ottawa or Granville) system of gneisses.

Now, although the Norian rocks are commonly called *Upper Laurentian*, it is possible to consider them as two geographical areas of one and the same system; in which case the abundance of *labradorite feldspar*† in the eastern area would be an accident of drainage. On any other hypothesis it is difficult to explain the absence of labradorite gneiss from the range of the New York, New Jersey and Pennsylvania highlands ; for it looks as if we had in this range the upper part of any Laurentian system which could be established on anything like a sedimentary basis of argument.

The argument from marble.

White crystalline limestone beds are interleaved with the gneiss rocks of the New Jersey highlands all along their northwest border, and some are pure marbles (96.50 : 1.13 : 1.30 : 0.30) ; others nearly pure dolomites (53.00 : 42.26. 3.50 alum. and ox. iron : 0.50 silica and insoluble).‡

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*With hornblende, hypersthene and magnetic iron.

†Or rather of the whole group of *plagioclase* (soda and lime) feldspars.

‡Cook's An. Rt., 1864, page 15.

Prof. James Hall, however, published at the Albany meeting of the A. A. A. S., in 1876, his opinion that the crystalline limestones of northern New York are no part of the Laurentian system, but are of later age.*

The azoic marble beds of New Jersey furnish precious information for studying those of Pennsylvania.

In Warren county, N. J.. at Lower Harmony are extensive quarries. An acre of marble was exposed in 1871, without penetrating more than 15′ of strata; indistinctly dipping steep S. E.; gray, in some places banded with alternate dark and light lines; with scattered nodules and masses of soapstone (*steatite*) and *hornblende;* some *graphite ;* a very little *pyrites* in places. In the deepest parts of the pit the stone is more solid and free from these minerals.†

In the Jenny Jump range of highlands the Rose Crystal Marble quarry (50×50×25 yards deep) have exposed 30′ of rose-colored marble beds, dipping 80° N. 75° W. Quarry beds, white, flesh-colored, rose-colored; with green-black *hornblende*, black *mica* and occasional crystals of black *tourmaline ;* calcite predominates largely ; stone can be burned for lime; polishes well, showing the other minerals ; blocks 8′×3′×2′ got free of seams or joint flaws. The overlying beds (to the west) are pearl gray. The underlying beds (to the east, 100′ thick as exposed are ordinary white limestone, none colored.‡

Two belts of azoic white crystalline limestone or marble traverse New Jersey in its Highlands. *The Pequest belt* has beds so thick and persistent that it can be located by color on the geological map of New Jersey; and its rare and beautiful minerals are fully described in the geology of New Jersey.§ The *Ramapo belt* is smaller and remarkable for *containing serpentine everywhere*, in such quantities (in places) as to spoil the limestone for lime-burn-

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*See Amer. Jour. Science. See also C. E. Hall's report on the Adirondack rocks ("Laurentian magnetic iron ore deposits of N. N. Y.") with a geol. map of Essex Co. in Rt. of State Geologist for 1884 (No. 161, page 31).

†Cook An. Rt., 1872, page 26.

‡Cook An. Rt., 1872, pages 27, 28.

§1868, pages 309, 326.

ing; both massive and also fibrous (*chrysotile*), especially both at Mountville and also near Winokie.

This union of serpentine with marble shows two things: 1, that the azoic lime deposits were in part highly *magnesian*, and, 2, that they were in part highly *siliceous*. Under favorable circumstances the hydrous silicate of magnesia (serpentine) has been generated in small quantities in our mixed magnesian and non-magnesian limestone beds of No. II.*

The sedimentary origin of the azoic marble beds, as ordinary lime-magnesia muds, can hardly be doubted.

Included beds of syenite-gneiss in the body of the marble mass and regularly *interstratified* with the marble beds complete the proof, and carry the conclusion one step further, that the gneiss was itself also an ordinary mixed sand-mud deposit, like all the sandy shale and sand rocks of after ages which have remained uncrystallized merely because they have not been subjected to the proper process.

In Pennsylvania the Highland gneiss areas do not show their marble beds enough to be well studied. The beds are not thick enough to encourage mining in competition with the marble quarries of No. II along the Chester valley. But where they are thus exposed—in southern Chester county—they reveal the same facts as in the New Jersey Highlands.†

In New Jersey the Pequest marble belt has been so extensively quarried that the story is plainly told. Take for instance the section S. W. from Hardystonville,‡ where two gneiss formations 10′ and 30′ thick respectively, and about 200′ apart, are regularly interstratified with about 1,000′ of marble beds. One such example would suffice, but many others present themselves.§ There can be no

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*As at Reading, see last foot note on page 103, above.

†See Report C4.

‡Wood cut in Geol. N. J., 1868, p. 313.

§These alternations of gneiss and marble beds are finely exposed at Mine Hill; on the Snufftown road, southeast of Hardystonville; on the Deckertown road over Pochunk mountain; east of that road near Ryerson's; and many other places. The interstratified gneiss beds appear in more doubt of the sediment of gneiss in this azoic marble formation than of the sediment of St. Peter's sandstone in the magnesian limestone of the west, or of the great sandbed groups in No. II throughout Nittany valley in central Pennsylvania, and near Chambersburg in Franklin county. It is evident that the agents which changed lime mud into marble, changed sand mud into gneiss. Consequently the great gneiss formation which contains in its own body the marble beds, was itself as a whole originally an ordinary sand mud formation.

The marble beds vary greatly in crystallization, texture, color, composition and imbedded minerals; generally coarsely (rhombic) crystalline; sometimes finely granular, or even amorphous to the eye; color grayish, pinkish, but generally pure white, with lustrous cleavage; sometimes dull, hard, siliceous. *Graphite scales* nearly everywhere disseminated through the mass. Mica quite common. Many other rare minerals occur in it.

Why is azoic marble so abundant in New Jersey and not in Pennsylvania? A true answer to this question would throw great light on our gneiss system.

It looks as if a far greater thickness of gneiss comes to the surface in New Jersey, and as if the great azoic marble formation must be deep in the Pennsylvania underground.

Part of the vast gneiss system holds these marble beds, and another part does not. This is evident from the fact that the first or *front range of gneiss* Highlands in New Jersey only shows four small outcrops of marble.* The *second range* contains no known outcrop of marble. The *third range* (and the interval between the second and third) makes a magnificent display of marble beds of great length

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all parts of the marble belt. Very frequently they are such local deposits that after running a few yards, or a few rods, they more or less suddenly turn into limestone. Some have a length of 100-200 yards and are from 120 to 300 feet in thickness. One at Ryerson's is 360′ thick (or wide). Most of the gneiss is a hornblende syenite, without mica; some of it contains mica. The *trap dykes* at Mine Hill cross the whole breadth of marble bed, gneiss beds, sandstone beds and blue limestone beds of No. II; but they are very thin, only a few inches wide.

*Wynokie, two; Montville, one; Mendham, one. Cook, Geol. N. J., p. 309.

and thickness.* The average width of the marble belt is one-third mile, rarely exceeds one-half mile, but across the New York state line widens to two miles. But approaching Pennsylvania "the range seems to thin out and at last disappear towards the southwest."†

Certainly there is nothing to compare with this in the Highlands west of the Delaware river. Now everything combines to show that our highland gneisses never rose to as high a level as those of New Jersey; and, if we were quite sure of the structure, we must justly infer that our gneisses from Reading to Easton were those of an *upper division* of the old Azoic; a *lower division* coming up to the present surface in New Jersey and New York, bringing with it the great marble formation. That would explain things. But the structure of the highlands is too obscure to allow us to rely on any such generalization. Therefore, we must accept as a possibility that the white limestone formation may not have extended westward originally. Any third hypothesis that the white marble beds are local plutonic or volcanic extrusions like outflows of lava cannot be seriously entertained now by any one.

But a fourth source of explanation for the small local exhibitions of marble in gneiss ‡ may be found in the fact of the close plication of the rocks; the limestone being preserved in short, sharp, collapsed synclinal troughs; or, as in the case of the Brandywine marble quarry, projected upwards as a sharp-tongued anticlinal fold.§

But in some cases the white limestone is merely an ele-

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*Twenty miles long, from Mts. Adam and Eve and Round Hill, in New York, along west side of Vernon valley, by Franklin furnace to Sterling hill. No palæozoic rocks seen. At Franklin the blue limestones of No. II lap over the marble beds. This state of things keeps on through New York state. Geol. N. J., p. 310.

†Prof. Cook, G. of N. J., p. 312.

‡Like the "detached outcrops surrounded by gneiss at North Vernon, described by Prof. Cook on pages 313, 314, and a number in Pennsylvania. One of these detached patches at North Vernon, N. J., seems to be 900′ long by 600′ wide; the other is 1,700′ long and "quite narrow;" a third is 5,000′ long and 900′ wide, with a good deal of gneiss included in it. It seems hardly possible to avoid the inference of complication and repetition in such a case.

§See my sketch in Report of Progress C4, page 239.

ment in the gneiss, and what is of more importance "it predominates largely in some of the beds and enters somewhat into the composition of the iron ores worked" at the Roseville mine.*

The argument from apatite.

The Laurentian age of the highland gneiss is testified to by the occurrence of regular *apatite* (phosphate of lime) magnetic iron ore beds enclosed in the gneiss, as in the Adirondack mountains of northern New York.

In New Jersey, in 1871, at Ferro-Mont (Dickerson M. Co.), a bed 8′ thick was opened, dipping 65° S. E., mixed magnetite and gray-white apatite, between regular walls of gneiss in which little if any apatite exists. Some parts of the bed show alternate layers (or lenses) of magnetite and apatite. Of the whole mass 50 per cent in bulk (35 per cent in weight) is apatite.† There is too much phosphorus for the lime; some of it is therefore combined with the iron. There is a little quartz, feldspar (orthoclase) and occasional spangles of brown mica.

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*Cook, Geol. of N. J., page 316. The marble at Lockwood is nearly pure carbonate lime, very coarsely crystalline, with scales of graphite distributed through it, and *beds and horses of gneiss in it.* Its whole length is only 360′ and its greatest width 50′. The white crystalline limestone (91 per cent carb. lime) along the Paulin's Kill contains graphite, *galena*, &c., and includes *alternating beds of gneiss* (page 317). The Andover white (sometimes pinkish) limestone, highly crystalline, is so pure that only traces of magnesia are detected in it (page 318). The Decker's Pond marble beds alternate with gneiss beds of the same strike and dip (page 318). But in the fourth (Jenny Jump or Oxford) belt the marble seems to be more mixed with magnesian minerals. It is a great formation, with an outcrop 4,000′ wide but with *interstratified gneiss beds.* The *alternation* is finely exposed at the east end of the 20 mile outcrop. The gneiss carries *magnetite* beds, and *copper* ore. The marble carries *steatite*, &c. The whole formation is in fact a dolomite, and one is tempted to think it a metamorphosis of No. II; especially seeing that some of its members are flaggy, flaky and finely crystallized (pages 319, 320). This is the Marble Mountain outcrop at the Delaware river.

†Cook, An. Rt., 1871, p. 35. An average specimen gave 54 of mag. iron; 17.21 lime; 14.91 phosphorus (=31.90 apatite). A picked piece gave 53.85 apatite. The two minerals can be separated by crushing and washing, or by magnetic machines. Soluble phosphoric acid can be made, worth in 1871 14 cents a pound.

In Berks county, Pa., apatite of a bluish color is found in very small white hexagonal crystals with the magnetite at the Jones' mine,* and at the Mt. Penn mines.† But no minable beds of it have been found; only scattered crystals in the gneiss of southeastern Pennsylvania.‡

The original character of the magnetite beds is indicated by the fact that hydrous phosphate of iron (*cacoxenite*) are found in the brown hematite (limonite) iron ore mines at Conshohocken, Montgomery county; at Chiques, Lancaster county; and that minute quantities of phosphoric acid (? in the form of cacoxenite) are found in almost all the limonite beds of the state. Also the hydrous phosphate of alumina (*wavellite*) occurs in Trimble's iron mine in the Chester valley, East Whiteland; also in concretions in the York county Peach Bottom slates; and at Chiques in limonite.§

It may be objected that the phosphorus in limestones and limonites is a derivative from that in the gneiss; or else that it comes directly from animal life-forms (as in the case of recent bog-ores); and, therefore, that it cannot indicate the origin of the magnetic beds. But if other and stronger arguments for the genesis of magnetite from brown hematite beds be at hand, then the distribution of apatite crystals and masses in iron-bearing gneisses can be adduced as an argument for viewing the gneisses themselves as sand-mud sediments, and their included magnetite beds as originally bog-ores or more probably beach iron sands.

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*D3, Pt. 2, page 394.

†Rogers' Geol. Pa., 1858, II, page 716.

‡Genth, Report B, page 138. Blue green hex. prisms at McKinney's quarry near Germantown, in massive orthoclase; at Megargee's paper mill; at Frankford; at Grey's ferry and West Philadelphia; at Leipersville and at Beattie's mill, Delaware county; at Unionville, Chester county. Fine yellow-green hex. prisms and conchoidal masses in Londongrove township, Chester county; in the limestone of Bernard's quarry, West Marlboro'; at Nivin's limestone quarry in North Garden. Bluish hex. prisms and grains and masses in Van Arsdale's limestone quarries, southern Bucks county. Straw and honey colored hex. prisms, with pyramid and basal plates, with crystallized dolomite, in Prince's soapstone quarries, Lafayette, Montgomery county.

§Genth, B, 144.

The argument from iron ore.

The great beds of magnetic iron ore in the Highlands show unmistakable evidences of sedimentary origin; therefore, the gneisses in which they lie, and into which they graduate by insensible stages, must be of sedimentary origin. That is the plain and simple argument.

In New Jersey, boring for magnetic iron ore is recommended by Prof. Cook on the supposition that the beds are practically continuous down the dip as along the strike, which is undoubtedly judicious. He assigns a useful limit of 2,000′ in depth, in view of the expenses of hoisting. In our ignorance of the depth underground he well says that "a single boring might develop the existence of more ore than is mined in the whole state in the course of a year."*

The replacement of ore by rock, and the alternation of bands of magnetite and gneiss are well shown by Cook in his report of 1873, pages 78 to 87. The ore is never in veins cutting the gneiss, but always in interstratified beds following the strike; report of 1874, page 34. The alternate banded structure is shown by Cook in the report of 1874, page 23; and again at the Ten Eyck mine in the report of 1876, page 52.

The hanging wall ore is clean; the foot wall ore is mixed with feldspar, quartz and hornblende. As in the case of the apatite mines of northern New York, so here, were the ore a solidified fluid filling a fissure the pure ore would not occupy one side and the impure ore the other, but the pure ore would be in the deep filling the whole chasm, and the impure ore would have occupied the whole chasm above it, as the cinder floats on the metal in an iron furnace. In the case of the Adirondack mines the apatite occupies the hanging wall part of the vein; but in the New Jersey Highland mine the impurities occupy the foot-wall portion of the vein. This signal distinction points still more strongly to original sedimentation.

The connection of the New Jersey magnetite beds with

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*An. Rt., 1872, pages 24, 26.

white chrystalline limestone, or marble, tells the same story in another form.

The Schuler ore pits, near Roxburg, in the Pequest belt of N. J., show fine-grained *magnetite* (with much manganese) *in grey-white crystalline limestone*, steep to S. E.*

The Roseberry ore, near Belvidere, is mixed with much mica and blue shaley rock.

The Barton black granular ore has a little hornblende and much dark micaceous gneiss.

The Shoemaker ore is a rock containing magnetite arranged in parallel lines with the usual gneissic minerals.†

The Redell ore is black manganiferous magnetite, nonsulphurous, in contact with gray *crystalline limestone.*

The Raub ore, N. W. of Oxford furnace, lies close to the *crystalline limestone*, if not in it.‡

The magnetite vein at the Kanouse mine has close to it a *crystalline limestone* containing a large percentage of *serpentine*, and in contact with this (conformably) a grey gneiss. (Cook, An. Rt. N. J., 1873, p. 28 V.)

The Marble mountain part of the Pequest belt of iron ores in N. J. is the most northerly, next the Great Valley limestone formation, and its ores differ from those of the other Highland belts. The belt is a continuation of that in Pennsylvania, and is therefore instructive for our geology.

The Marble mountain mine is especially interesting for the fact that the ore is *red hematite* in a *talcose* (magnesian) formation, included in or resting on gneiss, unconformably.§ This talcose slate occurs in this Pequest belt only and in no other in N. J.

The Titman shaft ore, S. E. of Bridgeville, is *red hematite*, in a grayish red slate formation, lying between micaceous and hornblendic gneiss on the south and common blue magnesian limestone on the north, and "probably nonconformable to both.‖

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*Cook, An. Rt. 1873, p. 73.

†Cook, An. Rt. 1873, p. 74.

‡Cook, An. Rt. 1873, p. 75, 76.

§Cook, An. Rt. 1873, p. 72.

‖P. 76.

The Welsh and Inschow's lean manganiferous magnetite is imbedded in grey *white crystalline limestone* (steep to N. W.) holding hornblende, a little mica, and much graphite, and some manganese. In one hole the ore was in thin strings through the limestone, which itself held brown garnet and serpentine.*

The Howell farm ore (10′wide) *includes impure limestone*, but lies in or against a hard gray close gneiss country. Near by the ore holds much *calcite* and graphite.†

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*Cook's An. Rt. 1873, p. 84.

†Cook's An. Rt. 1873, p. 86.

CHAPTER XI.

The Newer Gneiss of the Philadelphia Belt.

The Schuylkill river, after cutting through the *Older gneiss* of the Buck ridge already described, makes a picturesque narrow valley, bounded by low bluffs of newer gneiss and mica schists as far down as the Gray's Ferry bridge, in the south part of Philadelphia.

These rocks belong to one system and one age and have a general moderate dip toward the north-northwest. So that, if no reduction need be made for irregularities or repetitions, there must be visibly exposed along the river banks more than 20,000 feet of strata. But they have been subject to great pressure, as is shown by myriads of contortions, by a perpetual variation of local strike and dip, and by small faults, how many or how important it is difficult to determine with any accuracy. There may therefore be in reality no more than 15,000 feet, or even less.

Still, the mass is evidently so great, and in a large sense so regularly and conformably stratified from the visible top of it at Lafayette station, to the lowest visible beds at Gray's ferry, that the Lafayette station beds must have once risen southward into the air to a height of 10,000 or 15,000 feet above the present street grade of Philadelphia. In other words, a mountain range of that height once extended from Trenton, New Jersey, past Philadelphia, Baltimore and Washington into the southern states.

This mountain range has been gradually washed away. The length of time requisite to accomplish such destruction, slow as it must have been, is inconceivably great, a fact sufficient of itself to prove that we are dealing with one of the oldest geological rock systems of the world.

The mountain range, when at its full height, must have presented cliffs of great height and steepness towards the

Atlantic; cliffs representing the basset edges of all the strata which we now see in succession along the river from Lafayette station down to Gray's ferry. There is no arch visible, and no evidence that the strata, after rising to the full height, turned over and descended with an opposite dip. For, if that had happened, southern New Jersey would have now a geological character similar to that of the Philadelphia belt, and the Delaware river would not have established its channel on a course directly in front of and across the mouth of the valley of the Schuylkill.

All geologists would agree in the belief that the line of the Delaware from Trenton to Chester must be the line of one of the greatest downthrow* faults which the earth-crust has suffered; and that the whole series of strata seen along the Schuylkill exists now at a great depth underground beneath the Cretaceous and Tertiary plains of New Jersey, southern Delaware and eastern Maryland. In eastern Virginia and the Carolinas they spread out at the surface. In the opposite direction they underlie middle New Jersey and appear again at the surface at New York. Our Germantown hills are the hills of Staten and Manhattan Islands; and the whole formation continues broadening and rising east of the Hudson, through western Massachusetts and Vermont, where it constitutes part of the great Green mountain range.

The bottom of this system of rocks is unknown, because concealed beneath the Delaware valley muds and the New Jersey green sand marl formation. The lowest beds visible are those at Gray's ferry. They are very feldspathic schists, in a state of complete decay, being turned into a coarse sort of porcelain clay or kaolin. From these Gray's ferry beds upward the series may be examined along both banks of the Schuylkill river, in the cliffs of Fairmount, in the cuttings of the Pennsylvania R. R. on the west bank. in those of the Reading R. R. on the east bank, in the road

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*It would be more historically true to speak of it as an *upthrow*. For it is quite possible that the movement upward which evidently took place on the north side was not accompanied or balanced by a downward movement of equal value on the south side of the fault.

cuttings of the city park at Manayunk, at the quarries on Wissahickon creek, and along the drive-ways to Germantown and Chestnut Hill. No better exposures of a great rock sytem can be found anywhere.

Its three sub-divisions.

The lower, middle and upper rocks exposed along the Schuylkill differ in general character sufficiently to justify three sub-divisions of the system, named by Mr. C. E. Hall in his report C6:—(1) The lower, or *Philadelphia mica schist and gneiss group;* (2) The middle, or *Manayunk mica schist and gneiss group;* (3) The upper, or *Chestnut Hill garnetiferous schist group.*

The course of the river Schuylkill in its traverse of the whole belt is worthy of careful study.

From Spring Mill to the Falls of Schuylkill, 6½ miles, its course is almost a perfect straight line, square across the strike, *i. e.*, S. 45° E. In this distance it first cuts through the Old (Laurentian Buck ridge) gneiss, one mile; then the Chestnut Hill group, 1½ miles; then the Manayunk group, 3½ miles, and then half a mile through the upper beds of the Philadelphia group.*

At the Reading railroad bridge (Falls of Schuylkill) the Schuylkill makes a right-angle bend to the right and cuts nearly along the strike, about S. 40° W. 1½ miles to the Columbia bridge.†

Then it makes a right-angle bend to the left and cuts

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*The Wissahickon, the Schuylkill and the Brandywine all flow from the low limestone Chester county valley into and through gneiss gorges on their way to the Delaware. In the case of the Wissahiccon the act is startlingly bold, because accomplished by a small stream. But all the rivers of the state do the same deed repeatedly. How do they do it? The question presents itself in view of every mountain gap in the state. It will be discussed further on in this report; but it may be said here that when the gorges of the Schuylkill, Wissahiccon and Brandywine were made the Chester valley was at much higher level. Its lime rocks have been dissolved faster than the gneiss and its level lowered more rapidly.

†This part of the valley corresponds to the low ground which runs for miles at the foot of and in front of the Germantown hills, past Nicetown and the brickyards. At the Columbia bridge the river makes a bend around the west foot of the hill on which the East Park reservoir is placed.

nearly straight across the strike, S. 30° E. 2½ miles along the dam and past Fairmount to Vine street.

Here it swings round again to the right past the Market street bridge, and follows the strike 1½ miles S. W. to Gray's Ferry—after which its meanders to the Delaware are in river muds and have no regard for the underlying rocks.*

Had the Schuylkill prolonged its upper straight course across the strike four miles further to the last gneiss struck in the cellars of Kensington, at the edge of the river mud, and made its mouth at the bend of the Delaware below Port Richmond, we should have had 9½ miles of continuous exposures across the whole Philadelphia belt, say 50,000 feet in breadth, dipping practically all one way, at angles never less than 20°, often over 50°, and in places vertical. In spite of all disturbances of the dip it is not an unsafe estimate then which assigns to the whole system a thickness of 20,000 feet.†

1. *The Philadelphia (lower) sub-division.*

The Philadelphia rocks show themselves from Grey's ferry up to the mouth of the Wissahickon. The slope of the strata is always up river, but with many contortions to the right and left, sometimes through a quadrant of the compass. In the steep wall of Fairmount, under the old reservoir, the dip varies between 20° and 40°. On the railroad opposite it is generally about 20°. Further on through the park it often rises to 50° and 60°. At the foot of Lemon hill the most curious and beautiful wavings and foldings may be seen in the much-weathered and mouldered mica schists, marked by thin streaks of milky quartz, which has been deposited as a gelatinous solution in seams where the twisted beds moved on one another and were slightly parted here and there. The whole soil glitters with shining little flakes of brown and yellow mica, set free from the mould-

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*It is possible that the course from Market street to Gray's Ferry was determined by some past condition of the terrace gravel deposits. But that is not likely in view of the fact that it here repeats its conduct between the Falls of Schuylkill and the Columbia bridge.

†We shall see in the next chapter that the same system (probably) on the Susquehanna, in York county, shows a similar thickness.

ering rock. Very few solid beds can be found, and the surface stone is worthless. Even where quarries have been opened the undecayed stone can only be used for the roughest building purposes, although all cellar walls in the older and much of the newer parts of Philadelphia have been built of the grey micaceous gneiss. Railroad cuttings through tough and apparently enduring rock become in a few years mere ditches, with softened sides covered with the micaceous clay into which the rock is converted by the weather. This accounts for the lowness of the hills on both sides of the river; and, in fact, for the disappearance of the great mountain range which once occupied the Philadelphia belt country.

But among the grey micaceous gneiss beds and mica slate beds occur numerous beds of hard hornblende-gneiss, which is a good quarry stone and stands well. There are places where the dark hornblende-gneiss beds and the light-grey mica-gneiss beds are interleaved and alternate regularly, showing that the hornblende-gneiss is a true sedimentary rock and not in any sense volcanic.

Mr. Hall's description of the rocks of this group (H. D. Rogers' "first belt") is as follows: "The common varieties are grey schistose gneiss, composed of quartz, feldspar, and black or brown mica, and occasionally garnets, occasional beds of black hornblende slate, and fine-grained sandy gneiss." (C6, page 2).

2. *The Manayunk (middle) sub-division.*

The exposures extend from the mouth of the Wissahickon up to the mouth of Mill creek, three miles. But neither the one limit nor the other is well defined. The separation of this group from that beneath it and that above it is rather arbitrary. Its gneisses are, however, chiefly micaceous; fewer hornblende gneiss beds are seen. Yet the weathered surfaces and the soils resulting from the decomposition of the outcrops have a darker color than the surfaces and soils of the Philadelphia rocks, a dark iron-rust yellow, or brown, especially where the hornblende slates run.

The dip is still generally northwest up-river, but with numerous waves and folds in the bluffs and the railroad cuts. One arch of considerable size may be seen in the McKinney quarry on the south side of the Wissahickon at the ascent of Germantown.* Here also the excellent quality of the better varieties of gneiss is practically displayed. On the north side of the creek at its mouth the convolutions and sharp foldings of the schists plainly reveal both the mashing and the stretching pressure-strains to which they have been subjected.†

Mr. Hall's description of the Manayunk group, which he interpolated between H. D. Rogers' "first" and "second belts," is as follows: "Alternations of the above-named varieties of gneiss (named in the Philadelphia group) and a predominance of *sandy gneiss*, composed of quartz and a small amount of feldspar and mica in minute flakes. Mica schists and hornblendic slates alternate with finer-grained gneisses, the mica usually light-colored" (C6, page 2).

3. *The Chestnut Hill (upper) sub-division.*

The exposures extend from the mouth of Mill creek for half a mile up to the Lafayette soapstone quarries with a constant general northwest dip, and these continue for another half mile to a serpentine outcrop along the south edge of the Bear Ridge older gneiss belt, but with reversed (S. E.) dips. Therefore, there is here a synclinal basin, and then a great fault, in which must be buried (against the older gneiss mass) the Manayunk and Philadelphia sub-divisions.‡

The dips, both north and south, are however very steep

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*This quarry is extensively worked for city use and is famous for its specimen crystals of *hornblende*, *orthoclase feldspar*, *chrysocolla*, *malachite*, *bornite*, *chalcopyrite*, *heulandite*, *apatite*, etc. The presence of these copper and phosphorus minerals is noteworthy.

†A fine exposure of a double or S fold along the north Pennsylvania R. R. above Shoemakerstown, is represented in Mr. Hall's section in Report C6, page 28. The minor complications under the fold show how the schists slid upon each other with a certain difficulty and much friction.

‡At least this is the best explanation of the structure which has been obtained.

and often quite vertical; and the strata are even more contorted than elsewhere along the Schuylkill.

The characteristic features of the group are its mica schists crowded with *garnets*, its thin-bedded sandy gneisses, its hornblendic slates, and its two ranges of *serpentine* beds.*

The Lafayette steatite or soapstone quarry has been wrought for a century and is now regularly mined in galleries. The rock dips steeply northwest.† It is part of a line of *serpentine* outcrops which extends at least seven miles in an almost straight (but not continuous) line from Bryn Mawr N. E. to Chestnut Hill, crossing the Schuylkill at the soapstone quarry, and the Wissahickon a quarter of a mile below the gorge of older gneiss, where it is well-exposed on the road up to the village of Chestnut Hill.‡

Another line of serpentine outcrops crosses the river half a mile above the soapstone quarry; is traceable only half a mile east of the river; but west at intervals into Delaware

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*Mr. Hall says in another place "this second belt" of Prof. Rogers' (that part of it not included in my inserted Manayunk belt) is characterized by the serpentines; soapstone; silvery micaceous, garnetiferous schists; light-colored, thin bedded sandy gneiss, with disseminated light-colored mica in minute flakes;" and a very curious *peculiarity of fracture*, "the rock breaking into long narrow chunks, comparatively smooth on their sides, but excessively ragged on their ends; a style of fracture strongly resembling that of half-rotted fibrous wood." (Quoted from H. D. Rogers' Geol. Pa., by Hall, in C6, page 2.)

As for Rogers' "third belt," it is the Buck ridge Older gneiss. Hall traced it in a straight line to the Delaware river and found it everywhere overlaid *on both sides* by the quartzite ("Primal," "Potsdam," "Itacobumite," "Eurite") beds, which, east of Willow Grove, Moreland township, Montgomery county, are a coarse sandstone and conglomerate, holding fragments of the older gneiss, principally the characteristic blue quartz and syenite. (C6, page 3.)

†The soapstone quarry is about 100 feet wide, with walls nearly as high, and so dangerous that tunnel work has been substituted. Thousands of tons loosened by the decomposition of the magnesian substance fell with a great crash when the Pennsylvania railroad company cut their new valley branch across one end of the quarry. The tunnel work is about fifteen feet wide and as many high. A few hundred yards above the quarry a road ascends to Roxbury by a hollow in the woods called Rockdale, from the great number of loose rock masses scattered and grouped about, some as large as houses.

‡See Hall's large colored map on the scale of 5,000′-1″ in C6, and text page 92. Also T. D. Rand's sketch map in Ann. Rept. 1886.

county. This line of serpentine seems to outline the contact of the newer and older gneiss. If the other serpentine belt be in the axis of a synclinal, this one must be at least 2,000 feet lower in the series, *i. e.*, supposing both to be bedded and not volcanic rocks.*

The Chestnut Hill fault.

The extension of the Lafayette serpentine belt eastward far beyond the other to the north of it gives the key to the whole structure of the Philadelphia belt between the Schuylkill and the Delaware at Trenton.

All three sub-divisions are sliced off diagonally by a fault.

The Chestnut Hill group, whether synclinal or monoclinal, ends in a point at Jenkintown, 8 miles east of the Schuylkill. The Manayunk group fines away to nothing between the Pennypack and Pequessing creeks, seven or eight miles east of Jenkintown. The Philadelphia group narrows more and more, but reaches the Delaware at Easton.

In fact there is not a more remarkable feature of the geology of Pennsylvania than the *thirty mile long perfectly straight line* of the *Itacolumite* (*Eurite*) vertical beds which extends from the Wissahickon to the Delaware, and against which the various members of the Philadelphia, Manayunk and Chestnut Hill schists one after the other efface themselves. If this be not a great diagonal fault, then all common proofs of such a fault may well be set aside.† But it becomes of still greater importance when taken in connection with the *fifty-mile long straight line of vertical uplift of* the South Valley hill between the Schuylkill and the middle of Lancaster county. Straight geological lines are a great rarity. Curves are the rule. A straight line eighty miles long must mean something great. It deals with huge thicknesses of formations, and with im-

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*The steatite is probably an altered schist bed, for specimens can be found showing stages of the alteration, and the hanging wall rock contains crystals of staurolite altered into serpentine.

†M. Renevier's recent protest against such faults and advocacy of transverse deposition in the rocks of Canton Valais, however well sustained at La Tiniére, can have no force here.

mense depths beneath the surface. In the azoic rocks they mean dislocations, down or upthrow faults. In the palæozoic rocks they mean anticlinal and synclinal folds of a massive amplitude that take away the breath of the spectator.*

Look at the folds in a lady's thin silk dress, then at the folds in a heavy cotton shirt, then at the folds in a woolen winter cloak. See how the system of innumerable delicate, short and irregular crimples of the first passes into a system of long, straight solemn lines in the last. The sediments of time are the dresses of the planet, and their complications imitate the draperies of statuary. Therefore, the strikes of the rocks are sure indications of both quality and quantity of formations. If we had no other proof of the immense thickness of the Philadelphia gneiss and mica schist system, this vertically erect and perfectly straight long itacolumite outcrop would be alone sufficient; just as the forty-mile straight line of the Bald Eagle mountain in Lycoming, Centre and Clinton counties is sufficient proof that the great fold of Nittany valley deals with 40,000 feet of sediments as an integral mass, one and entire.

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*For example, the synclinal of Pottsville and the anticlinal of the Orwigsburg valley in Schuylkill county.

CHAPTER XII.

The Philadelphia rocks in Chester, Lancaster and York counties.

The structural obscurity of the azoic rocks of the region bordering the state line between the Schuylkill and the Susquehanna cannot be exaggerated. If the colored state map published by H. D. Rogers in 1858 be compared with C. E. Hall's colored county map of Delaware (1884), and Frazer's maps of Lancaster and Chester (1878, 1881), it will be seen how unsatisfactory is our knowledge of a district on which three independent geologists of great experience lavished years of patient field work, only to arrive at contradictory conclusions respecting the relationships of some of its large formations to one another, while they agree singularly well in their special observations of local facts, which, after all, are the only things of value to the public.

It is a region of excessive-pressure disturbance. Thousands of smaller rolls, and some great waves, traverse it from east to west. Its outcrops of gneiss, mica schist, hornblende schist, argillite, quartzite, serpentine and limestone dip at all angles and in both directions. The crumpling is complete. The alternations are infinite. Crystallization and metamorphosis have not only destroyed every trace of fossil life forms (if any there were originally), but changed the characteristic qualities of the rock itself. Secondary minerals have been produced abundantly. Groups of strata are inverted, the older upon the newer. Faults interrupt the run of the outcrops.

All this has been brought about by the general earth movement northwestward which produced the huge anticlinal and synclinal rock-waves of middle Pennsylvania. Measured by straightening out these waves the thrust from the southeast has shoved the country at least forty miles towards the Allegheny mountain, crumpling its stratification into this labyrinth of confusion and altering its lithology so as to deprive the observer of a clew through it.

If the distinction between the *Older* and the *Newer Gneiss* be a valid one, the Older gneiss seems to disappear from the surface going west from the Schuylkill into Chester county, and the Newer gneiss seems to occupy the whole field south of the belt of *South Valley Hill hydro-mica slate*[*] in Chester, and south of the great limestone plain of Lancaster county. Dr. Frazer assumes that it occupies his broad Tocquan belt in York county. His sections along the Susquehanna river are therefore of the greatest importance for comparison with the Schuylkill river section. It can hardly be doubted that the grey gneisses, mica schists, etc. of southern York are the same as those of Philadelphia, Manayunk and Chestnut Hill, although no such subdivision as Hall's has been made of them.[†]

I will therefore summarize Dr. Frazer's descriptions of the azoic formations in York county before attempting any concordance of them with the Philadelphia rocks, or any identification of them across the intervening counties.

The Newer Gneiss in York county.

The belt of azoic schists across which the Susquehanna river flows, between Lancaster and York counties, is about 15 miles wide at the river, which enters the belt at Turkey Hill and leaves it at Muddy creek. Low hillsides along the river, with natural outcrops and railroad cuttings, show the structure of the belt to be that of a broad flat anticlinal arch, its axis crossing the river at the mouth of Tocquan creek (McCall's ferry). There the lowest strata appear, the highest being of course at the north and south edges of the belt.

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[*] Nothing has as yet been said in this summary report about the hydro-mica slate belt, although it appears on the Schuylkill river opposite Conshohocken and ranges through Chester into Lancaster county, because it can best be studied on the Susquehanna and in York county, and in Maryland.

[†] Mr. Hall, in coloring his Delaware county map, abandoned the attempt to represent the distinction between the Philadelphia and Manayunk groups.

Dr. Frazer's sections along both banks of the river, showing north dips up river and south dips down river, gave him a closely-estimated total exposed thickness of more than *fourteen thousand* (14,400) feet.* How much more should be added for the oldest members of the formation concealed beneath the surface cannot be known.†

In York county the arch is not symmetrical, Tocquan axis being 10 miles from the northern and only five miles from the southern border of the belt. But in Lancaster county the belt is only about 10 miles wide and the Tocquan axis is nearly central.

The Tocquan arch seems to sink southwestward through York county into Maryland, and rise eastward through Lancaster into northern Chester, where the Laurentian gneiss comes up to and occupies the present surface.

The lower strata along the Tocquan anticlinal are thoroughly and coarsely crystallized. Those above them, towards the north and south borders of the belt, are less perfectly crystallized, or in much smaller masses.

The lower strata are distinguished moreover by larger amounts and larger specimens of muscovite, and more potash micas generally. The rocks are of lighter color, and there is often enough feldspar to make true gneiss; and this is the case more and more approaching the Tocquan axis. Toward the edges of the belt, that is, ascending in the series, the strata become more magnesian, softer and darker, usually greenish or yellowish green; containing large quantities of chloritic minerals, and cut by an extraordinary number of white quartz dykes.‡

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*The sections are given in the Atlas to his Report of Progress CCC. This belt of ancient rocks has suffered from all the earth movements of all subsequent ages, and its originally regular stratification has been so warped and fractured, compressed and bent, that scarcely two exposed plates of rock agree in presenting the same dip or strike. Accurate measurements of thickness are therefore impossible. But on the whole, the estimate given in the text may be accepted with considerable confidence.

†Dr. Frazer could find no rock strata on the Susquehanna to which he thought the term *Laurentian* (either Upper or Lower) would properly apply; in other words, none of the Chester and Delaware county gneisses which have been called Laurentian.

‡P. Frazer, Gen. Notes Geol. York Co., Proc. Am. Phil. Soc., Phila., Dec. 4, 1885, p. 395.

The whole belt seems destitute of metallic ore veins of any kind, even iron. And what is equally remarkable, only two very small local trap dykes have been noticed in it in York county; one, near its northwestern border, on the Maryland line, two miles east of Black Rock P. O., and the other, on the Susquehanna river, three miles north of York Furnace. It is needless to say that no trace of fossil life, animal or vegetable, has been as yet detected in these crystalline schists. The country is one of low hills, well watered and fertile.

A better understanding of this important belt of azoic rocks will be got by comparing a description of them lately published by one of the geologists of the United States Geological survey.

The Newer Gneiss in Maryland.

The Azoic crystalline (*holocrystalline*, or completely crystallized) belt of York county, passes into Maryland and is joined by the great crystalline belt of Chester and Delaware counties, the two belts encircling and holding in a synclinal the southwest end of the Peach Bottom phyllite belt.

These Maryland crystallines have been studied by C. B. Keyes of the U. S. G. Survey,* and described as thoroughly metamorphosed highly feldspathic sediments, penetrated by vast quantities of eruptive materials often of the same composition as the strata through which they break; in other words, eruptive granites cutting sedimentary gneisses; all together foliated by pressure, so that in parts of the area they can hardly be distinguished.

The gneisses which can be certainly regarded as crystallized sedimentary beds are thus designated:

a. Typical biotite and biotite muscovite (mica) *gneiss*, highly feldspathic, and in thin parallel layers, as in the quarries on Jones' and Gwynn's falls at Baltimore, cut by biotite pegmatite dykes, and full of eyes, lenses, or chunks of quartz. At Washington they hold well-characterized conglomerate beds.

b. Muscovite (mica) *gneiss*, with but little feldspar, but

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*See paper in Bull. G. Soc. Amer., 1891, Vol. 2, p. 309.

full of garnet, staurolite, cyanite, fibrolite, rutile, etc., and cut with innumerable white quartzite veins.

c. *Mica schist*, without feldspar, but with garnets, etc., full of white quartz veins; apparently a local variety of *b*.

These are evidently the gneisses, mica schists, garnet schists, and contorted and veined schists of Philadelphia.

There are other rocks which show little or no signs of any original sedimentary disposition, such as:

d. Setter's ridge *quartz-schist*, or *quartzite*, extensively quarried north of Baltimore, and affording at many other places a definite geological horizon; always perfectly foliated by parallel muscovite mica layers, at variable distances from each other; with plenty of stretched and broken tourmaline crystals in the foliation planes.

e. *Orbicular quartzite*, compact, fine-grained, with radiating quartz crystals; as at the Poor House quarry (along the western edge of the Texas augengneiss area) and in the Brooklandville marble.

f. Deer creek white conglomerate quartzite, in the center of Hartford county, four miles long and less than half a mile wide, marking a sharp, narrow 300-feet high ridge. Under the microscope it is seen to be completely re-crystallized, but showing to some extent the original pebbles, with a secondary growth of wavy membranes of muscovite, large radiating tufts of blue cyanite, chlorite, magnetite, tourmaline, garnet, rutile. When better studied this may turn out to be a basal conglomerate of the Peach Bottom phyllite series, for its outcrop is just along the line which separates the phyllite and gneissic areas.

g. *Marble* (highly crystallized magnesia-limestone, *dolomite*) beds occur among these rocks, in irregular, sharply-folded patches at Cockeysville and Texas in Maryland, as in Chester and Delaware counties on the Brandywine. Its coarse-grained variety is called "Alum stone." It contains crystals of phlogopite, tremolite, white pyroxene, tourmaline, scapolite, rutile.

h. The eruptive rocks are: (1) With a surplus of silica: granite, granitite, hornblende granite, granite porphyry, augengranite gneiss, quartz porphyry (felsite), graphic granite (pegmatite); (2) With sufficient silica: gabbros (of three varieties), norite, diorite, hornblendite and hornblende-biotite-quartz diorite; (3) With too little silica: pyroxenite, cherzolite, cortlandite, and the resulting *serpentine.*

The certain or probable eruptive rocks cover half the present surface area of this great belt. (Keyes, p. 310, 311.) It is open to doubt, therefore, whether the large areas in Delaware county colored on the map accompanying Report C5 as *Laurentian* may not, when well studied, come to be recognized as parts of the same eruptive system. For the belt of gneisses, mica schists, garnet schists, with steatite and serpentine and marble beds, which are so finely exposed along the Schuylkill, Crum creek, Chester creek and the Brandywine, is evidently continuous through Bucks, Montgomery, Philadelphia, Delaware, Chester and Lancaster counties into Harford county, Maryland, and so south into Virginia.

Chapter XIII.

The azoic hydro-mica slate formation; phyllite belts of York and Lancaster counties; South Valley Hill slate of Chester county.

The age of the South Valley Hill formation has been in controversy. Studied at the Schuylkill and along the south side of the Chester limestone valley, where its beds stand nearly vertical, Dr. Frazer saw it descending *beneath the limestone* to rise again in the North Valley Hill toward the Lancaster county line. Mr. Hall, on the contrary, saw it *overlying the limestone*, in two separate and distinct synclinal basins, one of which he represents upon his atlas map (sheet 3) crossing the Schuylkill and terminating at Marble Hall and Barren Hill in Montgomery county.*

In Dr. Frazer's cross sections from Quarryville to the Pequea, and from Marticsville to Neffsville, *i. e.*, across middle Lancaster county, a thin hydro-mica formation is drawn rising and falling in many waves under the great limestone formation (which includes clay slate or argillite beds); and beneath it the great floor of gneiss. Sometimes the gneiss is at the surface; generally the limestone; occasional outcrops of hydro-mica slate.

At Quarryville the Chester County Valley ends, not in a point, but by swinging sharply round to the north and effecting a narrow neck connection with the most southern point of the great limestone plain of Lancaster. The structure is not quite comprehensible; but the valley lime-

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*The broad rounded end of this streak of slate between two streaks of limestone is very suggestive of a spoon-shaped synclinal. At Gulf Mills, west of the Schuylkill, dips of 80° N. and 85° and 65° S. show a synclinal. Here also in the short nose are dips of 85° N. and 75° S. showing a synclinal. But it is dangerous to construct curves out of such high dips; and Dr. Frazer insists on reading the dips so as to convert the two synclinals into two anticlinals. If Mr. Hall's reading is correct, then these slates must be *Hudson River No. III*, as he makes them.

stone seems to end as a synclinal, in a trough of South Valley Hill hydro-mica slate.

But the phyllite belts of York county are a long way off, the northern one stopping (on the map) in the triangle made by the Susquehanna and Conestoga above Safe Harbor ; the southern one ending (on the map) eight miles south of Quarryville. There seems to be a probability that the South Valley Hill slates are geologically connected with the York county phyllites as one and the same formation underlying the great limestone. In fact, as the South Valley Hill slates are apparently several thousand feet thick, and as the York county phyllites seem to be of equal thickness, we should look for a great show of them in so complicated a country were they geographically connected across Lancaster county between Quarryville and Safe Harbor, or between Quarryville and Peach Bottom ; certainly all around the edges of the great limestone plain of Lancaster ; whereas that plain is edged with quartzite and gneiss. But not to puzzle over this and other collateral conundrnms here, the following description of the phyllites will suffice :

*The main York county phyllite belt.**

As described by Dr. Frazer, this extends from the Susquehanna river below Wrightsville (Columbia) to the southwest corner of York county, in a gently undulating way upon the map, and with a breadth of three or four miles. The land is lower than the crystalline country to the southeast of it, and the rocks are so decomposed that very few outcrops are seen, which makes the geology obscure. Dallastown, Loganville, Hetricks and West Manheim villages are in this belt, and Glen Rock on the Northern Central railroad is at its southeast edge, where the southern branch of Codorus creek issues from the gneissic belt of the Tocquan anticlinal.

This southeastern edge (the northwestern edge of the Tocquan belt) is drawn on Dr. Frazer's map, he says, not in a precise manner, but as an approximation to the truth ;

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*Creedner's term in general use in Europe for *finely-leaved* argillaceous, or clay slate strata, of which roofing slates are a variety.

because the phyllite strata do not differ from the Tocquan strata along the line as if there was an abrupt change from a lower to a higher series, but as if both belonged to one great series becoming more slaty or schistose upward. The dividing line upon the ground is therefore less definite than it had to be made on a colored map. It commences at the river opposite Turkey Hill in Lancaster county, passes a mile north of Windsor P. O. and a mile south of Dallastown to Glen Rock and Black Rock.

The strata are much folded and distorted as they descend northward beneath the clay slate, quartzite, hydro-mica slate, limestone and New Red strata, and rise to the surface again, twenty-five miles to the northwest, at the foot of the South mountain near Dillsburg in the northwest corner of York county, where again they seem to lie on the older schists, but are themselves covered by broken fragments of quartzite and other rock-wash.

The Loganville trap dyke, four miles long, prolonged north-northeastward (after the break of a mile) eight miles further, crosses the phyllite belt and penetrates the overlying Silurian rocks beyond it. Patches of *Hellam* (*Chiques*) *quartzite* of Upper Cambrian age occur, suggesting that it once covered unconformably and perhaps entirely the phyllite belt; and the quartzite occupies a strip of land along the northern edge of the belt, west of the river.*

Some limestone beds occur in this phyllite series interstratified with the slates, as at Glen Rock†

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*This fact by itself would make impossible the suggestion that the phyllites, schists and gneisses are nothing but metamorphosed Silurian or Devonian sediments.

†Small thin lenses of marble occur in the *Sericite* belt of Maryland, north of the B. and O. R. R. The marble is extremely hard and of a fine, even grain, the crystals almost requiring a lens to see; at the Westminster quarries, snow-white; more often streaked with black, gray or red; in contact with the copper of Liberty and New London and the lead of Union Bridge. These marbles of the phyllite (sericite) belt differ both from the uncrystalline blue limestone of Frederick valley and from the coarse (loaf-sugar) crystalline magnesian limestones (dolomite marbles) of Baltimore county. These last hold crystallized quartz-clay impurities, but the phyllite marbles show narrow bands of sericite or chlorite schist. (Keyes, p. 307.) *Fossil shells*, "well characterized," are reported to have been found by Prof. P. R. Uhler in slaty bands traversing the Westminster quarries, which lie very

Iron ore deposits also occur in this phyllite belt, the largest of which are the Brillhart and Feigley banks a mile or two east of Loganville, which Dr. Frazer is disposed to regard not as really belonging to the phyllite rocks, but as washings (segregations) from later formations which once covered the phyllite belt but have been removed by the general rain erosion of the country.

The southern or Peach Bottom phyllite belt.

This borders on the southeastern side of the Tocquan gneisses, and occupies a triangular area in the southeast corner of York county between Muddy creek and the state line; and in it appear the Peach Bottom roofing slates. If these are a part of the series, it is remarkable that they do not appear in the belt of phyllites above described on the northwest side of the Tocquan gneiss.*

It is quite evident that this phyllite area occupies a broad synclinal, and that its strata are superimposed upon the Tocquan gneiss series; for the phyllite ends in a point in Maryland surrounded by the gneiss,† and it seems to end also in Lancaster county.‡ There can be no other explanation of the geographical relationships of the phyllite and gneiss areas. The gneiss area entirely surrounds this phyllite area; therefore, the phyllites must either rise on an anticlinal or sink in a synclinal. The former supposition is precluded by the anticlinal structure of the Tocquan belt,

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near the eastern border of the phyllite belt, in 1880. Sent to the New Orleans exhibition, they were lost before any descriptions or identifications of them had been made. (Keyes, p. 307.)

*There is a roofing-slate belt in the heart of the South mountains; the quarries were long ago abandoned because their slate could not compete in the market with the Peach Bottom slate. What relation in geology the two bear to each other is not known.

†See the frontispiece map of C. R. Keyes' paper in Bulletin Geol. Soc Amer., Vol. 2, p. 301. The point nearly reaches the Northern Central R. R. 25 miles from the Susquehanna river.

‡See map of Lancaster county in P. Frazer's Report C3, Atlas, where the phyllite area is seen extending to five miles from the river north of the Little Britain, Lyles and Pleasant Grove serpentine belt. It does not come to a point, as in Keyes' map, but has an indefinitely square transverse termination; which merely indicates the fact that its geographical northeast extension could not be properly mapped. See Chapter XIX.

and the descent of the phyllites to form another belt on its north border, extending across the Susquehanna eastward, and across the state line to the Potomac.*

The phyllite belt is said by Keyes to "include the semi-crystalline slates and finely fissile schists which compose so large a portion of the Piedmont area in Maryland. They are capable of sub-division into a great number of varieties. They are beyond doubt argillaceous sediments which have undergone a greater or less amount of mechanical (cleavage) and chemical (crystallization) metamorphism, though they do not lithologically differ from beds which in many other localities are known to be of Devonian, Silurian, or Cambrian age. Their most important mineralogical component is a *silky white mica* (*sericite* or *kaolin*), whose individual scales vary greatly in size in different specimens. This is sometimes wholly or in part replaced by *green chlorite*, with inter-beds of *chlorite slate*. *Quartz* grains are common ;*feldspar* very rare (perhaps because changed to white mica); *iron*, in red hexagonal plates (or rounded grains) common, often so abundant as to make the rock an ore ; minute *tourmaline* crystals very common ; microscopic *rutile* needles everywhere abundant ; *ottrelite* finely-developed in some beds. The phyllite cleavage is always perfect, and of a satiny lustre increasing in proportion to the mica present, and of various shades of pale grey, green, blue, purple and black (roofing slates). The original sedimentation is attested by round grains and small pebbles of various composition. Where least disturbed the slates are jointed and cut by cross seams of chlorite or quartz ; where more disturbed they are puckered and filled with veins and eyes of quartz.

The Peach Bottom roofing slates.

As described by Dr. Frazer,† this narrow belt extends southwestward from Peters creek in Lancaster county,

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*This settles one of the great Azoic questions, and Dr. Frazer should have the credit of predicting its settlement and furnishing the evidences, which Mr. Keyes confirms.

†Second Geol. Survey Pa., Report of Progress C3, 1877, pages 179 to 190. Proc. Am. Inst. Min. Eng., Troy meeting, 1883. Proc. Am. Philos. Soc., Phila., Dec. 4, 1885, page 398.

across the Susquehanna river and the southeast corner of York county into Maryland. They are exposed to view in a line of quarries in both the adjoining states about nine miles long.* On Peters creek the black slates, 150′ wide, dip 64° (S. 40° E.) under the adjoining crystalline schists.† Here the old slate quarry of the Browns, after being operated for a century, was bought by Bonsall & Yard and was in full play in 1876, one-half the width of the belt being rejected as bony, and new quarries being commenced in view of the unprofitable depth of the old one. Masses weighing 500 to 1,000 pounds are blasted, lifted and sawn into lengths. The slates are not as smooth and black as the best from Slatington & Chapman in Lehigh county. They have a fine grain, but are liable to show incipient traces of flebby or bubbly texture even in the finest parts of the best varieties. In sunlight they have a purplish luster. They are so smooth and soft to the touch and so tough that nails may be driven through them, and they weather well. They are split into roof slates with Bonsall's patent knife. Mantles, tables, tombstones, etc. are sawn and finished on a large horizontal wheel. Much of the quarry rock is rejected, but part of the great refuse piles is ground into flour for paint, cement and roof slating.‡

In York county the slate ridge is well-marked and well-wooded, but neither high nor steep, with a rather uniform outline, its summit striking southwest,§ the village of Delta

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*See C3, p. 182, plate 7, view of Humphrey's quarry, near Delta, York county, and p. 184, plate 8, view of Jones & Co.'s quarry, in Harford county, Md., both from photographs.

†C3, p. 179.

‡The only other quarries on this (east) side of the river, owned by Coleman & Co., were not operated in 1880. In York county the first quarry is 2¼ miles from the river, near Slate Hill P. O.

§In J. Humphrey & Co.'s northern quarry the long excavation (of best slate) points S. 55° W. The neighboring Old Revolutionary bank, full of water, points S. 40° W. In Williams & Co.'s quarry, which is large and deep, but nearly full of water, the hanging wall strikes S. 55° to 60° W. In the next quarry the nearly vertical slates strike S. 40° W. (The ridge itself at W. Bangor strikes S. 45° W.) In E. Davis' quarry a *remarkable cross dip* of 87° (to S. 40° W.) demands special notice. At the west end of W. E. Williams' quarry the slates dip 88° (N. 10° W.) with a strike of S. 80° W.; but in the main they are vertical and strike S. 40° W. In W. C. Robbeing built on its northwest slope, and most of the quarries opened on its southeast slope; with dips very steep, nearly vertical, and preponderatingly to the N. W. on the quarry side.

The whole ridge is by no means good quarry ground, as is shown by the great number of abandoned trial shafts. Even the long-wrought merchantable strata are capricious and change quality both lengthwise and downward, requiring very judicious mining. While the whole ridge, half a mile wide, is of slate the paying belt (as at John Humphrey & Co.'s quarry) averages only 60 or 70 feet, of which total only 40 or 50 feet of the best slates are got from a number of narrow benches. This excavation is about 500′ long, 50′ to 70′ wide, and 175′ deep at its deepest place. A gradual change of quality took place in sinking the first 40′, but after that the quality remained constant to the bottom, and no doubt would be found the same to an indefinitely greater depth.

The roofing slate belt seems to belong to and be an integral part of the great "chlorite slate" formation. Such was the impression produced upon Dr. Frazer by his official study of it in 1877.* The marketable slate beds are interleaved with others which may be properly named chlorite schists. On the railroad at the river bank the width of the

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erts' quarry the jointage planes which govern the excavation dip 45° (S. 40° to 50° W.,) but in one of the best exposures the slates dip only 20° (N. 30° W.,) making the strike S. 60° W. In J. Humphrey & Co.'s quarry the vertical slates strike S. 60° W., and a jointage plane dips 30° (S. 70° W.) T. W. Jones & Co.'s quarry adjoins the last. In J. W. Jones & Co.'s quarry the vertical slates strike regularly S. 40° W. One jointage plane system dips 30° (S. 40° W.); the other 80° (S. 60° W.) In Hugh E. Hughes' quarry, close to the last, the nearly vertical slates (slightly north dip at one end and slightly south dip at the other) strike about S. 40° W. with several jointage systems, one of them dipping 50° (S. 40° W.,) producing an extra amount of waste. No valuable slates have been found further on in Maryland.

*Report C3, 1880, page 23, where he proposes the theory that the local production of roofing slate has been effected by the heat of a trap dyke, eighteen miles long, which traverses the schist country of south Lancaster, passes near the northeast end of the roofing slate belt and follows it to the river. This theory could be more easily accepted if trap appeared along the whole range of the slate hill in York county and Maryland; if other belts of slate were seen along the course of the dyke further north; and if trap was not unknown in the Lehigh roofing slate region and in Vermont.

slate belt is about 400 feet; but the really valuable roofing slates recur through this distance in special belts, or layers, each only a few yards thick. The country on each side (up and down river) is sharply plicated; and the slate rocks exposed about 100 yards north of the slate factory (some dipping 58°, S. 55° E., others 62°, S. 25° E.) "resemble the genuine marketable slates in many features, but are greener, more chloritic, and very much convoluted." A close examination of the texture of the rocks suggests a growing belief in "an insensible alteration of the more chloritic hydro-mica schists into the dark purple-black Peach Bottom slates."*

A chemical analysis of a piece of Peach Bottom roofing slate from the Humphrey quarry, made by Mr. A. S. McCreath,† shows that it is an almost *non-magnesian* clay-slate, holding 9 per cent. of ferrous oxide and blackened by 2 per cent. of carbon.‡ If this be a fair representation of the composition of the mercantile slate layers of the belt, no theory of igneous alteration from an original chlorite (*magnesian*) sediment can be accepted; for the action of a trap-dyke would add, not abstract, magnesia. We must therefore regard the good slate-plies as separate and consecutive layers or beds of iron-clay, foliated by pressure; like the roofing slate beds of Lehigh county, but of a much earlier age; therefore they may possibly be identical with the *Lowest Cambrian slates* of Georgia county, Vermont, which hold the *Olenellus fauna* of Walcott.§

No animal fossils, no trilobites, have been noticed in these slates; but on the surfaces of many slabs are seen shining ribbons, crossing each other, which seem to be fossil plants,

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*C3, page 133.—A specimen from J. Humphrey & Co.'s quarry shows a fragment of unaltered mica-schist in the mass of fine slate (C3, p. 190). In W. E. Williams' quarry a seam of chlorite slate and quartz, mixed with manganiferous iron oxide, occurs in streaks (C3, p. 188).

†Report MM, p. 370 (Copied into C3, p. 270).

‡Silica, 50; alumina, 22; ferrous oxide, 9; carbon, 2; water, 3.4; potash, 3.6; magnesia, 1.5; titanic acid, 1.3; manganous oxide, 0.6; soda, 0.5; lime, 0.2; iron disulphide and sulphuric acid, each less than 0.1; and a trace of cobalt.

§See Dict. of Fossils Report P. 4. See also chapter on Cambrian fossils further on.

probably sea weeds allied to *Buthotrephis*, but of uncertain species and even genus, and lending no aid to the determination of the age of the formation.* It would be unsafe to assign it to the *Lower Silurian* age of the roofing slate formation of Lehigh county on the strength of these fossil plants. There is no good evidence in favor of the Peach Bottom slate ridge being an isolated distant outlying basin of *Hudson river slate* preserved in one of the many folds of the *Chlorite slate country*; nor is there any easy mode of explaining the presence on the Maryland line of such an outlier of the Lehigh valley slate belt either by conformable deposition or by downthrow faulting. For the present we must be content to be guided by the lately improved classification of the *Cambrian slates* of Canada, Vermont, and the eastern counties of New York; and to consider the *Peach Bottom slates* as part of that early system; at all events, integral members of the *chlorite schist formation* in which they lie.†

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*Peach Bottom slates, etc., Proc. Amer. Inst. Mining Engineers, Troy meeting, 1883. These Peach Bottom fossils, found by Rev. I. N. Rendall, D. D., President of Lincoln University in Chester county, at the quarries near Delta in York county, were submitted to Prof James Hall, of Albany, who thought them more like the *Buthotrephis* of the Hudson river slate (formation No. III) than anything else.

Prof. J. S. Starr, of Franklin and Marshall College, exhibited some specimens to the Linnean Society in Lancaster, some of which, in his opinion, had an ill-defined resemblance to "ferns." See a report of the paper in the "New Era," of Lancaster, May 15, 1886.

These fossil ribbons do not stand alone; for in certain black silicious slates near St. John occur "black, linear, flat objects that appear to be of the nature of sea-weeds or graptolites, but not sufficiently complete to give a satisfactory indication of their relationship." (G. F. Matthew on "Eozoon and other low organisms in Laurentian rocks at St. John," in Bull. No. IX, Nat. Hist. Soc. New Brunswick, read Oct. 7, 1890.) It was in specimens from a neighboring limestone of the same age that Sir William Dawson many years ago detected fragments of *Eozoon Canadense.*

†There is nothing to astonish us in the belt terminating eastward near the river and not running on through Lancaster, Chester and Delaware counties to the Schuylkill, more than in the Northampton and Lehigh roofing slate belt terminating westward near the Berks county line, instead of running continuously across the Susquehanna and Potomac rivers far into Virginia. In both cases the mechanical agency for foliating the formation into roofing slate operated generally, but the particular kind of clay formation capable of being foliated was of limited extent.

CHAPTER XIV.

Geology of the South Mountains.

The South mountains, separating the Cumberland valley from the lower country of York and Adams county, are the northernmost end of the Blue ridge range of Virginia. The highest summit rises only to 2,100′ A. T. There are no rocky peaks, and very few cliffs. The slopes are all moderate and the surface everywhere rounded on a grand scale. The long, straight, sharp, rocky crests and boldly-terraced steep slopes of middle Pennsylvania are almost unknown to this mass of irregularly-arranged groups of rounded knobs and shallow valleys, for the most part bare, uncultivated, or covered with a low second growth of forest reserved for abandoned iron works of the old style.*

The whole measures upon the map ten miles in breadth by fifty in length, upon a curve extending from the Maryland line to its northeastern end fifteen miles west of Harrisburg. It ends like the human hand in four blunt fingers and a very short, small thumb on the Cumberland valley side. These five terminals slope with considerable beauty down to the plain country of northern York county composed of Trias rocks, and of eastern Cumberland composed of Lower Silurian limestone, the two parts of the plain being separated by the lower reach of Yellow Breeches creek, which in the greater part of its course flows close at the northern foot of the mountain mass.

Many brooks descend from the mountain through short and rather steep ravines to Yellow Breeches creek at its foot. At one place only in Cumberland county is the mountain mass breached to let out the rainfall of its interior surfaces. This is at Papertown, called Mt. Holly

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*See description of conglomerate ridges on p. 148.

Springs, opposite Carlisle, where Mountain creek, after flowing east in a valley twenty miles long, turns north and issues through a fine gorge to join the Yellow Breeches.

Mountain creek heads in the corner of Adams county at a summit-divide from which Conococheague creek flows southwestward on the same line with Mountain creek but in the opposite direction (that is, along a valley common to both) to the Gettysburg-Chambersburg turnpike at Greenwood Furnace in Franklin county, where it turns northwest and breaks out of the mountain opposite Chambersburg, exposing another rock section analogous to that at Mt. Holly Springs.

Here, at the pike, the Mt. Holly mountain range, which is the highest and most regular part of the South mountain mass, virtually ends, sinking southwestward into the Cumberland valley. The lower interior ridges however run on past Greenwood and Mont Alto to sink beneath the limestone cove of the Little Antietam East Branch creek, opposite Waynesburg, near the Maryland line.

Thus the northwest face of the South mountain mass is set back from the Cumberland valley, once opposite Chambersburg for four miles, and again opposite Greensburg for nearly five miles. It is this that produces the curve of the mass upon the map. But these *backsets* would narrow the mass to a point on the Maryland line were it not for corresponding *outsets* of its eastern face in Adams county, one at the pike near Coxtown, and another further south.

It is evident that the curve of the mass is not produced by a curving of the ridges which compose it, but by an eschelon arrangement of its ridges running past each other, like the synclinal spurs of the Broad mountain in Schuylkill county, or the anticlinal spurs of the Buffalo mountains in Union and Snyder counties.

This geographical eschelon arrangement of the South mountains is a good indication of their geological structure. It renders it probable that the strata, whatever may be their age, have been thrown into a series of anticlinal and synclinal waves entirely analogous to those with which the Palæozoic country of middle Pennsylvania have made us so well acquainted. It explains also the finger arrangement of the eastern end of the mass in the Susquehanna river country; and leads us to suppose that the South mountain series descends beneath Lancaster, Dauphin and Lebanon counties, and is in some unexplained way connected with the Highlands of Berks, Lehigh and Northampton counties, New Jersey and New York. But it does not in the least help us in solving the problem why the South mountain rocks seem to be absent from that Highland country.

The South mountain rocks are mostly quartzites and quartz slates; those Highland rocks are mostly hornblendic and quartz gneisses, merely veneered with quartzite patches. If the Huronian (or Cambrian) quartzites are in such force in the South mountains, why do they make so accidental and superficial an element in the Highlands? On the other hand, why are none of the Highland gneisses, especially the hornblendic schists, seen in the South mountains? The underground interval is but sixty miles.

Two groups of rock compose the South mountain mass, as shown in Dr. Frazer's cross-sections.* The northwestern (Mt. Holly) ridge is made by several thousand feet of the the lower quartzite and quartz conglomerate beds. The southeastern (Adams county) ridges are made by several thousand feet of an overlying feldspathic, micaceous and chloritic series, intersected by veins of milky quartz; the felsites varying in character "from a sandy and earthy slate in which the crystals of orthoclase feldspar are very much decomposed, indeed are almost clay,†—through a jasper-like variety—to a massive and coarsely porphyritic structure in which it is suited to be used as an ornamental building stone."

These two series, or great sub-divisions, seem at some places to graduate into each other, as if they were the earlier and later deposits of one age. In other places (as in the Greenwood section No. 10,) they seem distinct; the passage from the lower quartzite series to the higher por-

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*Especially well shown by his Section No. 8, Report CC, page 285.

†Compare Fontaine's "Kaolin slate" beds in the Virginia Blue Ridge section at Balcony Falls, on James river.

phyritic (orthofelsite) series being abrupt; with even an apparent difference of strike in some of the outcrops along the line of section.

The lower, or *quartzite and conglomerate slate series*, is certainly immensely thick. Its beds very generally dip southeastward at angles varying from 20° to 60°. Occasionally they dip steeply the other way (northwest) implying anticlinal and synclinal rolls; but on the whole they are elevated towards the Cumberland valley, as if they once passed in the air over the Silurians of that valley, which is a clear impossibility.

A master fault must therefore run along the northwest foot of the mountains, along the low drift-filled valley of Yellow Breeches creek, in which nowhere can any rock be seen in place, but only a series of brown hematite (limonite) iron ore deposits, some of them of great size and once extensively mined in open quarry work. The northwest face of the mountain mass is therefore in fact the eroded basset edge of the quartzite series dipping away from the fault.*

The thickness of the *quartzite and conglomerate series* may be imagined from cross-section No. 10, laid 2½ miles north of Greenwood, along which for five miles quartzite beds on a prevailing southeast dip are either seen or indicated, suggesting a total thickness of fourteen thousand feet (14,000′). Other sections across the mountains towards Mount Holly Springs (even on a rolling construction to satisfy every observed abnormal dip) exhibit a certain minimum thickness of 5,000′, and possible maximum thickness of 10,000′ and 12,000′ of the quartzite series † And if a

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*Mr. Lehman's topographical map shows southeast dips all along the summits on the northwest edge of the mountain mass; and they are dips so low that they cannot bespeak an overturn. They continue to the Conococheague backset; here, however, they swing round and become southwest dips; the quartzites sinking beneath the limestones instead of being thrust up over them, as along the fault.

†A rather wild theory has been recently advanced by geologists studying this range on the Potomac at Harper's Ferry, that the quartzites of the west side of the South mountain mass are the same as the *Medina sandstone* beds of the North mountain on the west side of the Cumberland (Shenandoah) valley. They claim that the structure along the river makes this evident. But if so, then the same should be the case in Pennsylvania. But

master fault really exists, as it must, along the foot of the mountain slope, there is no knowing how much more at the bottom is buried against the fault One single, perfectly regular and continuous outcrop of these southeast dipping strata was measured by Mr. Lehman, at my request, near Mt. Holly hotel, giving a thickness of 1,200′. In Section No. 11, near the Gettysburg-Chambersburg turnpike, there appear to be 3,200′ of quartzite and 6,400′ of "schistose conglomerate," Dr. Frazer's *Mountain Creek Rock sub-series.**

The thickness of the overlying *felspathic felsite series,*

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it is only necessary to compare the thickness of the Medina with the figures in the text above to show that the theory is a mere conjecture. The Medina, opposite Mt. Holly Springs, is only a few hundred feet thick, and increases in thickness to 2,000′ *in the direction of the Allegheny mountain.* See the Perry Co. Report, F2, and the Blair, Bedford, Huntingdon (T, T2, T3) and other reports of middle Pennsylvahia. It also increases greatly in thickness towards the Delaware river; but to and beyond the Potomac it *decreases* in thickness until it is only forty (40) feet thick in E. Tennessee west of Knoxville. Those who wish to see the grounds on which Messrs. Geiger and Keith rest their identification of the *Massannuttan* (*Medina No. IV*) *sandstone* with the quartzite of the Blue Ridge at Harper's Ferry, will consult their sketch map and sections published in the Bulletin of the Geol. Soc. America, Vol. 2, p. 158, where the crests are represented as synclinals of IV, supported by shale of III, overlying the limestones of II, unconformably resting on epidote schists and granite. The parallel synclinals are represented as compressed and overthrown westward.

It has been long known that the Silurians rode over the Blue ridge and South mountain rocks. This is evident in the case of the Highlands of Northampton county; evident in Lancaster and York counties; evident in the James river country; therefore there is no objection whatever to limestone synclinals capped by shale and sandstone (III, IV) on the Blue Ridge. Mr. Keyes' section (Bull. Geol. Soc. Amer., Vol. 2, page 320) shows the *Chazy* and *Trenton with their characteristic fossils* on the east side of the range (between Cotocton mountain and Sugar Loaf, in Maryland). Cotocton mountain sandstone may possibly be Hellam (Chiques) quartzite No. I, and Sugar Loaf certainly is; but nothing can suffice to identify the Medina with the vast quartzite masses of our Mt. Holly range.

But the greatest obstacle to finding the Medina in or on the range is the vast thickness of the limestones of II and slates of III on which the Medina lies. Any outlying crest of Medina would be supported by at least 5,000 feet of these limestones and slates, and if preserved by erosion in the body of the Blue Ridge range of Maryland and Pennsylvania, could only be so preserved at an elevation of 5,000 feet above tide. This topographical necessity is fatal to the hypothesis, even if profound downthrow faults be substituted conjecturally for synclinals. It is remarkable that Messrs. Geiger and Keyes do not explain the absence of the limestone from their map.

*CC, p. 295, and Section No. II.

along the Mt. Holly cross-section, No. 8, exceeds 6,000′, as shown in the broad synclinal with opposite dips of from 30° to 50° at the southern end of the section. The highest beds left in the center of this basin are green crystalline schists and orthofelsites. How many still higher beds have been removed by erosion cannot be known. In Section No. 11, near the G. and C. turnpike, a small synclinal holds 700′ or 800′ of hydro-mica slates, and over these a continuous monoclinal exhibition of orthofelsite a mile and a half long, "representing (if there be no unknown reverse dips) nearly 5,000 feet of strata" (CC, p. 295).

The *Mountain Creek Rock* sub-division of the Lower series is characterized by scattered pebbles and by occasional solid beds of conglomerate. Dr. Frazer gives it various names descriptive of its varieties: "Schist conglomerate," "chlorite schist conglomerate," "quartz conglomerate schist." "green schist with quartz pebbles," "hydro-mica schist with pebbles" (some of them of transparent quartz, others of amethyst-colored quartz), these last two varieties of conglomerate marking a transition to the Upper series. It is evident that the great Lower series, if indeed it be separable from the Upper, has a lowest set of beds which are almost wholly of metamorphosed sand, quartzite. Then higher sets of clay, sand and pebble beds, metamorphosed into quartzoze slates, shales, schists and pebble rock. The still higher and more or less magnesian slates, hard shales, crystalline schists with scattered pebbles, conglomerate beds, and porpyhritic beds, make an indefinite but recognizable Upper system, in which also occur true quartzite beds, like-those at the bottom of the Lower series. Occasional fragments of diorite trap appear on the surface, which may indicate interbedded volcanic rocks, or possibly very small dikes. The whole may have been capped by the Hellam (Chiques rock) quartzite, fragments of which are so abundant on the lower southeast slope of the South mountain mass.

It is hard to avoid the inference that our South mountain rocks represent the Huronian section of Murray and Logan.

It is impossible not to compare them also with the great quartzite masses, the roofing slates, etc., of Wolcott's upper, middle and lower Cambrian system.*

The *conglomerate beds* sometimes make bold features in the scene. North of the pike at Greenwood a narrow valley, one or two hundred feet in depth, is shut in by a straight sharp-crested little ridge produced by a few beds of coarse conglomerate, in all not more than fifty feet thick, whose fragments are piled along the narrow top, strew the steep northwestern basset slope and choke up two wild little ravine gaps through which the drainage of the back-valley relieves itself. One is appropriately called Dark Hollow. The dip of the conglomerate beds, and of all the strata on both sides of the ridge, is uniformly about 45° S. E. On the S. E. slope of the ridge, and therefore about a hundred feet geologically above the conglomerates, is the outcrop of a five or six-foot bed of iron ore, tunneled to and mined by Thad. Stevens for the use of his Caledonia furnace at the pike. I was not able to trace the conglomerate to the pike; but the ridge is represented topographically that far; and what seems to be the same iron ore bed, or one at about the same horizon, was opened and mined a little at the foot of the steep S. E. dipping rocky cliffs on the north bank of the creek, the turnpike following the south bank.†

Another *conglomerate* several thousand feet higher in the series than the last, and composed of a few rather massive layers, only 20 or 30 feet thick in all, makes a very curious triangular plate leaning against the face of the hill

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*But where have we the Huronian and Cambrian limestone intercalations? Possibly in the Pine Grove Furnace limestone on Mountain creek; which, however, Pennsylvania geologists have always referred to the great limestone formation of the Cumberland valley; considering it a synclinal outlier, like the Saucon, Oley and Downingtown limestone outliers in Northampton, Berks and Chester counties. If the Pine Grove limestone belongs to the South mountain mass, it is certainly a very extraordinary fact that it does not crop out anywhere else in the South mountains except just there along Mountain creek; and that it is there accompanied with the same decomposed damourite limeslates and brown hematite iron ores which range with the Cumberland valley limestones from the Delaware to the Potomac and far into the Southern States.

†These were some of the local facts which persuaded me that the mountain backset at the pike and creek had been made by a great cross-fault, with a throw of four miles.

on the northwest side of the Conococheague, four miles north of the turnpike. The base of the triangle is in the bed of the creek; its apex makes a little platform projecting from the side of the wagon road, here more than a hundred feet above the creek. The outcrop slopes slanting both ways down to the creek, and reappears again in low bluffs at the mouth of a branch further on, whence it can be traced a mile or two further northeast, ascending to the higher land.*

These two instances prove the general fact that these conglomerate beds are not mere local bunchings of gravel, but are widely extended gravel deposits at fixed horizons in the series, and may therefore be used as key-rocks for working out the geology and perhaps for breaking up the series into sub-divisions which may at some future time receive distinctive names. But they lend no help to the notion that they are of Medina age, because they are interstratified with a great thickness of other beds.

A *conglomerate* of coarse character and some thickness makes a ridge with a bold south-facing cliff end in the ravine issuing at Mont Alto. The dips here are vertical, and the place of the beds in the series is undetermined. The locality is ten miles south of the pike at Greenwood; a north and south road connects the two, and along this road the ridge is faced with jaspery grey and purple slates, quarried for road metal.†

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*Standing on the apex of the triangle and looking eastward across the valley of the Conococheague, one sees opposite, about half a mile away and at the same height, the apex of a similar triangular outcrop of the same conglomerate beds dipping northwest about 20°. The creek here flows in a shallow synclinal fold, as represented on Dr. Frazer's Section No. 11. The exhibition of erosion is unusual and very interesting. The conglomerate soon turns over to a southeast dip, sinks into the broad highland of S. E. dipping conglomerate schists at least 5,000′ thick, past another small synclinal roll, to the 70° S. E. dipping green hydro-mica schists and micaceous slates which introduce the orthofelsite country from Newman's (on the pike) to Cashtown at the northwest edge of the Triasic plain.

These features of topography—the straight sharp conglomerate ridges and gaps, the triangular outcrops and iron mines, are exhibited on my map of the Caledonia Furnace lands (surveyed by me in 1873) in the Atlas accompanying this Report.

†Such purplish red slates are an uncommon element in the South mountain mass, but they have been occasionally observed. There is no general ex-

The number of these conglomerate beds may be exaggerated on account of the rolling (anticlinal and synclinal) structure of the mountain mass as a whole. It is evident that the rolls must be more numerous than the outcrops show, the surface being smoothly eroded and covered with sand. The whole mass descends from northwest to southeast, but it descends in a series of rolls, some of which are very distinct, but most of them are mere crimples. It has just been said that the Conococheague north of the pike flows in a synclinal (see foot-note on last page).

Section 8 shows that Mountain creek, at Pinegrove Furnace, flows in this same synclinal, of the same shape and size; and that the rocks turn over in the same way southeastward. Several other small synclinals occur on that section (if the surface dips be properly correlated), one of them tightly compressed and thrown over to the west. There is a rather grand synclinal at the eastern end of that section.

Section 9 was made along the Gettysburg-Shippensburg road over the highest part of the mountain. It starts at the summit of the Mt. Holly quartzite range, 2,100′ above tide, and runs S. E. nearly five miles to the Conewago creek 4 miles from Arendtsville. A mile from the summit, approaching Beamer's mill on Mountain creek, the following opposite-dipping outcrops of quartzite are encountered in rapid succession: S. 45° E., 60° (two); N. W. ?; S. 45° E., 50°; N. 40° W. 40°; S. 35° E. 70°; N. 35° W. 55°, 70° (two). How many more such crimples are concealed under the sand which covers the mountain is not known. Then follows a gap of 6,575′, the surface being strewn with fragments of conglomerate schist and quartzite, but nothing exposed. In the last half mile the schist becomes more and more composed of small quartz fragments until the rock turns into a nearly perfect quartzite. Then appear quartzose conglomerate schist dipping S. 35° E., 45°, 50° (two outcrops); N. 60° W. 20°. A mile further orthofelsite and

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hibition of them as in the Cambrian country of Vermont and eastern New York. Pink quartzites occupy the west end of Section No. 11, on the high ridge 1½ miles west of the Conococheague and 2½ miles N. 20° E. of Caledonia furnace. (Report CC, p. 293.)

schist are exposed, dipping S. 15° E. 85°; S. 40° E. 55°. These two dips are evidently on the crest of a sharp anticlinal roll of unknown quantity.

The relationship of the South mountain rocks to the rest of the Azoic rocks of the state, to the Highlands, to the Philadelphia belt, to the York and Lancaster county gneisses and hydromica slates, or phyllites, is certainly obscure. But their relationship to the great Huronian formations of Canada and the northwestern states is also an interestingly doubtful problem, for the discussion of which a description of the Huronian in its typical locality is necessary and will be given in the next chapter for the use of Pennsylvania geologists. How the *Huronian* and *Cambrian* are related I do not pretend to discuss.

CHAPTER XV.

The Huronian system.

The Huronian system is a vast series of beds of gravel sand and mud (altered to quartzites, greywackes* and slates), with some beds of limestone and chert, and some beds of volcanic ashes (or lava ? greenstone trap), the whole being traversed by trap dykes, exhibited on the northern shore of Lake Huron in upper Canada.

Logan's section of 1863 † gives the relative proportions of the kinds of rock, thus: Quartzites, 10,820′; Graywackes (slate conglomerates) 4,280′; Chlorite slates, epidote slates, and trap-like beds, 2,000′; Limestone and schist beds, 900′. Total of undulating strata visible along the north shore of Lake Huron, 18,000′.

But the proportion of Quartzites is even greater than this and amounts to at least *two-thirds* of the whole; *one-sixth* consists of Graywackes (slate conglomerates); *one-ninth* of Chlorite, epidote and trap beds; *one-eighteenth* of Limestone and schist beds. In other words, 12: 3: 2: 1.‡

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*This term, *graywacke*, *greywacke*, *grauwacke*, has almost disappeared from geological literature, but is common in the older books. Lyell explains it in his Manual of Elementary Geology (N. Y. reprint 1853, p. 350) as a German miner's name for brecciated sand rocks of the Silurian system, composed of small fragments of quartz, flintslate (Lydian stone) and clay-slate in a clay cement. Similar grits are found in Devonian, Carboniferous, Cretaceous and Eocene ages; and they are common among Huronian rocks, where the cement is more siliceous and the feldspar fragments are in an altered condition (Irving). They are the Huronian "conglomerates" of the later literature.

†Geol. Canada, 1863, p. 55, Atlas Plate 3. This section has recently been verified by Irving; U. S. Geol. Sur. 5, Report 4, 1885, p. 188.

‡Murray described the series in his report to Logan (G. S. Can., 1847-8, p. 189) as "a set of regularly stratified . . . . quartz rocks (or altered sandstones), conglomerates, slates and limestones, interstratified with beds of greenstone." Under the term slates he included "thinly-laminated, dark-green, blackish and reddish rocks, some . . . . very chloritic (magnesian) and some containing epidote." Hunt makes the smaller items of the list

Thin sections under the microscope show the quartzites, graywackes and slates to be sediments hardened into rock chiefly by the infiltration of siliceous waters, the silica being deposited so slowly between the grains as to crystallize around them, so that the shape of the grain remains visible in the interior of the enveloping crystal of quartz.*

The chloritic and epidotic slates which make up so small a part of the column have been made by Dr. Hunt the basis of an immense generalization extending over Europe and America. From the typical locality of these slates, just east of Thessalon Point, Irving's specimens under the microscope showed themselves to be "merely eruptive diabasic greenstones in various degrees of alteration." The false idea that the Huronian series on Lake Huron is characteristically chloritic has been partly generated by the occurrence of greenish chloritic graywackes in the slate conglomerates.†

The alteration of the rocks on Lake Huron is not different from, but only more universal than, that of acknowledged sedimentary and fossiliferous sandrocks etc.

The basic traps are augitic in various stages of alteration,

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too important when he quotes Murray's rocks as "a great series of chloritic slates and conglomerates, with interstratified greenstones, quartzites and limestones." (Azoic Rocks, Report N, Geol Sur. of Penn., p. 70.) This puts a false face upon the whole formation, and raises great difficulties in the way of identifying it in other regions. Irving adds that a large proportion of the so-called slate conglomerates is quartzite, the balance being graywacke slates and graywacke conglomerates, which he describes in extenso in subsequent pages of his report to the U. S. Geol. Survey, 5th Rept., 1885. Logan includes various greenstone trap beds in his measured groups.

*Irving, 1885, p. 188. Also his chapter on enlargements of mineral fragments in certain detrital rocks, in same report, pp. 218, to 242 with figures, plates 30, 31, and wood-cuts on pp. 238, 239, showing how the planes of crystallization in the embedded fragment are continued outwardly through the encrusting quartz crystal envelope. He has pursued his investigation with fine results through quartzites of Potsdam and Medina age, and furnished a sufficient explanation of the process by which the loose sand and mud deposits have been more or less completely converted into hard, brittle sandrocks and slates.

†Irving's foot-note to page 188. Irving, Van Hise and Merriam made their study of the coast line from Sault St. Marie eastward to Serpent river bay, with Logan's map, in 1884, and far enough inland to get the whole of Logan's series, occupying the area between St. Mary's and Blind rivers.

hornblende being a secondary product. The bedded trap does not differ from the dyke trap.

The strata are so little inclined, so gently folded, so imperfectly metamorphosed, and so different in looks from crystalline schists, that the total absence of fossils *argues an age without life;* seeing that fossils are constantly found in rocks no more altered than these.*

The absence of red hematite ore beds from the section of typical Huronian strata is remarkable. In spite of this fact, however, it is generally agreed that the great series of highly-folded fragmental slates and quartzites, chert schists, magnetite schists, iron ore beds, limestones, dolomites, clayslates, micaslates and greenstone of the Marquette and Menomonee region south of Lake Superior is merely the geographical extension of those on the north shore of Lake Huron.† The greenish schists at the base of the Marquette series may perhaps belong to the underlying system of Laurentian gneiss.‡ Beds of strange-looking rocks may be explained by secondary alteration of basic eruptives, *e. g.*, hornblende schists and actinolite schists, the graduation of which into greenstone has been both affirmed and denied and given rise to the two opposite views, that either both are sedimentary, or both eruptive. But setting aside these doubtful elements of the whole section, its main features are those of the typical quartzite Huronian.§

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*Irving, p. 189. A curious and very different explanation of the absence of fossils from Huronian rocks has been offered by Dr. Morris in the proceedings of the Acad. Nat. Sci., Phila., April 7, 1885. After drawing attention to the fact that the oldest known animals have defensive armour, but no offensive weapons, and suggesting that they were descendants of unarmoured ancestors, in whom the appearance of predatory foes had developed modes of self-defense, *i. e.*, the secretion of shell structure, which compelled them to exchange a free swimming life for rest at the sea bottom, just as afterwards the secretion of the internal skeleton was acquired, he assumes that the unarmoured ancestry could leave no traces of their existence, *i. e.*, no fossils in the Huronian. But no one will dispute that life commenced at some date or other. Why not then in post Huronian times?

†See the Reports of Brooks, Rominger and others, who differ widely in their arrangement of the series.

‡Irving, p. 190.

§Irving, pp. 190, 191. Some of the greenstones are evidently contemporaneous lava beds now regularly interstratified; others are as evidently later lava dykes. As for the Marquette *jaspery iron ores*, the earlier geol-

Sir W. E. Logan's description of the Huronian section from the survey of Mr. Murray in 1847, '48 and '49, is as follows:*

The group consists of siliceous slates and slate conglomerates, holding pebbles of syenite; sandstones sometimes showing ripple-marks, some of the sandstones pale-red green; and quartzose conglomerates, in which blood-red jasper pebbles become largely mingled with those of white quartzite, and in great mountain masses predominate over them; the series intersected and interstratified with greenstone trap, and computed to be about 10,000 feet thick; a copper-bearing formation, etc. To this must be added from other descriptions of it its distinctive features: Chloritic schists, crystalline limestones and sulpher-copper ores; its sandstones all in the condition of quartzize, and a total absence of fossil forms.

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ogists saw in them eruptive outbursts with a flow-lamination; a view lately revived by Whitney and Wadsworth. Most subsequent geologists have looked upon them as iron-silica sediments. They differ from all known lavas in being so nearly a pure silica; and it seems impossible to imagine a molten flow of free silica in presence of free oxide of iron. If they be sediments, the question arises whether they were chemical or mechanical sediments. The latter view finds its support in the loose magnetic sand deposits on the shore of the lower St. Lawrence, of the Pacific coast and elsewhere, and in the constitution of the magnetite ore beds of New Jersey. (See also Julien's "Genesis, etc., in Eng. and Min. Jour. N. Y., Feb. 2, 1884.) Irving cannot accept the eruptive origin of the Marquette jaspery ores because they graduate from pure sediments into highly contorted and confused masses; but chiefly because magnetite sediments have been discovered in the Huronian quartzite series in Wisconsin and along the northwest coast of Lake Superior. Here the Animikie series (Huronian) are quite undisturbed and undoubtedly sedimentary. He agrees with N. H. Winchell that some of the Animikie magnetic ores occur in eruptive gabbro lavas, in isolated masses, and also disseminated; but they bear no resemblance to the Huronian jaspery ores. (See 10th An. Rt. G. Sur. Minnesota, pp. 88, 83.) The silica of much of the jasper ore is purely crystalline quartz; but much of it is amorphous (chalcedony). Many of the great belts of ore-bearing rocks of the Menomonee seem mainly composed of chalcedony, which Irving thinks is an original formation, but Wadsworth eruptive. But the occurrence of huge angular jaspery and chalcedonic fragments in the conglomerate beds overlying the Vermillion Lake iron belt shows that the jasper and chalcedony beds existed in that form before the deposits of the quartzites overlying them. They may represent the "chert beds" in Logan's original section. Irving, p. 193.)

*Proc. Am. Ass. Adv. Science, Aug., 1857.

Another description of it* is more precise and elaborate. By this it would appear that the beds first deposited were white sand, 500 feet in thickness; then, magnesian mud, 2,000 feet; then, white sand, 1,000′; gravel, sand and mud, 1,280′; limestone, 300′; gravel, sand and mud, 3,000′; red sand and gravel, 2,300′; red jasper gravel, 2,150′; white sand, 2,970′; limestone, sand and sinter, 400′; white sand, 1,500; limestone, 200′, and over all, white sand again, 400′, the whole amounting to 18,000; but this includes a great thickness of interstratified greenstone trap.

What first attracts attention is the vast quantity of stuff deposited in this ancient Huronian lake or sea or arm of the ocean, whatever it was; 18,000 feet in all, a thickness of strata equal to three miles of vertical depth. Secondly, the great preponderance in quantity of sand and gravel, 15,000 feet in all, over the quantity of finer muds, 2,000 feet, of limestone, 900 feet; indicating the force of the rivers which brought the materials to the shore. Thirdly, the alternation of coarse and fine deposits, representing, as is supposed, alternate risings and fallings of the sea level, and consequent retreatings and advancings of the shore line; for gravel is reckoned a shore deposit, sand and mud an off-shore deposit, and limestone a deep-sea deposit. But we have still much to learn on this subject. In any case, such alternations bear witness to repeated and considerable changes in geography during the deposit of these 18,000 feet of strata; and it behooves us to get some probable explanation of the cause of such changes, and some conception, however imperfect, of their geographical extent.

It is notable that at least one-fourth of the whole 18,000 feet of strata is reputed to be made up of volcanic materials. If so, it is plain to see that the land and sea and air were greatly disturbed by fiery phenomena on a grand scale, producing frequent changes in the sea bottom, coast line and drainage system of that district.

Probably then other districts were subjected to similar vicissitudes of land and sea, each district attending to its

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*Crystalline Rocks of the Northwest, N. H. Winchell, Address before Section E, Amer. Ass. Ad. Sci., Sept. 4, 1884.

own local and peculiar geological business, of a kind perhaps very different from that of the Huronian rock section cited above, and yet contemporaneous.

It would also follow that there must have been a universal, irregular, changing floor upon which, in many parts of the earth's surface at the same time, sediments local in their origin, local in their destination, and special in their nature were dumped into standing water, in variable quantities, at variable rates, under varying conditions and in a variable order. We know of no such floor if it be not represented at the present surface here and there by the areas of hornblendic granite and gneiss rocks; whether these be considered as the cooled and crystallized original crust-matter of the globe, or whether they be looked upon as most ancient sediments metamorphosed or recrystallized. Now, any sediments deposited upon the floor anywhere would necessarily lie unconformably upon the older gneisses; and therefore the first of the three questions proposed above—was there a historic break between the end of the Laurentian age and the beginning of the Huronian age?—would seem to be answered in the affirmative. But the answer is purely theoretical and does not help us a whit, unless we can convict the lowest bed which shows itself in the Lake Huron country of being really and truly the first and bottom bed deposited upon that part of the granite floor. Of this fact there is up to the present time no proof; nor is it known with an approach to certainty how the Huronian strata lie upon the Laurentian rocks; nor whether the so-called upper Laurentian series, with its limestones, be not a continuation downwards, or even sideways, of the Huronian strata.

In the midst of such uncertainties the term *Huronian* must be used simply as a proper and private name for a series of rocks exposed along that part of the northern boundary of the United States. Should a similar series appear in some other region and be called Huronian on account of the resemblance, the name would have no *time-value* whatever; unless we should imagine that in a so-called Huronian age the whole surface of the planet was stuccoed with a certain formation; and received successive coats of other kinds of rock in after ages. And in fact this is a popular view, but absolutely false. For, ocean sediments depend for their character upon the kind of country rocks through which the rivers flow which bring the sediments down to the sea coasts. It is impossible for the sediments of two water basins to be of the same character unless the geology of them both should be the same; and if two such similarly-situated water basins are filled successively, one after the other, then the similarity of their deposits cannot make them of the same age.

In like manner the most dissimilar series of formations are known to be of the same age; because brought by different rivers or groups of rivers from back countries of quite different characters. What is happening to-day has happened in all ages. Nothing could be more unlike than the deposits now forming along the various ocean shores, and in different lakes and inland seas; yet they are all of one age. Even the deposits making in one and the same basin radically differ; as, for example, along the northern and the southern sides of Lake Ontario; and along the eastern and western sides of Lake Champlain. It would therefore seem a useless task to seek for the Huronian rocks far from their native range. And in point of fact the task whenever attempted has been unsuccessful. If Huronian strata existed elsewhere, it would be around the Laurentian mass of the Adirondack mountains in northern New York. But they are not to be found there. To say that they once covered the granite and the gneiss of that country, but have been removed, would be to beg the question. It is not to be imagined that 18,000 or even 10,000 feet of such rocks could be removed without leaving a trace behind. The small exhibition of specular iron ore and slate in St. Lawrence county cannot be accepted as an equivalent of the Huronian system merely because it underlies the Potsdam sandstone and suggests the Marquette ores; especially in the face of the fact that Marquette iron ores are not represented in the section along Lake Huron; nor do they immediately underlie the Potsdam sandstone on Lake Superior.

Another region where we should expect the Huronian series to appear is the region of the Highlands in southern New York, northern New Jersey and eastern Pennsylvania; but they are nowhere to be seen in their supposed intermediate position between the Old gneiss rocks and the overlying fossiliferous sediments.

On the eastern side of the extension of this Highland range through Massachusetts and Vermont into Canada there is a narrow belt of *so-called* Huronian rocks, running along through Halifax, Marlboro', Townsend, Andover, Plymouth and Stockbridge counties in Vermont, gradually widening towards the Canada line and appearing on both sides of the central belt of gneiss.* Another belt further east commences in Norwich county on the west bank of the Connecticut river, widening and crossing to the eastern side of the river before reaching Canada. But there is nothing to show that these formations have anything to do in origin, time or character with those of Lake Huron. "The name Huronian is used," says Prof. Hitchcock, "*as a matter of convenience* to designate all the various schists of chlorite and argillite aspect overlying the gneisses, and inferior to the Cambrian, so far as known." "In southern New Hampshire the argillite, quartzose and micaceous divisions predominate nearly to the exclusion of the chloritic schists, which, with the characteristic dolomite, is seen in Raymond and Derry. Steatite occurs in it at Francestown in the ferruginous slates, and in the mica schists of Derry."

The Green mountain Highland crystalline rock range of Vermont is extended into Canada under the name of the Mountains of Notre Dame for 150 miles, being 30 miles wide at the Vermont line, 12 where the St. Frances river breaks through it, and 12 on the river Chaudiére; rising to heights of 3,000 feet above tide, and sinking south of the Isle d'Orleans beneath the sedimentary strata, to rise again 250 miles further on as the Shickshonk mountain range, 60 miles long and 3,000 feet high, ending eastward at the river

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*See description of XIII sections crossing N. H. and Vermont, by Prof. C. H. Hitchcock, Concord, N. H., 1884, and on page 14.

St. Anne in the river Gaspé peninsula.* The range is described as† made up of clayslates, micaceous, talcose and chloritic schists (often with much epidote); interstratified iron-bearing magnesian limestones, soapstones and serpentines; quartzites; and massive diallagic, hornblendic, pyroxenic and feldspathic rocks; with beds of magnetic, specular, titanic and chromic iron ore, beds of sulphuret of copper and native gold.

Now, are these exceedingly various kinds of azoic rocks arranged in any constant order of superposition to one another, and does the order as seen in Canada correspond to their order in Vermont, in New York, in New Jersey, in Pennsylvania? Such a fact, so essential to the proper writing of a history of events in the Azoic age, has never been made out by any geologist. The catalogue of rocks mentioned above includes all the principal kinds of pure and mixed sands, pure and mixed clays, pure and mixed lime-muds, argillaceous, siliceous, calcareous, magnesian, sulphurous, ferruginous, cupriferous, which might be expected from the drainage of any primeval region of the fundamental earth-crust, anywhere, at any time, in any water basin, large or small; subsequently more or less altered by the influence of heat and pressure through an indefinitely protracted length of time. For, it must be kept in mind, that these sediments lay originally miles beneath their present level as respects the present sea level, and were covered with a world of later sedimentary strata, fragments of which remain to tell the tale; for example, a piece of the Mohawk formation on the top of Mt. Eolus in Vermont, and some Niagara and Helderburg strata in Barnardston on the Connecticut river. No structural geologist can persuade himself that the Catskill formation stopped at the Hudson river, or that the Coal measures of the Schuylkill and Lehigh were not originally continuous with those of Rhode Island. All the formations of middle Pennsylvania were therefore at one time piled upon New England, which involves the statement just made that the Green mountain

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*See Report E, page 83.

†Idem, p. 85.

rocks were miles below their present surface, and subject to a constant temperature twice as great as that of boiling water, and a constant pressure of 40,000 pounds to the square inch, a pressure growing lighter of course as the superincumbent mass was gradually removed in course of time; leaving them in their present crystalline condition; a condition therefore not to be explained wholly by reference to their creation in any particular age, Huronian or otherwise.*

The opportunity for the removal of the superimposed strata, and for the erosion of a part of the crystalline rocks themselves, was afforded by an upthrust along the whole range from Reading in Pennsylvania to the shore of the St. Lawrence, irregular in its details, of unknown cause and of unknown date; producing a long and narrow arch, the sides of which were so compressed as to complicate the crown of the arch with minor folds, as seen in the Durham hills upon the Delaware, in the Highlands of New Jersey and New York upon the Hudson, and the sections made across Vermont. The body of the arch is underground; its crown, appearing at the present surface, consists of the so-called Older Gneiss. On its two flanks should appear the upper members of the crystalline series. But in point of fact, along its northwestern side much later strata lean against the arch; and the various crystalline schists and slates, micaceous and magnesian, the serpentines and soapstones, the talcs and chlorites, the chrome and gold and copper-bearing rocks, which are called the upper members of the series, seem to be confined to its southeastern flank and are spread abroad through the regions which lie in that direction. With all our efforts we cannot comprehend it; for the true nature of that first great movement has been almost entirely concealed from our inspection, and masked by the consequences of other more or less similar subsequent derangements of the ancient state of things along the Atlantic seaboard. The confusion and obscurity which

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*It remains to be explained however why the lowest Palæozoic strata are not more and more generally crystalline, although subjected to part of the same load.

characterize the literature of the geology of all New England, the several states of which have been studied by eminent geologists for half a century, the conflict kept up between the advocates of the sedimentary stratification and the advocates of the volcanic or plutonic outflow of the granitic and gneissic rocks, and the irreconcilable differences of arrangement of its rock masses and rock belts as well-characterized formations in sequence of time, prove how little is yet known of the geological history of the Azoic age or ages in America.

It cannot be wondered at then that the difficulties encountered in New England should be felt with equal force in studying the azoic areas of New Jersey and Pennsylvania, and that the geologists of these states should refuse to use the names applied to New England and Canadian rocks until their validity be better shown. The application of local names to distant regions under such circumstances can only be a delusion and a snare. In the case of unaltered well-stratified and fossil-bearing deposits a name can safely be allowed to follow a geographical outcrop to any distance; but even then, as will be shown further on, the difference of character and thickness which one and the same continuous formation exhibits when traced for hundreds of miles makes the use of the name first given to it in one locality of delicate and doubtful propriety elsewhere, especially when the name is intended to indicate the special geological age in which the sediment was deposited.

The supposed English equivalents.

In 1879, Hicks read his paper on a new group of *Pre-Cambrian Rocks* (the *Arvonian*) in Pembrokeshire, before the Feb. 5 meeting of the Geological Society of London.* This paper gave rise to a controversy which has thus far shown no abatement; but on the contrary has drawn into its vortex most of the geologists on both sides of the Atlantic; so that the peninsular of St. Davids has been the typical battle-ground between those who multiply pre-Cam-

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* Q. J. G. S. XXXV, ii, p. 285-294, with a little map.

brian formations and those who refuse to classify them on account of their obscurity.

The *Arvonian* of Hicks are supposed to underlie the *Pebidian*, which underlie the *Cambrian*. They are supposed to rest upon the *Dimetian* (*Laurentian*) gneiss; and therefore to be the equivalents of the *Huronian* in America, and of the *Hälleflinta* series in Scandinavia; sedimentary beds; the rock being a "micro-crystalline mass of quartz grains with some intersticial light-gray substance having but little action on polarized light; but the chief peculiarity consists in the manner in which the quartz is separated away into nests, so as to give that curious *porphyritic* appearance. . . . .; the grains so compressed together (and yet distinctly fragmentary) that all other material is removed and nests of pure quartz grains only are seen having a very crystalline appearance. . . . . .; the darker material is brought together and made to fold round the nests, so that a banded or imperfect flow-structure is given to the rock . . . . as if an incipient gneiss was being formed," etc. Fragments of these hälleflinta beds are said to be found in the *Pebidian* measures, which are therefore accounted of later age and seem to rest against the *Arvonian* everywhere unconformably.* The different characters of the three formations are thus stated:

Pebidian; (*a*) micaceous, talcose and chloritic schists, with slaty and massive green bands containing epidote, serpentine, etc.;† (*b*) tuffs, indurated ashy shales, breccias, silvery schists, porcellanites, conglomerates and agglomerates.

Arvonian; breccias, hälleflintas and quartz-felsites.‡

Dimetian; quartzose rocks, granitoid gneiss, and compact granitoid rocks with bands of crystalline limestone (*Laurentian*?).

Dr. Hicks read at the same meeting another paper on the pre Cambrian (*Dimetian*, *Arvonian and Pebidian*) rocks

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*See Hicks' previous paper in the Q. J. G. S. XXXIV, p. 153.

† These correspond somewhat to our South Valley Hill rocks.

‡ These are supposed by Hunt (T. S.) to correspond to our South mountain rocks, in Adams county, south of the Chambersburg-Gettysburg turnpike. See his Report of Progress E.

in Cærnarvonshire and Anglesea as a sequel to his paper of December, 1877, Q. J. G. S., XXXIV, p. 147) in which he describes his re-examination of the district in company of Prof. Torrell of Stockholm, Mr. Tawney and Prof. Hughes of Cambridge, and Dr. T. Sterry Hunt of Montreal, and the evidences they obtained of the reality of the distinction and order of time ascribed to the three great formations. The paper contains a map of the country from Holyhead to Portmadoc, and Prof. T. G. Bonney's description of microscopic rock sections.*

Prof. Bonney, however, read at the same meeting a paper on the Quartz-felsites of Cærnarvonshire, in which he decidedly rejected on microscopic grounds the views of Dr. Hicks and Prof. Hughes about their sedimentary and metamorphic origin, and affirmed that they have the characteristic features of fluid igneous rocks (*rhyolites*), lavas of Cambrian age; of which he gives six remarkable pictures (pl. 13, p. 320) showing the internal flow-structure, magnified 50 diameters; also a cross-section (with one great anticlinal and one great synclinal) of (5) Pebidian rocks; purple slates resting on (4) green slaty grits; on (3) grits and conglomerate beds; on (2) lower conglomerates interbanded with green slates; on (1) green slates not less than 3,000′ thick, cut off from the (supposed older) quartz-felsite group by a greenstone dyke.

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* Q. J. G. S., XXXV, p. 295-308.

Chapter XVI.

Formation No. 1; Chiques sandstone; Hellam quartzite of York county; North Valley Hill sandstone of Chester county; White Spot sandstone at Reading; "Potsdam sandstone" of the Reports of Progress; Upper Cambrian quartzite of Walcott; Sugarloaf sandstone of Maryland.

It is best to get rid of the old name "Potsdam sand stone" at the outset of a description of this the long considered oldest of our fossiliferous formations; for there seems to be no satisfactory evidence that the proper Potsdam sandstone of the Canada Line and Lake Champlain extended as far south as southern Pennsylvania; although it seems to be traceable into the northwestern states.* It is possible however that the friable sandstone beds of Sand Ridge in Nittany Valley, east of Bellfonte, Centre county, may represent the New York Potsdam. They underlie the *Chazy* and *Trenton*, as the fossils show; but they have limestones beneath them, as the South Ore Mine borings show.†

Chiques sandstone is not only the oldest name for our formation No. I, but expresses the locality of its finest exposure, the great rock mass which towers above the east bank of the Susquehanna, for a mile above Columbia, and ends abruptly at the Haldeman mansion and iron furnaces,

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*The identification was based upon two facts, first that it lay almost immediately underneath the great limestone formations (Calciferous, Chazy, Trenton); second, that it contained worm burrows (*Scolithus*). But curiously enough diligent search for *Scolithus* at the Potsdam village outcrops have failed to find it; whereas Scolithus is very abundant in the Cambrian quartzites, at different horizons, in eastern New York, and in various places in Pennsylvania.

† E. V. d'Invillier's Report of Centre Co., T4, p. 31.—See also Report T3, p. 152, where M. Sanders' measurements on the Little Juniata make 5,400′ of upper limestone beds, about 40′ of sandstone, and 1,160′ of lower limestones, bottom not reached.

where Chiquesalunga (Chikiswalunga, as Haldeman spelled it) creek enters the river.*

Hellam quartzite is a name adopted by Frazer in his York county report, C2, because of the extensive spread of the formation over Hellam township, where several large quarries work it out, and its characteristic *Scolithus* fossils are exceedingly abundant and admirably exhibited in place.†

North Valley Hill rock is the popular name for the formation in its long outcrop through Chester and Montgomery counties, where it edges the Welsh Mountain region and looks down upon the narrow limestone valley of Coatesville, Downingtown, Conshohocken and Willow Grove.

At the *White Spot* on the mountain behind Reading it has been famous since the early settlement of the Great Valley. But so far from being an unique occurrence, we now known from the long and minute geological surveys of Prime and d'Invilliers that the formation spreads over the whole range of the Highlands of Berks, Lehigh and Northhampton in discontinuous outcrops and isolated irregular patches, between which the older gneisses show. It very generally forms the north slopes of the range, facing the Great Valley; and rises also in more than one place through the limestones of the valley itself.‡

Primal sandstone is the name of it always used by Prof. Rogers in his Geology of Pennsylvania, 1858. And it would be a good name but for the fact that it is not an ordinary sandstone but a quartzite; and for another fact, that it seems to take its place as the last not the first of the great quartzites, being probably in what Walcott calls his Upper or Potsdam subdivision of the Cambrian system. There is reason for believing that it overlies in York and Adams the upper strata of the South Mountain and has

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*See description and section by H. D. Rogers, in Geol. Pa. 1858, page 193. Also Dr. Frazer's Report C3, plate 4, page 108, and plate 5, page 112, from photographs of the cliffs.

†See the figures in Prof. Wanner's contribution to the Annual Report for 1876, part ——.

‡See the Index sheet of the great topographical map of the region by Prime and d'Invilliers, and the county maps accompanying Reports D, D2 D3.

nothing to do with the great quartzites of the Mount Holly range on the Cumberland and Fayette side, except as belonging to the same Cambrian (or Huronian ?) system.*

Prof. Rogers' *lower primal slates* are evidently Dr. Frazer's phyllites.†

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*In England the "Stiper Stones" of eastern Wales represents our Chiques sandstone; a rocky formation 1,000′ thick, vitrified by trap eruptions; standing in picturesque pillars and castle-like masses of white crystalline quartzite intersected by quartz veins; passing *geographically* into coarse grits and siliceous sandstone; good road metal; flagstones from a few inches to 3′ thick, separated by "way-boards" of sandy shale, or greenish white unctuous clay; ripple marked; showing casts of sea weeds (?) *i. e. Cruziana*, or *Bilobites;* also vertical worm-burrows (*Scolithuss linearis*) sometimes syphon-shaped at the bottom, and with trumpet-shaped mouths, (see good picture of a slab on p. 41 of Murchison's Siluria, London, 1859); also the characteristic shell *lingula*, in, over and beneath the Stiper Stone mass. The Stiper Stone graduates *downward* into and in fact forms the upper part of the *Lingula flag formation.* (See columnar section on p. 156 of Siluria.) It graduates *upward* into the *Llandeilo* grey flags, slightly micaceous, weathering brown (alternating with schistose darker beds) at least 3,000′ thick, and quite conformably overlying the Stiper Stones (Siluria, p. 48, 49). The underlying *Lingula flag* formation (*Upper Cambrian* of Lyell) is roughly divisible into upper, middle and lower; the upper and lower full of fossils, the middle almost destitute. (See Phillips' Manual, London, 1885, p. 45.) The upper and middle together are Sedgwick's *Ffestiniog group;* the lower is Salter and Hicks' *Menevian group.*

† Dr. Frazer says (General Notes, etc., Proc. Amer. Philos. Soc., Dec. 4, 1885, page 398): "There are no good exposures of the Hellam quartzite *with the slate below it* at any place in York county which I recall. On the flank of the South mountain the quartzite is very much rent and crushed into fragments, while of the small patch on the map about two miles west of Case's ore bank (No. 8 on the map) no accurate dip was recorded. The quartzite, of which a part composes the "Chikis mountain," exhibits indeed in its numerous foldings the rock called by Rogers "talcose slate" *between its two principal beds of quartzite*, but not appreciably lower than the latter."

The quartzite mass seemed to Prof. Rogers to be double where it makes the river cliffs a mile below the mouth of the Codorus. Here an upper quartzite mass of beds "are underlaid by a tolerably thick belt of striped slates; this again by a succession of thick sandstone (quartzite) and slate, the latter predominating until we reach the limestone at New Holland. Sometimes the slates dip slightly north from the axis and sometimes they are *inverted* or dip towards it. Half a mile above the furnace on Codorus creek the compact white sandstone dips N, 60°." (Geol. Pa., Vol. 1, p. 193.) But from the above description it is evident that the "sandstones and slates, are not beneath, but above, the quartzites, as Dr. Frazer's map shows.

No. I on the Susquehanna.

The *Chiques quartzite* is a very hard rock; of white or grey color, often pinkish, brownish or blueish; almost always crystalline; and so brittle that the disturbed strata have a smashed and confused appearance, sometimes leaving the spectator in doubt which way the beds really strike or dip at the special point of observation, although the run of the outcrop as a whole is marked by a ridge of ground more or less bold.

Prof. Rogers' description of the Chikis rock section from Columbia up to Chikiswalung creek, although not quite comprehensible at one or two points, will serve to explain the relationship of the exposed formations. See Geol. Pa., Vol. 2, page 193.

From the old railroad engine house in Columbia to the furnace (1,100′) appear (1) for 250′, magnesian limestone crystalline, mottled, dipping 50°, S. S. E., beds obscured by cleavages; (2) for 250′, ferruginous olive slate baked hard, cleft with oblique steep joints; (3) for 400′, magnesian limestone, more sandy, crystalline, cleft, white and mottled. These are the lowest beds of the great Lower Silurian (Ordovician) limestone formation *No. II*, forming the valley of York and the plain of Lancaster.

From the furnace to a little north of the second ravine, 2,500′, is a fine natural section of "Upper Primal Slates," apparently dipping all southward at say an average of 45°, but there is a small compressed double fold at the tunnel; total thickness possibly 1,800 feet, but probably much less, judging by their thickness "in the North Valley Hill of Lancaster and Chester."

Chiques Rock is the square west end of Chestnut Ridge, which runs due east 4½ miles to Hempfield P. O. A fine section of the formation has been made by the river, and a beautiful anticlinal arch is plainly seen at the foot of cliffs by the side of the road.* But it is not so easy to make out

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*Here a cave of erosion, of no great depth, was inhabited by men, abandoned, filled up, and re-excavated by Prof. S. S. Haldeman, who was rewarded by finding a multitue of human implements, etc. See his paper in the Trans. Amer. Philos. Soc., Phila., with many plates and figures.

the true structure at the north end where another and collapsed and overthrown anticlinal was seen by Prof. Rogers,*and only the south half of one by Dr. Frazer, the north leg being lost in a fault.†

These primal slates are greatly altered, hard, olive green inside, weathering dingy brown, excessively cleft, dips decreasing from 80° to 65° at the contact with the underlying quartzite at the second ravine.‡

Here a low, oblique, irregular arch of quartzite (500′ across) lifts the slates; with two gentle waves on its southern side; and its northern side completely inverted, so that the beds all dip southward, the arch being tightly compressed. In and under the arch of quartzite appears an arch of slates. The quartzite beds only measure in all about 25′, the underlying slates say 300′.

From the arch to Chikis creek is 3,000′, with three quartzite exposures; in the first one the quartzite, 27′ thick, rises at 60° (S.); then the slates, 300′ thick, rise at 50° (S.); then the lower or main body of quartzite rises at 50° (S.), turns over sharply and descends again vertical, only 20 feet of the top beds of this lower quartzite appearing in the arch, white, without joint or fracture or trace of cleavage,

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*See Geol. Pa., 1858, Vol. 1, page 193.

†See Report C3, 1880, page 108.

‡The metamorphism of the slates and quartzites which Prof. Rogers describes falls far short of that of the newer and older gneisses; and this is of itself a guarantee of inferior age. It is however an additional proof, if any were required, that 50,000 feet of the Palæozoic formations, Ordovician, Silurian, Devonian, Carboniferous and Permian, have been removed by erosion from the York and Lancaster county region. The center line of the Dauphin county coal basin is only thirty miles distant (N.) from Chickis Rock. The forward thrust of the whole country shifted all the geological localities out of Maryland into Pennsylvania. The movement took place upon the floor of the gneiss, after the gneiss floor had lost more or less of its own mass by previous erosion. Consequently it must have already suffered some metamorphism by heat and pressure before the quartzite and primal slate were deposited. The added palæozoic time, heat and pressure increased the gneiss metamorphism.

The pressure and heat to which Chikis rock was subjected at the close of the Permian age amounted to say 50,000 tons to the square yard (90,000 lbs. to the square inch), at a temperature of more than 1,000° Fahrentheit; 600° being the melting point of lead, and 4,000° of iron. The metamorphic process was consequently one of slow *baking*, under enormous pressure, increasing through all the palæozoic ages, reaching its maximum at the end.

the bedding barely discernable, but showing how plastic it must have been to submit to such a lap while retaining its solidity. The arch of overlying slates up the hill sides is pressed into a sharp crest, and is full of cleavage.

A third "grand waving" arch at the north end of the rocks brings up the lower main body of quartzite, making the fine cliffs back of the Haldeman mansion. The arch at the road is 1,000′ across. Its top shows two synclinal waves. Its south beds dip 30° and then 45° (S.). Its north beds plunge vertical, and probably bend back underground, and rest their broken ends on the sides of the south dipping limestones of the valley, as seen just across the creek. Here the cleavage plains dip steeply N. Everywhere else steeply S. about 80°

The lower quartzite (with intercalated slate bands) cannot be closely measured, but seems to be about 300′.

Some of the middle and lower quartzite beds are crowded with *Scolithus linearis*, which are all nearly straight, and sometimes furnished with a little knob at one end. This knob is the cast of the funnel-shaped mouth of the worm's burrow; the best illustration of which is given by Walcott on plate LXIII of his Monograph on the Olenellus Fauna of the Lower Cambrian, published by the U. S. Geological Survey, in 1891.

Dr. Frazer's general description of it as it exhibits itself two miles north of Wrightsville; in fragments on the summits of the range of hills from York to the Susquehanna; on Shunk's hill just south of York; on the Pigeon hills (line of York and Adams); in the outcrop three miles north of Hanover Junction; and on the south flank of the South mountains, especially in Adams county; is as follows: "a very fine grained and compact rock, exhibiting generally heavy bedding and joints of cleavage, the latter frequently rendering its structure difficult to represent, owing to the confusion arising from the surface planes. Its prevailing color is flesh red or wine yellow, but it is sometimes beautifully white." (C2, page 108.)

An analysis of Chikis rock, by Mr. McCreath, shows:

silicic oxide, 97.100; ferric oxide, 1.250; alumina, 1,390; lime, 0.179; magnesia, 0.129; total, 100.148.*

The Chiques Ridge fault.

Along the north side of the Chiques Ridge runs the south edge of the great limestone formation (*Calciferous IIa*) of the Lebanon Valley. Along its south slope runs a belt of hydromica slate 3 miles long; south of which again runs a belt of the limestone under Columbia and Mountville; then a belt of the slate from Washington Manor, east northeast, 3 miles; then a belt of limestone; then the phyllite area; then the gneiss. The two limestone belts widen out into the great Lancaster limestone plain. It is logical to consider them synclinal belts, supported on the hydromicas; these supported by the Chiques quartzite; this by the phyllite formation; this by the gneiss of the Tocquan anticlinal.

If then the hydromica belt first mentioned ends in a point (east) against the south side of the quartzite, and does not encircle the east end, nor appear on the north side of the quartzite belt (see Frazer's Lancaster Co. map), the natural explanation (although a very unsatisfactory one) must be got by supposing faults.

A fault, however, undoubtedly ranges along the northern foot of the Chiques ridge, between the limestone and the quartzite, whether the quartzite beds simply are thrown steeply upward (north) against the fault, or are doubled over and crowded back downward into the fault. In the former case we have an ancient basset edge wall of quartz-

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*I well remember my astonishment, many years ago, when my dear old friend John F. Frazer, Professor of Chemistry in the University of Pennsylvania, told me that he had just analyzed a specimen of Chikis rock sent to him by our common friend, S. S. Haldeman, and found that it was not at all a quartzite, but a *silicate of lime*. I never got an explanation of this curious adventure. Probably the specimen had been changed, and was not from Chikis rock. Possibly there may be beds in the mass of the composition of which we are ignorant. Dr. Frazer adds that a quartzite from Geo. Keller's farm, through which magnetite crystals are disseminated, is so compact that its grains cannot be distinctly separated under a high power lens; but that small irregular patches of limonite intersect the mass; while in polarized light separate systems of concentric colored rings mark each original quartz fragment. (C2, page 108.)

ite (facing north) now represented by the long line of fine cliffs against which the river impinges at the mouth of the Codorus, is deflected east along its base, five miles, to the mouth of the Chiquesalunga, and then breaks through it to Columbia. The line of the river proves the fault; the rock cliffs over the Haldeman mansion exhibit it.

Now, the slates along the south flank of the quartzite ridge cross the river just above Wrightsville, edge the south side of the triangular quartzite area in Hellam township, turn the west point of the triangle, and make its northwest border back to the river, down the Codorus to its mouth.

The geographical proof that the slates *overlie* the quartzite is complete; and establishes the correctness of Prof. Rogers' *upper primal slate* formation.

The geological evidence is equally conclusive; for the general dip in the Chiques rocks is southward, under the slates; and of the slates southward under the limestone.

It is possible that the slates do actually crop out along the north foot of Chiques rock; for there is a concealed interval of half a mile between the limestone and the quartzite along the railroad, although in the bed of the river, at very low water, Dr. Frazer says the two can be seen only say 100 yards apart. But as the dips are nearly vertical, this interval may mean nearly 300 feet of slate, even supposing none of the slates are swallowed by the fault.*

There can be no doubt about the anticlinal structure of Chiques ridge; for, after running a straight east course for eight miles, and losing itself beneath the Lancaster lime-

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*C3, page 108. The first quartzite beds are seen dipping a little E. of S., nearly vertical, for a distance of about 1,400 feet down from the creek. About 300 feet further south dips of 44° (southward) begin and continue 200 feet. The next 500 feet is a synclinal trough holding chloritic and hydro-mica schists (*Upper Primal slate*); the basin being collapsed and overthrown, showing south dips of 48°, 34°, and then south dips of 70°, 65°. The next 1,600 feet is occupied by a broad anticlinal (broken in on the crown) with one plain S. 35° E. dip of 50° (at 700′), another N. 65° W. dip of 78° (at 1,000′), another S. 35° E, dip of 74° (1,250′), and another S. 30° E. dip of 76° (at 1,450.) Then descend the same hydro-mica schists with dips of S. 70° E. (!) 21°, S. 23° E. 60°, and S. 35° E. 50° (for 200′ to Henry Clay furnace=115′ of slates). Here an intercalated quartzite of peculiar aspect, S. 24° E. 24°. Then come more hydro-mica for 800′, and so on down the river.

stone plain, it reappears seventeen miles further on, upon the same due-east course, at Laurel Hill, and begins to spread around the Welsh mountain gneiss region into Chester and Berks counties.

That it underlies the Lancaster limestone plain goes without saying; but we have visible testimony to the fact in the shape of two outcrops near Manheim, 4 miles north of Lancaster, of oval form, each a ring of quartzite and slate around a core of gneiss, and probably marking an elevated point or hump high enough to reach the present surface on the crest of one of those sharp collapsed or overturned anticlinal rolls which pervade the whole underground of the Lancaster plain.

No. I east of the Lancaster plain.

From Laurel Hill one belt of it extends along the north flank of the Welsh mountains E. N. E. 12 miles to the extreme east point of the county, and thence along the Berks-Chester county line, partly in Berks, partly in Chester, 10 miles further, and is then, before it reaches the Schuylkill, covered by the Trias.

The other belt passes south of the Welsh mountain, and occupies in Chester county much of the surface of West Caln and Sadsbury townships; with three outlying smaller areas in West and East Brandywine and Wallace. From Sadsbury a continuous belt of it runs east northeast for 25 miles, through Valley, Caln, East Caln, Uwychlan, West and East Whiteland, Charlestown and Tredyffrin townships to the Schuylkill river at Valley Forge, where it is covered by the Trias.

This is the well-known North Valley Hill, bordering the Chester or (Downingtown) limestone valley on the north.

In all these outcrops of Lancaster and Chester counties (except the three outlines above mentioned) the belt of quartzite and slate runs between the gneiss and the limestone, overlying the gneiss and underlying the limestone. The reason of the exceptional cases is evident; erosion has removed the limestone from the quartzite patches, which are themselves only remnants of a once universal outspread of quartzite over the gneiss.*

In Montgomery county, the North Valley Hill belt of quartzite undoubtedly continues beneath the Schuylkill valley, on the same nearly east course, nearly to the Bucks county line; for we see it issuing from beneath the south edge of the Trias in a series of four anticlinal spurs, or very low hills, which sink diagonally (E. S. E.) beneath the limestone of the valley.† Beyond the last spur the belt itself issues from beneath the Trias at Fort Washington, on the North Penn RR., and runs on six miles into Moreland township. Here it ends, spooning to a point and then sweeping round the east spoon-point of the limestone (2 m. E. of Pinetown) it returns westward as the south border of the limestone to the Schuylkill at Conshohocken.‡

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* Even in the case of the two uplifts of quartzite at Manheim, above-mentioned, they have the shape of rings around a nucleus of gneiss. And in one place, near Green Bank P. O., 4 miles east of Laurel Hill, Lancaster county, the area of quartzite is broken through by a surface patch of gneiss.

† This system of diagonal quartzite anticlinals separated by limestone synclinals is a most curious phenomenon. Dr. Frazer has shown that it continues in force along the quartzite belt of Chester county. It proves a widespread pressure movement in a N. N. E. direction; and the movement must be of a late date if we are to explain by it the astonishing anticlinal and synclinal structure of the Trias country of Bucks and Montgomery discovered by Mr. B. S. Lyman and exhibited on his forthcoming geological map of those counties. (Aug., 1871.)

‡ Here the South Valley Hill begins and runs west into Lancaster county. We should of course suppose that this southern barrier of the synclinal limestone valley would be made by the quartzite. But it is made of hydromica slate. Repeated reports have been made during the last fifty years of the discovery of the quartzite ("Potsdam sandstone") at various points along the South Valley Hill; and no doubt specimens of quartzite have been picked up, and even thin outcrops of thin quartzite beds among the slates have been seen. But these amount to nothing. They cannot be accepted as expressing with any certainty the reappearance of the North Valley Hill belt on the South Valley Hill side of the limestone. It looks as if the North Valley Hill rocks descend against a great fault, running along the foot of the South Valley Hill and are there entirely cut off by it, probably thrown by it (in company with the lower limestone beds) high into the air on the Delaware side of the fault.

Now it is just at Conshohocken that the Schuylkill river breaks out of the Chester county limestone valley to find its way to the sea, viz., in the short interval between the east end of the hydro-mica belt of the South Valley Hill coming from the west, and the west end of the southern quartzite outcrop coming from the east. What does this mean? Surely it is an added

In a previous chapter has been given Mr. C. E. Hall's description of a belt of vertical quartzites running along the south edge of Bear Ridge (older gneiss) from near Jenkintown, in Montgomery, to near Morrisville, in Bucks, in a straight E. N. E. line about 16 miles long, with adjoining outcrops of vertical limestone beds (in Huntingdon valley). Here the quartzite (called 60 years ago *eurite*) is a sort of *itacolumite*, although it scarcely at all exhibits the peculiar flexibility of the well-known Brazilian stone. Perhaps the true relationship of these beds to the Chiques quartzite of the North Valley Hill will never be quite satisfactorily made out.

Rogers' Primal in the Chester Valley.

Prof. H. D. Rogers studied his "Primal Series" very carefully, and devoted many pages of his Final Report of 1858 to its description. He divided it into three formations: a middle sandstone, with slates below and slates above; but warns his readers at the outset that all three divisions are not always present, and that "in the more southeastern zones especially, the Primal Upper Slate, and in some localities the Primal White Sandstone would seem not to have been originally developed, or to have been deposited interruptedly. Even where present the recognition of the slates is rendered in many cases very difficult from their close approximation in aspect and composition to the more ancient metamorphic schists." *

In the Willow Grove-Barren Hill outcrop, east of the Schuylkill, it is most metamorphosed, resembling a regularly bedded quartzose felspathic gneiss, decidedly crystalline, but the felspar crystals not so completely separated from the quartz crystals as they are in gneiss or granite, the silica being diffused through the felspathic mass without much influencing its crystallization, "very much as the sand occurs in the Fontainbleu carbonate of lime." So

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proof of a great fault; and of the total difference of the two formations; and of the futility of all endeavors to discover a southerly synclinal rise of the quartzite along the South Valley Hill.

*Geol. Pa., Vol. I, page 149.

gneissoid is the rock, however, that it has been regarded as a variety of eurite. It is traversed by innumerable joints, dividing it into small rhombs. Along this whole Barren hill outcrop this thin-bedded altered sandstone has in its upper part much altered slate of a felspathic and talcose character.* But there are no purely siliceous massive beds to be seen, as on the Susquehanna, and therefore no real quartzite. The disappearance of the sandstone west of the Schuylkill, along the South Valley Hill, he ascribes to an actual thinning out.†

On the northern Montgomery Co. outcrop, between the Pennypack and Wissahickon creeks, the principal mass is an alternation of thin bluish-grey sandstone beds and still thinner brownish sandy slate layers (much like the "older primal slates" on the Susquehanna above Columbia) sometimes showing an incipient talcose crystallization (Geol. Pa., p. 154).

In the North Valley Hill west of the Schuylkill the sandstone beds and upper slates run its whole length ; the

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*Wherever *talc* is noted by Rogers, it is well to read either *pholerite* or *damourite;* for analyses have cast doubt upon the magnesian character of the mineral. This induced Dr. Frazer to adopt Dana's name "hydromica slate" for these apparently talcose beds.

†On this southern Montgomery Co. outcrop, between the Schuylkill and Wissahickon, Prof. Rogers divides the formation into three, but places the sandstone on top, thus : The *lowest* or semiporphyroidal group, of altered sandy slate, regularly laminated (bedded) alternately dark and light, so thin as to have many in an inch, white earthy imperfectly developed felspar, and dark earthy perfectly developed hornblende, with scattered concretions of felspar from the size of a pin to a bullet. Maximum thickness at the Schuylkill 300′ (visible at Spring Mill 100′). *Next*, imperfect talcose and micaceous slate, wavy, garnetiferous, as at the mouth of Aramink creek opposite Conshohocken. When less altered, an impure sandstone, holding imperfect mica and talc. Weathers to a greasy clay mottled deep red and bue, evidently the source of the brown hematite ore deposits of the Valley. Large segregated chunks of cherty quartz strew the ground. Thickness about 200 . *Upper* member, the white sandstone of the Barren Hill anticlinal, thin-bedded, yellowish white, very compact, with imperfect felspar crystals tending to rhombs ; the more solid layers seldom over two inches thick ; schistose bands of felspar-quartz, with minute partings of mica and talc, holding innumerable specks of pure black schorl (tourmaline). Thickness 35′ to 40′ : toward Willow Grove, 100′ ; further east at least 300′ (Geol. Pa., p. 155).

It is hard to believe that this represents the series on the north side of the valley, which lies just as close to the northern area of gneiss as this does to the southern.

sandstone lying directly on the gneiss; the lower slates wholly absent; the sandstone holding a certain quantity of purely siliceous beds, altered to quartzite; some of the beds showing needles of *hornblende* and a little crystallized *talc;* general dip about 70° to the south conforming to the dip of the overlying limestone.

The white sandstone exhibits a remarkable constancy of character from the Schuylkill to the Susquehanna; sometimes more vitrified with imperfect felspar specks, partings coated with talc, surfaces embedding minute crystals of schorl; sometimes less vitrified or cemented, more porous, soft, crumbling, less flaggy, but still showing some talc and schorl (tourmaline), (Geol. Pa., p. 156).

In the North Valley Hill the gaps of the East and West Brandywine, and at Gap station, show the beds to be about 100′ thick, and the overlying slates a little more than 100′. But in the South Valley Hill no continuous outcrop of it appears, although it rises vertically next the limestone at the foot of the hill near and west of Coatsville, projecting conspicuously a rugged outcrop of beds in all about 30′ or 40′ thick, and of the usual character.*

The most easterly appearance of the Chiques sandstone in the North Valley Hill of Chester county is a mile east of Valley Forge at the east point of Mount Sorrow, where it emerges from under the Trias, and where its lower altered slates are half a mile wide. The sandstone increases going west, along Mount Joy, to the west point of Tredyffrin township (Ayre's store). At the Diamond Rock, where its crevices hold fine rock crystals, the lower slates are seen on its north flank. Several anticlinal rolls, closely folded, make the summit and south slope a broad outcrop of quartzite beds. Here it is set back northward, and a new set of waves begin. Most of it, however, has been eroded from

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*About 1½ miles east of Downingtown it was exposed in the road gutter and in a well, and much decomposed and talcose. Opposite Spread Eagle and Paoli, it was struck in T. Biddle's well, and its fragments lie in the soil at the foot of the hill. (Geol. Pa., p. 166.) Mr. Rand reports other such exhibitions. But it is still a question how far any of them warrant their identification with the North Valley Hill rock, as they may be sandstone intercalations in the South Valley Hill slates.

the gneiss, leaving only a south dipping outcrop going down under the limestone. Between this and Lancaster county its outcrop fluctuates in breadth, owing to local waves, which, as Dr. Frazer shows, run obliquely and produce a toothed line of junction with the gneiss. Two or three such anticlinal waves may be seen in the Brandywine gaps, although their close compression makes all the dips steep southeast, as shown in Prof. Rogers' cross sections.*

In the gap north of Downingtown the lower slate can hardly be found; and the quartzite is so complicated as to seem a formation a thousand feet or more thick; whereas there are only about 100 feet of beds.† Here the first outcrop against the limestone shows perfectly regular quartzose layers with thin partings of white talc; and in the rock many needles of schorl, always broken by the plastic movement of the matrix.‡ On the outcrops nearer the gneiss the rock becomes more altered, a granular quartzite holding specks of felspar and mica, a good deal like a fine-grained white granite; but the schorl identifies it.§

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*Geol. Pa., 1858, page 175. Fig. 21, section from Diamond rock across the Valley south of Paoli. Fig. 22, section north of Coatesville, showing two fine arches, one double crested. Fig. 23, section north of Parkesburg, showing one sharp roll, and north of it a deep synclinal with its south side beds vertical. Thus the belt varies in width from 400 to 1,200 yards. Sharp saddles of the underlying gneiss also present themselves at the surface, splitting the belt lengthwise; and with the gneiss these saddles bring up the slates which lie upon it (and beneath the quartzite beds) and so altered, crystalline and gneissoid as hardly to be distinguished from the gneiss itself. East of the East Branch Brandywine the upper and lower slates seem very thin; but they thicken rapidly and steadily approaching the West Branch (Coatesville); which may help us to understand how the quartzite of the North Hill (50′ thick at Diamond Rock) is almost wanting in the South Hill, while the lower slates, so thin on the North Hill side of the Valley, are so very thick on the South Hill side. Prof. Rogers ascribes this to irregular deposition; but I think it must be due to some sort of pressure faulting; if in fact the formations be identical.

It is almost unnecessary to add that the limestone of the Valley is crumpled in the same manner as the quartzite and slate; nor to urge the importance of keeping in view all this movement as a wholesome check to any theory of irregular, local, exceptional deposits.

‡ As described by Keyes in his paper on the Piedmont country of Maryland, quoted already.

§ Geology Pa., page 177. Prof. Rogers always uses this old-fashioned name for black tourmaline.

No. I in Bucks county.

That the quartzite of the North Valley Hill, and of its diagonal comb-teeth spurs in the valley east of Norristown, passes broadly beneath the great *Trias formation* of Bucks and Montgomery, making its descending floor, is proved by its sudden re-appearance at the surface in Buckingham township, a few miles east of Doylestown. Here its outcrop makes a bold low ridge nearly 4 miles long, running about N. 40° E. with a belt of limestone on its northwest edge. The limestone belt extends 10 miles to the Delaware river at Centre bridge. Both formations are brought to the surface together by a great fault, which will be described hereafter. As there are at least 15,000 feet of Trias south of the fault, we are justified in saying that the quartzite floor, which disappears beneath the Trias at Fort Washington, must slope down northward at the rate of at least 1,000 feet per mile, *i. e.*, on a gradient at least 10°. But as the average dip of the Trias beds hardly exceeds 5° (although very variable, and hard to calculate by average) it would follow that a very considerable amount of limestone overlies the quartzite floor underneath the Trias region. Mr. Lyman's constructive sections however will make this interesting subject clearer.

No. I in the Highland range.

The quartzite floor emerges from beneath the north border of the Trias in Springfield township, Berks county, where the North Penn R. R. crosses the Lehigh county line. It rises upon the south flank of the Highland gneiss, and runs thus, eastward, for 13 miles to the Delaware river at the county corner, between the gneiss and the synclinal limestone belt across which the river cuts at Durham furnace. The limestone belt spoons out, westward, at Pleasant Valley P. O., and the quartzite (forking) surrounds its west end, and puts another belt south of the limestone, and between it and the gneiss of the Durham hill.

In Northampton county the quartzite formation must be very thin, for although it undoubtedly forms floor of the

the numerous limestone valleys between and among the Highland gneiss hills, it makes little show around their edges, where it lifts its outcrops against the gneiss.*

In Lehigh county the quartzite crops out from beneath the limestone and against the gneiss all along the foot slope from Saucon creek westward past and around S. Bethlehem, and along the south bank of the Lehigh to the west point of the mountain two miles south of Allentown.†

In fact the Lehigh river, after passing Allentown, turns at a right angle into a narrow synclinal trough of limestone, floored with quartzite lying on gneiss. It is a curious gateway between the Lehigh mountain (gneiss) on the south bank, and the low gneiss hill on the north bank.

Five miles southwest of this right angle bend of the Lehigh, and in a line with the Lehigh mountain, there rises a low hill of gneiss flanked with quartzite, a fine section through which is made by the Little Lehigh creek.

Another outcrop of quartzite runs along the foot of the mountain past Emaus (opposite the low hill aforesaid, and two miles from it, with limestone between) for about five miles.

Another very short one is noticeable at the foot of the mountain, three miles E. S. E. of Alburtis, and another a mile west of Alburtis near the county line. With these exceptions little or no quartzite has been reported in Lehigh county.

But in Berks county the quartzite makes a great show.‡

A continuous outcrop of it faces the range of mountains overlooking the East Penn RR. all the way from Alburtis to Reading, 25 miles, ascending the vales between the

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*For instance, at the river bank 3 miles below Easton; on the slopes 4 miles east of S. Bethlehem; on the slopes 2 miles south of Hellertown; at the west end of Chestnut ridge 3 miles west of Easton; at the west end of the strip of gneiss 3 miles northwest of Bethlehem; and around the gneiss hills in the bend of the river between Allentown and Bethlehem.

† At one place along this line there is a fine exposure of it, but only 25 feet thick, dipping about 30′ N. and laying *directly* and *conformably* upon the gneiss. It is an exhibition well worthy of serious attention.

‡The mapping of Northampton and Lehigh was done by Prof. Prime, and a subsequent revision of the mineralogy by Mr. C. E. Hall. The mapping of Berks was done by Mr. E. V. d'Invilliers. This may account for the apparent greater show of quartzite in Berks.

ridges and spreading over the highest summits. A southern belt crosses the Schuylkill a mile below Reading, and encircles the whole of the Oley limestone valley. Another surrounds the isolated little Dale Forge limestone valley. Another borders the limestone of Seisholtzville, on the Lehigh county line. Three others border the limestone exposures at Treichlersville, Churchville, Bechtelsville and New Berlin, where it emerges from the north border of the Trias. It is made perfectly certain by all this that the Chikis quartzite formation once covered the whole Highlands, and that it underlies now the whole Trias region east of the Schuylkill. That it underlies the Trias west of the Schuylkill, in Berks and Lancaster county, is demonmonstrated in the same way by a long outcrop of it, beginning 3 miles southwest of Reading, and running west 6 miles to the Reading and Columbia RR. at Fritztown, curving northwest and west around the north flank of Mulbaugh hill (gneiss), six miles further to the Lebanon line, and so round south to pass out of sight under the Trias south of Mulbaugh hill. But it is equally evident that the quartzite is otherwise entirely covered by the limestone under the whole Lancaster, Lebanon and Dauphin Trias belt.

Before going west from Hellam township, York county, let us see what evidence we have that the Chikis quartzite once extended from the line of the Chester county valley southward toward the Atlantic.

No. I in southern Chester county.

In Delaware county no rocks assignable to the Chikis quartzite have been noticed by Mr. Hall; nor any in southern Lancaster by Dr. Frazer. But in southern Chester Dr. Frazer (certainly the best authority on the subject) has mapped a considerable area of the quartzite between two belts of limestone, and between two areas of gneiss, extending from the Pennsylvania and Delaware RR. south of Doe Run P. O. eastward, for 8 miles, to a little beyond Red Lion—an area four miles wide between the limestone belts, and running out east in a long straight line along the long straight line of the southern limestone belt. Upland and London Grove are in the middle of this area.

Another short narrow belt of quartzite runs from Kennet Square along the Baltimore Central RR. west, along the north side of another limestone belt. A similar outcrop borders the limestone from West Grove station, westward, for 3 miles. Another small triangular patch in Kennet township has its south point within a mile of the Delaware State line. Another more important outcrop surrounds the limestone on Broad Creek in London and Britain townships, and passes over into the State of Delaware.

It is evident, then, that if the rock of these outliers be rightly identified, the Chickis quartzite had an unknown extension southward, as it plainly had eastward.

No. I in southern York county.

In York county its former southward extension is guaranteed, but for a comparatively small distance, by one long outcrop south of the Wrightsville and York limestone belt, and by a great many isolated patches in the country north of the phyllite belt.* Even inside the phyllite belt there is noted on the map one spot of quartzite 3 miles S. W. of Prospect, in Lower Windsor, 4 miles west of the Susquehanna; and a small group at the Maryland line in the S. W. corner of Manheim, and close to the north edge of the gneiss. The absence of quartzite exposures on the surface of the great Tocquan gneiss belt in York and Lancaster counties, and in Delaware, Philadelphia and southernmost Montgomery and Bucks counties, may be due to complete erosion; or it may be indicative of a *supposible* fact that it was only through Chester county that the quartzite and limestone formations at the beginning of the Palæozoic age were *thickly* deposited far southeast of the great Palæozoic region.

Rogers' Primal sandstone in its North Valley Hill char-

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* It is possible that some of these isolated patches are short outcrops of other quartzite beds intercalated among the hydromica slates. But they may be sharp anticlinals penetrating the slates from below upward high enough to reach the present surface.

acter, was recognized by Rogers in the Peach Bottom locality, and for four miles down the Susquehanna river into Maryland. He assigns its principal outcrop a thickness of 90 feet, and sees in the accompanying slates the upper and lower members of his Primal Series, especially the lower or South Valley Hill slates; but as his principal exposure of sandstone is in his opinion an overthrown compressed anticlinal, some at least of the slates must fall into his upper division.*

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*I give three very interesting paragraphs on p. 189 of his Geol. Pa., 1858, verbatim for the readers' consideration:

"The next belt of strata cut by the river, and indicated on our section, extends from below Slate Point to the second canal-lock below the State line, a distance of about four miles. The rocks here exposed are various forms of mica-slate and talcose-slate, alternating with talcose white sandstone, certain outcrops of which bear the unmistakable characters of the Primal white sandstone. One or two outcrops of chlorite-slate occur, and occasionally the mica-slate graduates towards a micaceous quartzose gneiss. Much of the finer-grained talcose slate is undistinguishable from rock, so-called, which near the Schuylkill, and along the South Valley Hill, both east and west of it, and also in the anticlinals of the Montgomery and Chester Limestone Valley, is seen in intimate alternation with the Primal white sandstone. Either from the more frequent presence in this district of the middle part of the Primal series, the White Sandstone group, or from a less excessive degree of metamorphism, the strata here exhibit a far lower condition of crystalline change than in some of the tracts further N., having fewer of the features of true micaceous schists, and more of the characters of genuine sedimentary sandstone. Indeed, at several places between Slate Point and the State line, we meet with a rock which, in its composition, lamination, colour, fracture and whole lithological aspect, is absolutely undistinguishable from the main bed of the Primal white sandstone, as it is seen in Edge Hill and other notorious localities of this readily recognized rock. One of the localities is just below Slate Point, the sandstone forming, in fact, the south flank of the Slate Hill, and reposing, regularly bedded, immediately upon the slate itself, which near the contact is highly nacreous, and in that minutely wavy or crinkled lamination which usually denotes a metamorphism approaching the rock usually called Talc-slate.

"About 1700 feet further down the river, there is another outcrop of Primal white sandstone immediately north of Hough's Run at the canal lock. Here the rock is between 90 and 100 feet thick. It dips at the canal level 45° to S., 30° E.; but rising into the hill it grows flatter until it becomes nearly level, as if bending to form an anticlinal arch; indeed, it is difficult to resist the conclusion that these two south-dipping belts of sandstone are simply the two abutments of a wide fold or flexure, the northern flank of which is inverted into a somewat steeper south dip than the southern. This view is confirmed by the crushed and contorted condition of the dark slates which fill the space between the outcrops of the sandstone. It is further confirmed by the presence in this neighborhood, both within the supposed arch and at

The southwestern extension of the Chickis quartzite formation in York and Adams counties, and into Maryland, is in two lines: (1) by the Pigeon hills; and (2) by the south edge of the South Mountains.

No. I in the Pigeon hills.

The Pigeon hills are a range of high ground ranging N. E. and S. W. through Jackson and Paradise townships of York, and Berwick township of Adams county, at some distance from and parallel to the limestone belt along which the York Short Line RR., and its continuation, the Littlestown Branch RR., run. Between the Pigeon hills and the limestone runs a continuous belt of hydromica schist from half a mile to a mile wide. At the foot of the hills, marking their southern limit, is a range of iron ore banks: S. Emig's, W. S. Johnson's, And. Mengis, Mich. Meyers', S. Roth's, J. Roth's, J. L. Miller's, Geo. Bechtal's, O. Ferry's, Ashland Co.'s.* The Sprenkle ore is on the slope of the hills, where they encroach so upon the limestone belt as to reduce its breadth to a quarter of a mile.†

The Pigeon hills, beginning near Farmers P. O. 8 miles W. S. W. of York, run on about 8 miles further into Adams county, along the S. E. edge of the Trias. They are a belt

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Slate Point above it, of a steep south-dipping cleavage, a feature quite usual in the slaty rocks throughout the district.

"At other points further down the river, especially between Rock Run and the State line, a material having all the aspect of the Primal white sandstone under a more extreme condition of metamorphism reappears. We meet it again, though materially more altered and crystalline, about two-thirds of a mile below the State line, and here, as we should expect, it is in contact with a dark crystalline slate, precisely such as we find the talcoid slates of the South Valley Hill, Chester county, where, in alternation with the sandstone, they are more than usually metamorphosed. In truth, we encounter repetitions more or less frequent and distinct of this altered white sandstone and its contiguous slates all the way along the river to the mouth of the first stream in Maryland, more than a mile and half below the State line. In other words, we may recognize these outcrops of the Primal white sandstone throughout a belt nearly three miles and a half broad, from the south flank of the Slate Point Hill to near the crossing of the great belt of serpentine."

*Frazer's Report C2, pages 55, 58, 63.

† C2, page 100. This slate *over* the limestone, not between it and the quartzite of the hill, dips S. 60° E. 78°; the limestone under it dip S. 30° E. 69°.

of quartzite and slate; the slate on the southern flank between the hills and the York valley limestone, as at Columbia; the slate belt being in fact traceable (with two or three slight breaks where bridges of limestone cover the slates) all the way to Columbia. Evidently a sort of anticlinal axis connects the Chickis arches with the Pigeon hills; but the country is too much crumpled to permit any geographical regularity to the outcrops. The slates are dark; the sandstone (quartzite) beds light colored and of various degrees of fineness and compactness.*

No. I along the South mountains.

No Chickis quartzite is seen *in place* along the southeast foot of the South mountains in York and Adams counties; but great quantities of quartzite fragments lie on the surface of the hydro-mica schists as if the formation had been wholly broken up and disintegrated. The belt of fragments runs along between the Dillsburg limestone, marl, trap and trias and the schists of the mountain in York county; and past Lattimore, Idaville, Bendersville, Arendtsville, Cashtown, and so down south past Fairfield, down Tom's creek to the Maryland line, between the trap and trias and the mountain.

In Maryland the same exhibition is continued; but after a while hills of quartzite appear, and at last a bold high ridge of quartzite called the Sugarloaf mountain, advanced several miles in front of the Cotoctin mountain which is the eastern ridge of the South mountain (Blue Ridge) mass of the Potomac country.

The Sugarloaf sandstone (quartzite) is described as an unmistakable sedimentary rock. Under the microscope it shows no crystallization, not even an enlargement of the quartz grains, although its cement is sometimes silica (chalcedony), sometimes decomposed felspar (kaolin). No new minerals have been generated in it. It has in fact not suffered any appreciable metamorphism. The series of sandstone beds (dipping east) pass upward through alternations of clay sand and sandy slate, into the overlying

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* H. D. Rogers, Geol. Pa., 1858, p. 195, 197, condensed.

slates and schists. They seem to be the same as the sandstone beds of the Cotoctin mountain on the west side of the Frederick limestone belt, brought up by a great fault. To the east of Sugarloaf however is the great phyllite country of alternate belts of hydro-mica and chlorite slate; and these seem to be of later age than the Sugarloaf sandstone.*

In this opinion Mr. Keyes agrees with Dr. Frazer's views as expressed in his third or Lancaster county report, although in his earlier York and Adams reports, and in the coloration of the York county map, a broad distinction is made between the "hydro-mica schist" belt and the "chlorite schist" belt to which in later years he applied the term "phyllite." It is necessary to state the uncertainties more in extenso in a following chapter.

No. I in middle Pennsylvania.

On the Little Juniata above the Tyrone Forges, in Huntingdon county, the great Nittany Valley faulted anticlinal brings to the surface the bottom beds of the great limestone formation No. II. It is the only spot in Pennsylvania north of the South mountain range where we can look for the appearance at the present surface of the Chicques quartzite or the hydro-mica slates above it; and in fact, about three-quarters of a mile above Birmingham, crushed and massive grey sandstone strata are exposed (dipping 35° S. E.) for 150 yards. Under them red shales appear; over them alternations of sandy lime shales and limestones. These must belong to Rogers' Primal series, although they are not metamorphosed, but only crushed a little by the fold of the anticlinal and the slip of the great fault.†

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* Keyes, in Bull. G. S. A., II, 306, 320, and figured microscopic sections on 321.

† Geol. Pa. I, page 503. Dr. R. M. S. Jackson in 1837 thought these Potsdam. C. E. Hall supposed in 1877 that he found Potsdam fossils in them. (Report T4, p. 152). Specimen 2,662 of the survey collections above the Birmingham covered bridge is a white, compact fine-grained sandstone; Specs. 2,653 to 2,656, are sandstone; Specs. 2,657 to 2,669, are a ferriferous sandstone; Spec. 2,661, marked "Potsdam" by C. E. Hall, is a hard grey sandstone got below the bridge opposite the railroad station (T4, p. 365). Prof. Rogers likened the solid sandstone beds to Medina.

CHAPTER XVII.

On Scolithus linearis.

Scolithus was for many years accepted as the fossil trade mark of the Potsdam sandstone, and was supposed to stamp with genuineness any outcrop, any specimen, in which its notable form could be plainly seen. It is so prominent an object on the surface of the cracked stone, it is so unmistakably unlike other fossils, it seemed at first to be so entirely absent from the overlying Palæozoic, Mesozoic and Kainozoic formations, that the study of it by Haldeman in the fallen fragments of Chicques rock near his home at Columbia, on the Susquehanna river, and his description of it, in 1840, *as the oldest fossil in the world*, was hailed by geologists with enthusiasm.*

Of late years the gravest doubts have been thrown upon the plant character of most of the most ancient "algæ,"

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* See his supplement to Monograph of Limniades. Although he constructed the name from *skolex*, a worm, and *lithos*, a stone, he described it as the stem of a seaplant, and made it at first a subgenus, and then a genus, under *Fucoides*.—H. D. Rogers mentioned Haldeman's fossil in his second annual report, 1837, as a *marine plant*, and suggested the name *Tubulites*, which was not adopted.—Hall's description of it is that of a plant . . . "numerous linear stems, often extending to two or three feet in length. Ordinarily . . . like a series of small pins or pegs driven into the rock in a somewhat regular manner and at uniform distances. It preserves its distinctness even when the surrounding rock is much altered . . . stained with oxide of iron, and the rock cleaves more easily in that direction. (See Hall's Pal. N. Y., V. 1, 1843, page 2; figures on Plate 1.) Even the famous fucoid of the Bird's eye limestone (in No. II) Hall's *Phytopsis cellulosum, and Phytopsis tubulosum*, 1846, is now regarded by many as a worm burrow, in spite of the cross connection of its stems and way in which they sometimes radiate from a sort of center in all directions outward, curving and returning into each other. But the internal fibrous structure, and the interlacing of the fibers in mathematical forms, represented in the fine plates of Hall's first volume, seems to place the organic (plant) structure of the Bird's eye fossil beyond all reasonable doubt. (See Pal. N. Y., Vol. 1, Plate 8, Plate 9.)—The extravagant conclusions of Nathorst, which would, if accepted, expunge seaplants from palæo-botany, have produced a beneficial reaction towards a closer study of these mysterious forms.

"fucoid" or "seaweed" markings, and as Etheridge says in his edition of Phillips' Manual, p. 34, the "term Fucoids must be modified or almost expunged from our nomenclature, because nine out of ten of them are not casts of sea-plants but of worm burrows."* The analogy of the present lob-worms on all seacoasts seems to be a satisfactory explanation of Haldeman's Scolithus, which has been found abundantly in the sandrocks and quartzites at the base of the Palæozoic system from Canada to Georgia, and from Tennessee to Wisconsin, and similar or allied forms in Scotland, Ireland, Wales, France, Spain, Bohemia, Silesia, Finland and Scandinavia.

In 1856 Salter named similar worm burrows of about the same or still greater age in Shropshire, *Arenicolites*† *didymus*, because they were usually seen in pairs, joined by a loop at the bottom, suggesting the idea that the worm descended by one hole and returned to the surface by the other.‡

In 1858 *Kinahan* found in the Lower Cambrian (Solva group) of Brayhead, Ireland, curved trumpet-mouthed burrow-casts, made by worms with tentacles. He named them *Histioderma hibernicum.*§

**Scolithus linearis* (Hall) 1847, found in Formations Nos. I, II, III. *Scolithus verticalis* (Hall) 1852, in Medina SS. No. IV (Pal. N. Y. II.) *Scolithus canadensis* (Billings) 1862, in Potsdam No. I (Pal. Foss. I.) *Scolithus danieloi* (*Tigillites danieloi* of Renault) in the Potsdam of France (Aguidam, &c.); *Scolithus* (*Tigillites*) *defontaines* (Renault) in the Potsdam of France (Guichen, &c.); *Scolithus* (*Tigillites*) *dufresnoyi* (Renault) in same. (Thesaurus Siluricus of Bigsby, p. 31); *Scolithus bohemicus* (Barrande); *Scolithus cylindricus* (Barrande) in Potsdam, D. d. 2 of Bohemia. (Thes. Sil. p. 197.) See Hall's Pal. N. Y. I. 2.

†The name *Arenicola carbonaria* was given by Lamarck to a worm burrow in the Wigan Coal measures of England as early as 1818, and this induced Salter to substitute *Arenicolites* for *Scolithus*, for Cambrian forms. American geologists, however, continue to use Haldeman's name, while English geologists prefer Salter's.

‡*Arenicolites sparsus* (Salter) was found in the Longmynd of Shropshire (Thes. Sil., p. 29.) *Arenicolites uricomiensis*, found in the quartzites of the Wrekin in Shropshire, is the oldest fossil as yet found in Great Britain (or except the Eozoon canadense, in the world) provided the right age has been assigned to these quartzites. (Etheridge. Phillman, p. 34.)

§Thes. Sil. 30.—Nicholson's Manual, 142.—Etheridge's Phillips Manual, 34 in which it is wrongly given *hibernica.*

Salter's *Scolecoderma tuberculata*, 1866, in the Tremadoc slates of Wales, is regarded by him as the membranous tube of a mud worm.*

In the very old Cambrian rocks occur other forms, named by Sternberg in 1833 *Chondrites*, the oldest forms of which are now regarded as the casts of worm burrows.†

D'Orbigny in 1842 named a kind of worm burrow with traces of a tube lining *Cruziana*. In the oldest Cambrian (Lingula flags) Salter found *Cruziana semiplicata;* and in the nearly as old "Stiper stones" formation another species; but the numerous forms of *Cruziana* named by geologists occur chiefly in the Caradoc sandstone (Trenton period.)‡

The confidence with which *Scolithus linearis* was at first assigned to Potsdam sandstone is illustrated by W. B. Rogers' paper on the Gravel and Cobble stone deposits of Virginia, in which he describes finding, in 1842, a large pebble of compact vitreous sandstone in a pile of paving stones in Richmond, and opines without doubt that the pebble had come from the nearest outcrop of Potsdam on the west flank of the Blue Ridge. Subsequently the cobble stone deposit of Richmond was discovered at Washington, and multitudes of *Scolithus* and other Palæozoic fossils were seen in it. Here it consisted of two gravels of very different ages, one subcretaceous, the other post-tertiary, both giving *Scolithus*, &c.§

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* He found a similar form, which he did not name, in the Caradoc. Haldeman's *Scolithus chordaria*, 1847, from Silesia, is put into the category of worm fossils by Bigsby.

† *C. acutiangulus*, McCoy, in Lingula flags; *C. antiquus* and *informis*, Sternb. in Livonia; *C. regularis*, Harkness, in Llandeilo rock; *C. tener* and *tribulus*, Eichw. in Finland and Esthonia; *C.* ?, Salter, in N. Wales.—But Brogniart's *C. antiquus* was found in the uppermost Silurian (Ludlow) beds. (Thes. Sil. p. 29.)—The Devonian forms of *Chondrites* (*andrea, antiqua, major, minor, lineata, foliosa, nessigii, tæniola*) are all placed among plants by Bigsby in Thes. Der. Carb. 1878, p. 2.

‡ *C. bronni, C. cordieri, C. furcifera, C. goldfussi. C. lyelli, C. prevosti, C. st. hilaire* (all of Rouault); *C. carpetana, C. murchisoni, C. torrubiæ, C. Ximenezii* (all of De Prado); *C. rugoso* (D'Orb); *C. harlani* (Hall); &c. (Thes. Sil. p. 30).

§ Proc. Bost. S. N. H. 1875; reprinted in Geology of the Virginias, 1884, pp. 709–913. See more of this under Wealden and Glacial ages.—Prof. Heilprin exhibited a pebble containing *Scolithus linearis* found in the Yellow Sand formation of New Jersey, near Glassboro'. (Proc. Acad. Sc. Phila., May 5, 1885; and Amer. Nat., Sep., 1885, page 928.)

It would be strange indeed if worm burrows should be confined to one geological age, and still more strange—to one petty formation. Nor are they; for they have been found in sandstone strata of all ages; and their essential identity with the *Scolithus linearis* of the *Chiques* (*Hallam*) *quartzite* is now generally recognized. Worms of different species have different habits, and their burrows differ; but the generic resemblance remains. Thus *Scolithus* is common in the *Portage formation* (*VIII f*) in Bradford and Tioga counties, and in western New York.* It has been seen also in some of the Coal Measure sandstones, in America and in England. But it is everywhere abundant in the *Cambrian* quartzites of all the American Cambrian regions. Whether Dr. Walcott is right or not in carrying the Cambrian system so high as not only to include the *Potsdam* sandstone of New York, but also the lower part of the *Calciferous* sandstone, some of the Calciferous beds are full of *Scolithus*.†

I have devoted an entire chapter to this fossil form, because the identification of Chiques rock with the Potsdam sandstone of the St. Lawrence and Champlain country has been hinged upon it, to the confusion of our earlier Palæozoic geology in Pennsylvania. It has of course raised the question why all the well-known fossil forms of the Potsdam were not discoverable on the Susquehanna. No other fossil but *scolithus* has been seen in the Chiques rock. Obscure shell-like forms have indeed been seen by Prof. Wan-

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*H. D. Rogers, Geol. of Penna., 1858, Vol. I, page 296. "In the higher part of the formation some of the layers contain a *vertical fucoid*, if it can be so termed, a simple stem-like form, crossing the plane of the bedding. This is evidently a species of *Scolithus*, and except that it is a little less regularly cylindrical, resembles greatly the species so characteristic of the Primal andstone."

†Brainard and Seeley who sub-divide the 1,800 feet of Vermont Calciferous into five stages, say that *Scolithus* does not characterize any single one of the five, but appears abundantly in various horizons of D: the most abundant display of it seen by them being, however, at the bottom of C, 600′ or 800′ above the top of the Potsdam; and yet pure limestone beds are plentiful in B. (Bull. Geol. Soc. Amer., Vol. I, 1890, p. 510. See p. 4, Dict. Foss., 1889, Vol. 3, page 943.)—This should teach us to look for sandstone beds in the body of our great Valley limestone formation; and such are found.

ner in the Hellam quarries, but none plainly enough to recognize. Probably they are Cambrian fossils ; for the Cambrian rocks have furnished a plentiful supply.* It was indeed the age of worms, as in an insect sense the age of coal was also the age of Cockroaches ; but a solitary cockroach wing has recently been found in France in a sandstone of Silurian age. So, the Devonian age was one of great armoured fishes; but fishes of that order have recently been fonnd in Trenton rocks. The age of worms now appears to have swarmed with living creatures of both lower and higher grades. It is impossible to believe that where the Hellam worm-burrows are in millions, no other fossil forms can be discovered. It only requires sharp self-trained eyesight to discover them. The South mountains of Pennsylvania will probably prove to be a good collecting ground for students of palæontology; and perhaps even the semi-crystalline region of the Philadelphia belt.

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*Even in 1886, Walcott had defined 393 species (92 genera) of Algæ (9), Spongiæ (13), Hydrozoa (5), Crinoidea (3), Annelida (5), Brachiopoda (67), Lamellibranchiata (1), Gasteropoda (29), Pteropoda (20), Crustacea (15), and Pœcilopoda (226). Of these, 76 (32 genera) were found in the Lower; 107 (43) in the middle; 213 (52) in the Upper Cambrians; 14 genera were common to the Lower and Middle, 15 common to the Middle and Upper, 11 common to the Lower, Middle and Upper, and 12 common to Lower and Upper (Am. Jour. Sci., Aug. 1886, page 149.) But this arrangement has been exchanged by him for another quite different (based upon his later discovery of the subordination of the Middle to the Lower, or of the *Olenellus* fauna to the *Paradoxides*) in his Monograph on the Cambrian recently published by the U. S. Geol. Survey, 1891.

CHAPTER XVIII.

On Cambrian fossil life as known.

The great thickness of the Cambrian system may be judged from the fact that Walcott assigns to the Lower division of it (the *Olenellus zone*) in the two eastern counties of New York, Washington and Rensselaer (the nearest Cambrian region to Pennsylvania as yet studied) a possible thickness of 14,000 feet;* and to the Middle and Upper divisions of it (*Paradoxides* and *Orthis zones*) an additional 2,000 feet.† But in eastern Massachusetts, Newfoundland, Georgia and the Rocky mountains, the Cambrian would have a different thickness as a whole, and different thicknesses of its three palæontological sub-divisions.‡ The fossil zones are no guides for us in the South mountains (if the rocks there be Cambrian) because none of the Cambrian fossils has as yet been found there, or indeed anywhere in the state.§

The abundance of marine vegetation and animal life in the Cambrian age was long ago inferred from the copious life of the immediately following Lower Silurian (Ordovician) age. It began to be proved by discoveries in Bohemia, Sweden, Wales, New Brunswick and Massachusetts.

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*Amer. Jour. Sci., Vol. 35, 1888, page 242.

†The sub-division is not made on the basis of stone character, but on the stages of groups of fossils. He says: "About 2,000 feet below the summit of the strata assigned to the Cambrian the fauna contains *Olenellus asaphoides*," &c. The Fauna of the Lower Cambrian, in Tenth An. Rt. U. S. Geol. Sur., Washington, 1891, page 583.

‡In both the "Eureka" and "Highland" sections the *Olenellus zone* is comparatively narrow. In British Columbia it lies at the base of the Castle mountain limestone, and beneath it are 10,000 feet (estimated) of dark clay-slates and sandstones (*Pre-Cambrian* or *Algonkian*) as in the Wasatch mountain section. Walcott, in U. S. G. S., Annual Rt. X, 1891, p. 585.

§Except *Scolithus*, and Prof. Wanner's undetermined shell forms in the York county quarries, and perhaps the ribbon plants of the Peach Bottom roofing slates.

It is now magnificently illustrated by Walcott's and Ford's collections in Vermont and New York, and by Walcott's and Dawson's collections in the Rocky mountains. Other geologists have contributed their several discoveries; so that Walcott's latest list (1891) includes 51 genera, 141 species, and 11 varieties. See Monograph, page 576.

Cambrian fossils are wholly of marine forms. No traces of land plants or land animals have been seen in Cambrian rocks.

True *Seaweeds* (*algæ*) have not been certainly seen, although it is impossible not to believe in their existence. The so-called seaweeds (even the *Cruziana*) appear to be trails of worms or of shellfish (mollusks).* *Sponges* were very abundant.† *Jellyfishes* (*Medusæ*) seem to have lived even in Lower Cambrian times, and traces of their soft forms are recognized on the clayslates and fine sandstones of Sweden and on the Upper Cambrian rocks of Alabama.‡ Even the modern *Sea-sludge* or Whale-food order of creatures were represented.§ *Graptolites* also, those curious and prolific leaf-shaped animals of Silurian times floated on the surface of the Cambrian waters.‖ *Corals* (*Actin-*

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*Matthew however has described what he believes to be true seaweeds, from the St. John, N. B., rocks, under the names *Buthotrephis antiqua, Phycoidella stichidifera, Palæochorda setacea, Hydrocytium* (?) *silicula, and Microphycus catenatus.* On Cambrian Organisms in Acadia, Trans. Roy. Soc. Canada, VII, 1890, p. 144. Compare the fossil plant-like forms of the Peach Bottom slate quarries in York Co., Pa., said by James Hall to resemble a *Butrotrephis* of the Hudson river formation (No. IV) more than anything else.

† *Protospongia* is found in the upper beds of the Olenellus zone and also in the Middle Cambrian of our east and west, and in Wales and Sweden. *Leptomitus* is wholly Lower Cambrian. There are two other genera. Walcott, page 587.

‡ The Swedish geologist, Nathorst, thinks that the once supposed seaweed *Eophyton* is the cast of the trail of a jellyfish moving over the sea-bed. Possibly *Dactyloides asteroides*, an American species, may be so explained. It is very remarkable that nothing like a Medusa has been found in the Palæozoic and Mesozoic rocks, nor until we ascend to the Upper Jurassic lithographic slate. Walcott, p. 587.

§ Matthew describes *Monadites globulosis, M. pyriformis, M. urceiformis and Radiolites ovalis.* Camb. Org. Acadia, 1890.

‖ At least two kinds, *Phyllograptus* and *Climacograptus.* Matthew has assigned two Middle Cambrian forms to the genera *Dendograptus* and *Protograptus.*

ozoa) had hardly begun to appear.* *Sea urchins* existed early and became numerous in the Middle Cambrian.† *Worms* were infinitely numerous, swarming, trailing and burrowing over and in the sea bed and shore sands, from the beginning to the end of Cambrian times, and undergoing no change so far as the casts of their tracks and burrows can teach us anything of their character. They have been grouped in four genera: *Planolites*, *Hilminthoidichnites* (lobworm tracks), *Scolithus* and *Cruziana*.

The *Brachiopod* shell life of Cambrian times was abundant; ten genera (and 29 species) are known in the Lower Cambrian (Olenellus), zone, viz., *Lingulella*, *Acroteta*, *Acrothele*, *Iphidea*, *Kutorgina*, *Linnarssonia*, *Obolella*, *Orthis*, *Orthisina*, and *Camarella*.‡ These have no special embryonic traits of character in the Darwinian sense, leading to higher development in the Middle and Upper zones; but after that, in Lower and Upper Silurian times, the superior *articulated* families (Orthidæ and Rhynchonellidæ) predominate over the inferior *inarticulate* families (Obolellidæ, Siphonotretidæ and Lingulidæ) which

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* "The first true corals . . . . occur near the base of the Silurian fauna." It was disputed whether *Archœocyathus* was a sponge or coral. But Hinde and Walcott agree in placing it among the Zoantharian families, allied to the perforated corals. In the later Cambrians no *Archœocyathus* is known except Matthew's doubtful *A. pavonoides* from the Paradoxides zone at St. John. Walcott, p. 588.

† In the Lower Cambrian a few scattered plates of a *Cystid*, perhaps an *Eocystites*, are all we know about the beginnings of the Echinodermata. Walcott, p. 588.

‡ *Lingulella*: of four genera three occur in the Paradoxides zone. *Acroteta gemma* ranges from the base of the Lower into the Upper Cambrian. *Acrothele subsidua* ranges through Lower and Middle, and *A. matthewi* in the Middle. *Iphidea* is Lower Cambrian in Labrador and Middle in Arizona and Sweden. *Kutorgina labradorica*, *stissingensis*, *pannula*, occur in Lower and Middle, the first with a wide geographical range in the Lower zone. *Linnarssonia sagitalis* (var. *taconica*) came late in the *Olenellus* zone and lived on with the Paradoxides. *Obolella* has 6 species in the Lower, none in the Middle, but some in the Upper zone. *Orthis salemensis* and *highlandensis* (the broad and the narrow hinge types) of the Lower zone is not known in the Middle, but recur in Silurian strata. *Orthisina orientalis* of the Lower zone is very like the *O. pepina* of the Upper; and *O. festinata* of the Lower very like *O. exporecta* and *O. billingsi* of the Middle zones. *Camarella antiquata* and *minor* of the Lower zone have no known existence or representatives in the Middle and Upper zones. Walcott, p. 588, 589.

abounded in the more ancient Cambrian times, indicating a general law of progressive evolution for the whole class.*

Lamellibranchiate shells were scarce in Lower Cambrian time. The class seems to have sent three forerunners to announce its coming at a far distant subsequent date.†

Gasteropod shells of 6 genera (13 species and 5 varieties) have been collected from the Lower zone in America alone, viz: *Scenella*, *Stenotheca*, *Platyceras*, *Pleurotomaria*, and *Straparollina*. These belly-creepers with their conical or horn-shaped, sharp-edged and sharp-pointed shells, must have scratched and furrowed the Cambrian muddy sand, leaving those marks on its layers which in too many instances have been taken for fossil seaweeds and even land plants.‡

Of *Pteropods*, winged shells, the Oldest Cambrian sea was full. Four genera: *Hyolithes*, *Hyolithellus*, *Coleoloides*, *Salterella*, embraced at least 15 species.§

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*Walcott, p. 587. Superior and Inferior are terms which beg the question. It is more likely that hinge or no hinge was a point in dispute settled by the habitat of each species and the adaptability of the shell to the food which that kind of habitat supplied, or to the comfort of housekeeping there.

† *Fordilla troyensis* and *Modiolopsis prisca* and an undescribed species. These came and disappeared. None have been seen in the Middle or Upper zones. Suddenly a group of species is seen in the Welsh Arenig rocks (Lower Silurian). In Devonian times the class flourished in all seas.

‡ The *Scenellas* of the Lower zone are represented by at least one species in the Middle zone, and by simple *Patelloid* shells in the Upper zone. *Stenotheca rugosa* of the Lower zone is closely allied to *S. acadica* of the Middle zone. A small *Platyceras* in the Lower zone is represented by *P. romingeri* in the Middle; and one single species found in the Upper zone passes the genus on upward into the Ordovician (L. Sil.) age. *Pleurotomaria attleboroughensis* of the Lower zone "does not appear to have a representative before reaching the Lower Ordovician fauna." *Straparollina remota* of the Lower zone has no known connection with the Ordovician.

§ *Hyolithes princeps*, a large and abundant shell, had a range from Nevada to Newfoundland, and seems to have lived into the Newfoundland Paradoxides (Middle) zone; and it differs only in details from the Bohemia *H. maximus* of that zone. *H. americanus* of the Lower zone is closely allied to *H. acadica* and *H. primordialis* of the Middle zone. *H. billingsi* is found in Lower and Middle, in Labrador, New York and Nevada. *H. similis* is like *H. primus* of the Bohemian Middle zone. *H. communis*, *impar*, *quadricostatus*, *terranovicus* have not yet been found in the Middle zone. *Hyolithellus* and *Coleoides* are not certainly known in the Middle zone. "*Salterella* of the Lower Cambrian is not again met until the Ordovician fauna is reached, and there very doubtfully." Walcott, p. 590.

Of *Crustaceans* five genera (8 species have been found in the Lower Cambrian zone, viz., *Isoxys*, *Leperditia*, *Aristozöe*, *Nothozöe and Protocaris.* It is as wonderful as anything else in geology, finding thus a world of schrimps in the first hour of the long day of the planet's life.*

Trilobites, of 16 genera (53 species), constitute nearly one-third of the entire Lower Cambrian fauna; trilobites with eyes, and trilobites blind; trilobites with facial sutures, and trilobites with unjointed faces or head shields: *Agnostus* (3), *Microdiscus* (8), *Olenellus* (7), *Olenoides* (3), *Zacanthoides* (2), *Bathynotus* (1), *Avalonia* (1), *Conocoryphe* (2), *Ptychoparia* (10), *Agraulos* (3), *Crepicephalus* (2), *Oryctocephalus* (1), *Anomocare* (1), *Protypus* (4), *Solenopleura* (5 species).†

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*Of the true crustaceans *Leperditia dermatoides* has two representatives in the Middle zone. *Isoxys* is a new genus. *Aristozoe* has not been found in the Middle zone, but in Europe it has many Silurian species. Of the Phyllopod crustaceans *Protocaris marshi* is the earliest known, the next being *Hymenocaris vermicauda* of the Upper zone. Walcott, p. 590.

† *Agnostus*, which has been theoretically considered the lowest and oldest and ancestral form of all the trilobites, seems not to have lived early in the Obolellus zone; undoubted specimens having been found only in the upper part of the zone and with Middle Cambrian forms; for Ford's *Agnostus nobilis* is probably *Microdiscus.* In Sweden it seems also to belong more to the Middle zone.

Microdiscus, with its 3 or 4 segments and no eyes, is found at the base of the Lower zone, and with so many species (8) must have had a long previous existence, coming to a maximum development in the Lower and fading away in the Middle zone (as the *Agnostus* increased in importanc), and being represented in the Upper zone by the solitary *Pemphigaspis bullata* of Hall (while *Agnostus* lived on into Ordivician, L. Silurian, times).

Olenellus is known from all Lower Cambrian areas except New Brunswick. It varies so that Walcott has grouped some of its species in a subgenus (*Mesonacis*) and Matthew has proposed *Holmia* to include *O. kjerulfi.* It differs from *Paradoxides* in having no true facial sutures, in the form of the central portion of the head, and in the form of its eyes. *O. thompsoni* differs most strongly from *Paradoxides*, which latter has nothing at all like the long-tail spine (telson). But *O.* (*Mesonacis*) *vermontana* with its typical Paradoxidean tail-piece (pygidium) links the two groups of species of *Olenellus* together. Walcott invites attention to the fact that there is a depressed line on the *under side* of the head-shell of Olenellus corresponding to real suture in Paradoxides. Also, that *Olenellus* resembles our King Crab (Limulus) in having well-developed eyes without having facial sutures. not to speak of its tail-spike. He thinks the Newfoundland *O. bröggeri* as highly or more highly organized than any Paradoxides. American palæontologists, he adds, have considered Olenellus the descendant of

The study of the Olenellus fauna proves that an immense time had already elapsed since the beginning of life on the planet. During Cambrian times the evolution of life produced almost no new classes of living creatures, but only new generic and specific variations of those which were already in existence. The most notable apparent exception to this statement is found in the subsequent appearance of the class of Cephalopod shells (*Orthoceras*, *Lituites*, etc.), none of which have as yet been found in rocks below the Silurian.* It is hardly necessary to add that nothing is known of fossil fishes in the Cambrian, much less of any

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Paradoxides, but it has turned out that Olenellus lived first. The student of Evolution may profitably ponder on the paragraphs of his 592d page.

Olenoides marcoui is the only species found in the lower portion of the Olenellus zone (the other two border on the Paradoxides zone) and seems closely related to *O. nevadensis* of the Paradoxides zone. *Zacanthoides eatoni* and *levis* serve to unite the two zones. *Bathynotus*, *Avalonia*, *Oryctocephalus* and *Protypus* are genera confined to the Olenellus zone.

The blind *Conocoryphe trilineata*, and *reticulata* are two of the best-marked types of the Lower zone, but are closely related to the blind *elegans* and *coronata* of the Middle zone.

Ptycoparia has nine species, all more or less closely related to Middle and Upper Cambrian forms. The Lower Cambrian *Agraulos strenuus* is represented by the Upper Cambrian A. socialis. *Ellipsocephalus* has a species in the Lower and in the Middle zones. *Crepicephalus augusta* and *liliana* are also Upper Cambrian, but have not been found in the Middle zone. *Solenopleura* is also well developed in the Middle zone.

Walcott concludes (page 593) that we have a poor knowledge, as yet, of the Middle (Paradoxides) fauna and may expect great discoveries to be made somewhere "on the western slope of the Apalachian shore, and on the west coast of what then existed as the North American continent." The Paradoxides fauna is merely a contribution. Surely the Lower Cambrian creatures continued in existence longer than the rocks as yet have shown. For instance, what became of the Archæocyathine corals of the Lower Cambrian? *Obolella* had a fine development in Upper Cambrian time; why is it almost completely absent from the Middle Cambrian rocks? What happened to the Brachiopod shells as a class to render the number of both their species and individuals smaller in Middle Cambrian time than before? We have Lamelli-branch shells from the Lower; none from the Middle. So also of the Gasteropods Pleurotomaria and Straparollina, and the Phyllopod crustacean *Protocaris marshi*. "The cause of the abrupt change from the Olenellus to the Paradoxides faunas is not yet fully recognized. While a considerable number of the genera pass up, very few of the species are known to do so, and in none of the sections has there been found a commingling of the characteristic species of the Lower and Middle faunas." (Walcott, page 594.)

*Walcott, page 595.

fossil vertebrates of a higher order, reptilian or mammalian. But whereas only three or four years ago it was disputed whether our Perry county Upper Silurian* fish spines and plates (the oldest known to science) were not the spines and plates of crustaceans, and whereas now true fish remains have been found in the Lower Silurian (Ordovician) Trenton limestone in the Rocky mountains,† it is easy to fancy that cephalopod shells and ganoid fish may have lived even in Cambrian times. As yet no air-breathing land animal remains have been discovered in any rocks older than the Carboniferous; but, considering the extreme difficulties attending their preservation, as compared with the easy and safe burial of water animals, it is not at all a wild conjecture that some sharp eye will light upon the traces of their existence in earlier ages.‡ Only a few years ago the Cambrian rocks were supposed to be non-fossiliferous. I have inserted this chapter on Cambrian fossil life to guide and stimulate students of geology in Pennsylvania, especicially the more youthful, curious and keen-sighted, to a closer examination of our so-called "Azoic" or "No-life" formations.

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*See Claypole's discoveries in the Clinton formation No. V *a*. in Report F2.

†See C. D. Walcott's descriptions read at Washington, August, 1891.

‡If the discovery of a Silurian cockroach wing in Calvados, France, be genuine, there was a Silurian world of land insects, and of course of land animals to devour them. If Lesquereux was not mistaken about his fossil Silurian land plants, there must have been land animals living upon their fruit or foliage. In all ages foods have been followed (or accompanied) by feeders. On the other hand, feeders presuppose foods. What did the Lower Cambrian worms, polyps, shells and crustaceans live upon? Certainly not upon mineral matter. Worms pass vast quantities of mineral matter through their intestinal canal and leave it packed behind them in their burrows, and this packing constitutes most of the "fossil cast." But they do this in order to suck from the surface of the grains of sand and mud orgenic matter which must have belonged to other creatures either alive or dead. If alive, then microscopic animalcules. If dead, then the decomposed tissues of other worms, shell-fish, etc., absorbed by the sand and mud. But the first worms must have found living food. If the worms came first and the polyps and mollusks afterwards, then the beginnings of life must be conceived of as microscopic, cellular and vegetable; in other words, an Algoid or seaweed world, feeding on the chemical elements of the rocks held in solution by the ocean water; therefore casts of sea weeds in the oldest rocks must be realities and not mechanical imitations.

CHAPTER XIX.

South Valley Hill slate belt.

Before leaving the dark geology of southern Pennsylvania to enter upon the brilliantly illuminated geology of the middle region, something more must be said of those enigmatical belts of hydro-mica slates which Prof. Rogers placed as his Upper and Lower Primal slates, above and below the Chiques quartzite (N. Valley Hill sandstone)—which Dr. Frazer places wholly above it—and which Mr. Hall placed still higher, above the great limestones, as Hudson river slates in an altered condition.

In York county the last theory receives no support. A belt of hydro-mica slate surrounds the Hellam quartzite area between Chiques rock and York, and is surrounded by the limestone of York valley and the Codorus. The hydro-mica beds are evidently *above* the quartzite and beneath the limestone; and they run on between two belts of limestone to the Pigeon Hills, and along the south side of the hills into Adams county, where they enclose the southwest end of the limestone area, and, uniting with the broad belt of hydro-mica country south of the limestone, pass into Maryland, where Mr. Keyes finds them *overlying* the Sugarloaf and Cotoctin quartzite.

South of the York limestone belt at Wrightsville, on the river opposite Columbia, a hydro-mica belt a third of a mile wide between the limestone and a long outcrop of quartzite runs west to the South Branch Codorus, where its width is five miles, widens to six miles at Xenia, and contracts to three miles at the Adams county line. Many isolated outcrops of quartzite are located on the map inside this belt, and they should represent sharp anticlinal rolls of quartzite exposed by erosion.

The phyllite ("Chlorite schist") belt, already described in a previous chapter, borders this great hydro-mica schist belt on the south, and two long prongs of phyllite country penetrate the hydro-mica belt, one pointing west towards the S. Br. Codorus, the other pointing east to the river a mile below Wrightsville, both on one line, and the two representing (theoretically) an eleven-mile long anticlinal exposure of the phyllites from under the hydro-micas.

Around the east point of the east phyllite prong at the river below Wrightsville, and along its southern side from the river west for six miles, there runs another belt of hydro mica slates, bordered on the south by the limestones. As an outcrop of quartzite borders the north side of the phyllite prong and laps around its pointed end onto its southern side, it seems evident that the hydro-mica over-lie the quartzite and under-lie the limestone.

But why is there not such an outcrop of the quartzite between the phyllites and hydro-micas along the whole contact line across the county? There is but one answer: The quartzite is an insignificant formation, an irregular deposit, thin here, thick there, absent altogether elsewhere, and in fact generally towards the south. This seems to be the case in Chester county, and especially in southern Lancaster. But if so, then the contact plane of hydro-mica on phyllite must be insignificant, unreliable and deceptive; and the contact line between the two great belts in York county can hardly be relied upon as accurate. In fact the distinction between the Chlorite schists and Hydro-mica slates is not recognized by the Maryland geologists; and Dr. Frazer says that chlorite slates occur in the hydro-mica belt. He establishes the distinction on a general larger proportion of magnesia in the lower and less in the upper; and on the local separation of the two by the quartzite beds. That is precisely what Prof. Rogers did in constructing his series of Primal lower slate, Primal (middle) sandstone, and Primal upper slate. But then, the chloritic phyllites of York become the Primal lower slate of the South Valley Hill in Chester. Whereas I understand Dr. Frazer's Chester county report to make the South Valley Hill a belt of the hydro-mica slates.

I see but one solution of the problem, which if correct will conciliate the apparently contradictory identifications of these two able geologists, viz., that both the lower more magnesian and upper less magnesian series are present *together* in the South Valley Hill.*

The South Valley Hill slate belt is two miles wide at the east end of Chester county, and the slates stand vertical. That means 10,000 feet of slates! To diminish this enormous thickness to agree with his observations on the opposite side of the valley (in the North Valley Hill) Mr. Rogers supposed many tightly-compressed rolls. Certainly two such rolls show in the double-spurred east end of the hill at the Schuylkill.† But two rolls, whether anticlinal or synclinal (and there is not room for more) will not reduce the thickness to one-fourth. There would still be more than 2,000 feet of slates.‡

Opposite West Chester the belt is three miles wide; opposite Coatesville, five miles wide; before reaching the Lancaster line, still wider; and so continues, covering much of the southern townships of Lancaster; a region where Dr. Frazer does not feel justified in mapping a contact line between his chloritic series and hydro-mica series. In

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*In this case however we must neglect Prof. Rogers' obscure outcrop of the Primal sandstone at the north foot of the hill, along the border of the limestone.

†The two "synclinals" on which C. E. Hall relies for placing the slates *over* the limestone; the two "anticlinals" on which Dr. Frazer relies (in this vicinity) for placing the slates *beneath* the limestone.

‡ Rogers conjectures that his *Primal Lower slates* between the Brandywine and Adams county may be 2,000 feet thick; in Virginia 1,200, with 150 additional as a conglomerate base which does not appear in Pennsylvania.

His *Primal Sandstone*, around the outlying limestone patches of southern Chester, in the Street road and in Dochranaman hill, thin; then at Peach Bottom on the Susquehanna, 90′; in Chiques rock, U. SS. 27′, slate parting 300 L. SS. with bands of slate, 300′, total 627; at Parkesburg, Chester Co., U. SS. 20, slate 300′, L. SS. 50, total 370; at Coatesville, Chester Co., U. SS. 40′, slate 70′, L. SS. 15′, total 125; at Edgehill, 300′; at Willow Grove, 100′; on Schuylkill and Wissahickon, 40′; Durham on the Delaware, 100′; Chesnut Hill north of Easton, 100′; below Reading thicker, but too much crumpled to measure.

His *Primal Upper slates*, wanting east of Willow Grove; Barren Hill, thin; Diamond rock and Paoli section, 300′?; Coatesville, 700′; Parkesburg, partly visible, 300′+; Columbia and Chiques about 1,000′. (Geol. Pa., 1858, page 122.)

fact hydro-mica slates with chloritic interpolations and chloritic slates with hydro-mica interpolations can be called "phyllites" with equal propriety (are so called in the Maryland survey) and alike belong really to one system of sediments, more or less magnesian.

Now, it would be wonderful indeed, if there were not sand beds in two or three thousand feet of mud deposits. When the magnesian muds were altered into chlorites and the potash-soda muds into hydro-micas, then necessarily the sand beds became quartzites. So we ought to expect sporadic quartzite beds in the slate belts. The occasional quartzite spots on the York county map in the phyllite belt, and much more numerously in the hydro-mica belt, may therefore have nothing to do with the Hellam-Chiques quartzite, which, itself, as we have seen, actually plays the same rôle of irregular distribution over its original floor as all lenticular sand deposits do of every age.*

The South Valley Hill hydro-mica schist belt from the Delaware-Chester county line west to the Brandywine has a south border fairly defined by a straight range of serpentine outcrops and limestone quarries. The line crosses the railroad south of Patton station, cutting across the north end of West Chester, to the Brandywine at the mouth of Valley creek, and the west branch at Embreeville; passing along the north side of the Doe run limestone and the little gneiss area of Buck run. But hence westward through Londonderry, Upper Oxford and Lower Oxford "there is an indefinable transition from the belt of mica slate to the felspathic micaceous gneiss country which borders it on the south †

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*The Oriskany sandstone, Formation No. VII, is a notable example of this general law, as we shall see in a future chapter. If it had been preserved from erosion in a metamorphic region it would be almost a facsimile of the Chiques quartzite. The Chiques quartzite ought not to be regarded as a unique, nor reasoned on as a universal formation of recognizable classical age and place in the great series. That would be to repeat the old error of the "Potsdam sandstone." It is but one of many, and our sketch of the South mountains in a previous chapter shows its insignificance in comparison with the huge quartzite formations underlying the hydro-mica and chlorite slates of that range of mountains.

†Criticising the map of Chester county which he was unable to revise before its publication, Dr. Frazer writes: "The chloritic and hydro-mica

The general tint of the slates is greenish. and the beds are frequently separated by lenticular beds of light-colored or pure white quartz. The slates along the southern edge of the belt are somewhat garnetiferous ; and at two places, at Williston and East Goshen, turn into a true garnetiferous schist. All the roads indicate its presence, but the best exposures are along the creeks and railway cuts descending to the valley.*

The South Valley Hill hydro-mica slates are therefore not the York county hydro-mica slates of Dr. Frazer above the Chiques quartzite, but the chloritic phyllites lying directly upon the Tocquan (Philadelphia) gneisses and mica schists, and may in fact be the upward continuation of C. E. Hall's garnetiferous (Chestnut Hill) upper sub-division of the Philadelphia series.†

The South Valley Hill belt holds so straight a course for fifty miles from the Schuylkill into Lancaster county that there can be no doubt of its extension to the Susquehanna

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schist areas in York and Lancaster were easily distinguishable, both from the less thoroughly metamorphic appearance of the latter, and from the fact that the quartzite (Potsdam) generally came in between them. This was generally true of the chlorite and underlying gneisses, though an isolated patch of the former in the latter on the Lancaster county map (with no definite upper boundary) is frankly acknowledged in the text to be an attempt at a lithological distinction run into a *cul de sac*, though abundantly justified and confirmed by a close study of the rocks in its strike in Chester county. When Chester county was reached *all sharply-defined boundaries ceased to be possible. The quartzite failed altogether on the southern side of the valley*, *the mica schists became more gneissoid*, *the gneisses showed chlorites, and the chlorites modified their distinctive character.* Add to this *that a thin unknown series*, representing the rotten representatives of all these, has since appeared to increase the confusion. Nevertheless an attempt was made to define on the Chester county map *the chloritic masses* wherever the eye detected them, leaving an explanation of them for a future task. The result however was to completely demonstrate *the futility of separating the chlorites from the mica schists* in this area (Chester county.) The area became dotted over with small and large masses of chlorites which preserved no regularity in dip, strike, zone," etc. (Report C4, page 35. Italicised by J. P. L.)

*Notes by C. E. Hall, published in Report on Chester Co., C4, page 60.

†Then the serpentine at the top of this sub-division (at Lafayette station on the Schuylkill) would coincide with the serpentine at the bottom (or south edge) of the North Valley Hill slates (south of Greentree, and west to West Chester) and also with the serpentine of Lancaster along the south edge of the Peach Bottom phyllite belt.

river twenty miles further on; and the county maps, in spite of their inconsistent coloration,* when laid together show that the straight forward continuation of the belt brings it to the Susquehanna where the Peach Bottom phyllites exhibit themselves for five miles in cross-section, mostly vertical or on very steep dips, but complicated.

Prof. Rogers was therefore correct in calling the S. Valley Hill schists *Primal Lower slates;* and no doubt if exposures allowed we could see them graduating downward into the upper schists and gneisses of western Chester and southern Lancaster just as they seem to do across York county.†

In spite of their general vertical or steep dips they are undoubtedly closely and tightly crumpled into innumerable more or less parallel small anticlinals and synclinals, upon a general floor of Philadelphia (Tocquan) newer gneiss; and that this floor participates in the crumpling is proven by its frequent and sometimes abundant appearance at the present surface along lines and over larger or smaller areas of erosion from which the chlorite hydro-mica slates have been removed.

Prof. Rogers was also correct in extending the South Valley Hill belt of slates to the Susquehanna, although in his final report he confined their identification chiefly to the phyllite and hydro-mica slate region of middle York county north of the Tocquan gneiss. That he identified them also with Peach Bottom belt slates is evident from his seeking there and, as he supposed, finding an outcrop of Chiques quartzite, 90 feet thick, which he calls "its most southern appearance in the state."‡

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* For which I hold myself solely responsible.

† This view certainly simplifies the geology of our southeastern counties but it is not wholly satisfactory, for it fails to explain the hornblendic gneiss areas of Delaware county, leaving it an open question whether they are volcanic outflows, or anticlinal (or fault) uplifts of older sedimentary fully crystallized rocks.

‡ Geol. Pa., 1858, I, p. 122, and special detailed description, page 189, which I have inserted *verbatim* in chapter 16, page 183, above. It is a fine example of the lucid and forcible style of the great geologist of Pennsylvania, the closeness of his field observation, and the wealth of material facts to be found in his immortal book. Would that he had been himself immortal, and on earth to conduct the second geological survey of the state, and to write this summary of it instead of myself.

Chapter XX.

Iron mines in the Primal upper slate.

Many of the first-class limonite (brown hematite) mines of Pennsylvania are in Rogers' Primal Upper slates, over the Chiques quartzite and under the Great Valley limestone. Such are the Chestnut Hill mine back of Columbia in Lancaster, the Warwick (Jones) mine in the south corner of Berks, the Trexler mine in Lehigh, the Old bank in Cumberland, and the Mont Alto banks in Franklin, and a large number of other more or less important open mines elsewhere; some dating far back in the last century, and others but a few years; some abandoned if not exhausted, others actively exploited at present whenever the iron industry is prosperous.*

It is not always easy to account for the vast quantities of iron ore collected by nature at these mines. In some instances the whole mass of slate seems to have been changed into ore by a sort of chemical cookery; the original slaty stratification remaining visible, but in so wavy a state as to suggest both a swelling and a settling of the mass against the walls of a gigantic chaldron.†

In other cases the ore seems to be a sediment, with clay, brought into a depression by inflowing waters which had passed through the slate rocks and obtained by a leaching process the iron which they contained; the clay being a decomposition of the felspathic body of the rock. The potlike mines of Cumberland and Franklin ranging along the

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*Other similar and even more important mines not mentioned in this chapter will be described in a future chapter, because they belong geographically to the belts of limestone outcrops, although geologically they originate in the same way from the decomposition of slates of much the same kind, but placed higher in the series of formations.

† See the pen and ink sketch of the Chestnut Hill mine face as it looked forty years ago in Rogers' Geol. Pa. 1858, I, page 183, fig. 24*a*.

foot of the South Mountain, ending with the Mont Alto banks, are certainly of this character.*

The hydromica slates of York and Lancaster are not uniform in aspect. The beds immediately beneath the limestone are massive enough to make hills, like those which line the Susquehanna from Wrightsville to Cabin Branch run. Others of the series are disintegrated to a dust of little glinting particles of mica. The more solid beds contain innumerable beautifully perfect cubical crystals of pyrites (sulphide of iron, and occasionally copper) or the hollow casts from which such crystals have been dissolved out. Here we have one most evident and copious source of brown hematite (limonite) iron ore.†

There are Cambrian argillites in Vermont which are similarly studded with perfect cubes of pyrites. I have seen 50 on the side of a slab a foot square, most of them casts, but some of the crystals projecting from the face of one slab and leaving a cast in the face of the slab from which it was split off. Their number was incalculably great. Supposing the whole formation filled with them on an even distribution there would be 67,500 in a cubic yard, and a hundred thousand million of them in an outcrop a mile long by 90′ wide and 90′ deep. As most of them were only a tenth of an inch on a side, 27,000 would go to make a cubic yard of solid pyrites, weighing say 2½ tons of iron and 2½ of sulphur, and such a prism of country would hold about a million and a half tons of iron. Usually, however.

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*See my description of them in Proc. Amer. Philos. Soc. Jan. 3, 1873. But these deposits, although on the outcrop of the slate, and deriving their birth from it, are of a very late age. The same may be said of the great Huntingdon county banks, formed in the same way and time from similar slates, higher up in the series, interpolated among the great limestones. See my Report to Lyon, Shorb & Co. (1874), incorporated into the Reports of Progress in Huntingdon and Centre counties, T3, T4.

† Frazer, Amer. Philos. Soc. Dec. 4, 1885, page 401. When a boy, at Lafayette's visit to Lancaster, I had given me a lot of these crystals which had been picked from the bed of a stream. They were about the size of dice, but varied on an edge up to an inch and down to the sixteenth of an inch; blackish-brown on the surface; when broken, a glittering gold within; most of them absolutely perfect cubes, but some with imperfect corners, not from recent fracture, for the defective corners had the same brown skin as the sides.

the slates contain the iron in the form of ferrous oxide, uncrystallized, and of percentages varying from 7 down to less than 1. Even so the amount of iron held in the rock is quite sufficient to account for great deposits of limonite produced by erosion and oxidation in clays.*

The Chestnut Hill ore bank is 3½ miles northeast of Columbia in Lancaster county, in a shallow synclinal (?) vale on the south flank of Chiques ridge.† The ore is at the bottom measures of the slate, next over the quartzite which

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*Dr. Frazer discusses the origin of the limonite deposits in Report C, 1874, page 137, and thinks it most probable that it is to be found in "the pyrite crystals of the brown slates. Even the slates which are not so situated as to permit the percolation of water through them exhibit a porous structure, the pores being filled with brown ochreous limonite; and this occurs to an unknown depth, and the slates seem to merge by imperceptible degrees, in a direction normal to the plane bedding, first into completely metasomatized pseudomorphs of limonite after pyrite (but still retaining the form of the latter); then the same with a kernal of pyrite; then the pyrite itself, first with a shell and then with a mere stain of ferric hydrate; and finally the same slates are revealed porphyritic from the pyrite, and not at all decomposed." This suggests that the limonite was manufactured by percolating waters in the body of the slate mass and merely set free by erosion and gathered together into low grounds or cavities of the surface, or caverns in the neighboring limestone, by running waters carrying the mud of the triturated slates together with the limonite of the cavities as fast as exposed, and both dumped together (slowly) into the reservoir to settle.

On page 139 Dr. Frazer makes his own calculation of quantity. A specimen of slate from under the York limestone taken on the railroad five miles southeast of York, 3½″x2½″, showed to the naked eye 350 pits left by decayed crystals of pyrites, varying from $\frac{1}{16}$ to $\frac{1}{48}$ of an inch, or 40 to the square inch. Nine layers of such pits were visible in the thickness of ⅜ inch. This would amount to 12.27 cubic inches of pyrites in a column one square inch five feet long, or 32 pounds in five cubic feet of slate. Every running mile of outcrop five feet thick and 1,000 feet high (eroded from the present surface) must have yielded 75,000 tons of pyrites, or 48,700 tons of iron, or 80,000 tons of limonite. He carries the calculation further on page 140, but the above is enough to justify him in saying that allowing for all contingencies we have more than enough to account for the largest ore banks.

† Dr. Frazer does not accept the simple synclinal structure. Ore beds at mouth of a drift 250 long sink N. W. beneath the floor of the drift. In the middle parts of the mine the ores lie flat. One or more anticlinal waves are therefore probable. On page 213 he makes a curious, novel, but by no means useless, suggestion that possibly the weight of the high walls of the open mine has helped to convert a shallow synclinal into a very low anticlinal. His numerous close observations to settle the question of anticlinal wave structure of the mass in this and the neighboring mine occupy several instructive pages of his book.

has been exposed in the mine floor. The dips are gentle; bottom flat; an open quarry, 100 feet deep, ore from top to bottom of the slope walls; area in 1856, about 11 acres, in 1877, 1400′ wide by 3350′ long. The old Grubb mine half a mile east is in the same slate and merely a continuation of the formation towards Lancaster.*

The decomposition of the slate mass into limonite is evident to the eye. The upper half or more of the walls are of a bluish, yellowish and white greasy clay, laminated as it was before the change. Underneath is a mass of solid ore, 10 to 30 feet deep, lying on the quartzite floor; brown, cellular fibrous hematite (limonite) precipitated from above as the heavier element of the wet clay which filled the hollow. The present drainage passed beneath the slate over the face of the quartzite; and this has always been the agent of decomposition. Layers of such ore however occur in the slates above, resting on tight clay strata which formed subordinate drainage planes. In only one place was the ore changed to magnetite; a band from one to three inches thick is full of beautiful small octahedral crystals of magnetic iron ore.

Dr. Frazer says that the general appearance of the Chestnut Hill mine is that of all the banks of York county along the slate belt, but on a much larger scale; the ores being in all of them of two kinds: (1) Wash ore, distributed through the upper part in planes but without the regularity of a bed of sediment, i. e. concretionary shot, balls and chuncks embedded along rude planes of clay; (2) Solid concretionary ore, usually low in the mine, hard, massive, usually darker and more botryoidal or bunched like grapes. Quartz fragments are seen sticking out of the slope walls.

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* "All the ores which lie above the Chikis quartzite from the mouth of the Chikiswalunga through Silver Spring and to the German settlement and the works of the New York Company should be included are parts of the same system." Frazer, Report C3, p. 203.—The *Shirk bank* is north of Chikis ridge 3 miles N. of Columbia and E. of Marietta. It produced 8000 tons a year for ten years, afterwards less; at first 4 tons of ore to one of wash, later 1 ton of ore to four of wash. It was an exceptionally rich pot, very wet, slate clay mass, required heavy timbering. No quartzite seen. Limestone exposed in the wall. Grade of ore 40% to 48%. Stopped 1874.—Coppenhoffer's and Garber's are small banks along the same north foot of Chiques ridge, following the fault.

Hollow bombs of ore, sometimes filled with very soft fine clay or simply with water and lined inside with black oxide of iron,* are common.

Until the introduction of the Lake Superior Marquette and other red hematite ores Pennsylvania easily held its preëminence as the great iron smelting state of America by reason of the great number and remarkable size of its brown hematite (limonite) iron deposits; and by importing the richer magnetic and specular ores for mixing with its own stock of limonite and fossil iron ore it still remains the principal iron state, furnishing always about one-half of all the iron produced in the United States. She was the first to adopt Bessemer's process of making low steel in 2, and afterward 5 and 10 ton flasks.†

Most of the great limonite beds are, as has been said above, in the Upper Primal slates. Others are in the lime slates above the Trenton limestone No. II*c*. Others are in the slates interbedded in the great limestones. Others are in the slates over the Oriskany sandstone No. VII. These will be described in their proper places.

The Upper Primal Slate limonites range along the north side of the Chester county valley; along the hydromica belt in York and Lancaster; along the north foot of the Highlands from Easton to Reading, and along the northwest foot of the South Mountains from Boiling Springs to Mont Alto. It is probable that this is also the geological horizon of Pine Grove mines on Mountain creek in the heart of the South Mountains; and possibly of the Richmond ore bank in Path Valley north of Mercersburg in Franklin county, although this last range is along the

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*This lining is often oxide of manganese, a metal constantly accompanying iron in limonite deposits; often beautifully crystallized in fibers or needles. The bombs and balls show plainly enough that the peroxide of iron was distributed as fine particles throughout the plastic clay, and that these particles slowly concentrated around points of mutual attraction, probably in most cases towards minute quantities of organic matter which have disappeared by oxidation.

†A process virtually invented and practiced by Wm. Kelly at his furnace in Kentucky, when he boldly blew air into the molten metal in his furnace hearth. See my Iron Manufacturers' Guide, 1858.

Path Valley fault, on the contact of the limestone with the Hudson River slates ;. as described in a future chapter.

Chester valley limonite mines.

The mines of the Chester county valley have never been of first-class importance. Prof. Rogers' description of them in 1858 was condensed and re-published in C4, 1883, pages 141, etc. It has hardly more than a historical value, since the change in the iron industry has concentrated the iron works and destroyed local small mining by the importation of distant richer ores. But it has a geological value for those who study our formations.

Some of the old banks are on the edge of the valley, and evidently in the Upper Primal slates, above the sandstone and beneath the limestone. Others are as evidently washings from these iron-bearing slates into ancient caverns in the limestone, the roofs of which have been removed by erosion, leaving great pots of clay filled with wash and ball ore. Of this kind are the deserted—

Hitner banks near Marble Hall, Montgomery county, from one of which were taken 10,000 tons in 1852, and 12,000 in 1853. From all the pits dug east of the Schuylkill up to 1858 probably 60,000 tons were taken, in a belt seven miles long and a mile wide. The ore deposits ranged in long narrow strips, as deep troughs of iron soil sunk in the limestone outcrop ; the two most productive being one just north of the Barren Hill range ; the other just north of the belt of marble. But outliers were found ; as, Wood's pit, one mile north of Marble Hall, where shallow ore soil rested on limestone so thin that the North Valley Hill sandstone was struck beneath it.†

West of the Schuylkill several pits were made south of Bethel Hill (Whitehall's pit, Fisher's pit) for Merion furnace use.

The Baptist Church old shaft, 75′ deep, got superior ore, resting on white marble. Another pit was sunk 200′ feet further east.

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† See C. E. Hall's Report, C. 6.

Fisher (*Geo.*) *bank*, 300′ N. E. of Henderson's marble quarry in U. Merion, is large, and until 1854 yielded good ore; afterwards more of an earthy wash ore.—Another pit, 1250′ N. E. of the last, and a later pit for the Phœnixville works gave ⅓ ore.

Widdart's bank, 800′ S. of last, was reopened before 1854.—*Millerton's bank* near the school house sent ore to Jones' furnace above Conshohockin.—*Otto's bank*, newly opened in 1854, had ½ ore.—*Supple's & Hampton's* pits were small. *Hughes & Jones*' pits were also small, but made a large group.

Howellville, Tref. town. had its group of pits from which good ore was got.—*Wilson's*, N. W. of village.—*Woodman's* had ore ⅔, dirt ⅓; sent to Phœnixville.—*Jones*', *Beavers*', & *Bucks and King's*, near the Baptist Church ½ m. from Centreville, were all three large banks.—*S. Beaver's* bank, ½ mile S. E. of head of Valley Forge dam, lay along the north side of the valley, and got its ore-wash (Rogers thought) from the lower magnesian part of the great limestone formation.—*Holland's bank*, 1½ m. N. W. of Howellville, 43′ deep in 1854, sent excellent ore to Phœnixville.

West of Paoli was another group of diggings: *Buchanan's*, 1200′ N. of Oakland hotel, ⅔ ore, sent to Jones' furnace.—*Jacobs*', 2 m. E. of Oakland, and two others ¼ m. S. of Ship tavern.—*McGuire's*, 1 m. N. of tavern; much good ore.—*Evans*', ¾ m. E. of tavern; much good ore.—*Neal's* three pits.

An untried pit was opened 1 m. N. W. of Downingtown.

West of Coatesville several small pits on the south side of the valley.*

York county limonite banks.

The mines of York and Adams county in the hydromica (Upper Primal) belt are described by Prof. Frazer in his

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* Rogers' Geol. Pa. 1858, pp. 217 to 219, gives some very interesting details of Lancaster Co. limonite banks in evidence of his belief that the South Valley Hill mica slates (bearing iron) underlie the Chester Valley limestone formation.

Report of Progress C, 1876. On pp. 5 to 9 is given a list of 158 mines in all the formations of the two counties, in alphabetical order, many of them small openings, others old, large and deep mines.*

Gohn bank (67) 2 miles W. of Wrightsville, at the N. edge of limestone belt, S. edge of slate belt; opened 1854; in 1874, 400′ long, 25′ deep at west end, in sandy clays.

B. Strickler bank, 1 mile west of the Gohn, on the same line; 1854; worked by Musselman; then by Haldeman till 1864; 1874 abandoned; half an acre; 30′ deep to water.

Stoner bank, half a mile further west on same line; 1850 to 1873, 40,750 tons to Musselman and Watts; partly by shafts; open ¾ acre, 25′ deep.

D. Rudy's banks, half a mile further west on same line; 1862 to 1870, 9,872 tons; 1¼ acres, 25′ deep; abandoned.

Ruby's bank, half a mile (4½ m. from Wrightsville) on same line; 1862; worked 4 years; 400′ long E. and W. or ½ acre; abandoned; much loose quartzite.

Keller's bank, half a mile further west; ¼ acre; 10′ to water; ore exhausted.

Heistand's bank, a mile further west on same (midway between Wrightsville and York;) 1864; Musselman & Haldeman; 2 acres, 600′ long, 20′ deep to water; abandoned 1871; walls, clay and gravel.

Blessinger's bank, one mile further west; and 1000′ N. of limestone limit; ¾ acre; trench 750′ E. and W.; exhausted; sandstone fragments and sandy slate.

Norse's bank, half mile further west, and ¼ m. N. of limestone; ⅔ acre, 300′ long, 25′ deep; abandoned.

Miller's bank, one-third mile further west, and 2000′ N. of limestone; ⅓ acre, 15′ deep; has only yielded 300 tons; ground strewn with sandstone and slate blocks.

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*Of these are described 126, arranged in nine lines running N. E. and S. W. and numbered from N. E. to S. W. Nos. 1 to 6, from Shrewsberry to the Maryland line; 7 to 14, S. of Margaretta furnace, from Red Lion to S. of Jefferson and Loganville to Red Lion; 15 to 66, from S. of Wrightsville by Hanover Junction to Littlestown in Adams; 67 to 109, from Wrightsville through York to N. of Hanover in Adams; 111 to 118, a group north of York; 110, near the river N. of Wrightsville; 119, 120, S. of Wellsville; 121, W. of Wellsville; 122 to 126, near Dillsburg. In this chapter only those in the hydromica slate belts will be noticed.

S. and I. Deitz's two banks, ¼ m. apart, further on, 1500′ N. of limestone; about 1864; abandoned 1870; yielded 2000 tons; 8′ stripping over ore lying in pockets in white and yellow clay; in all ½ acre, 20′ deep; water scarce.

Susanna Fritz's bank, a mile west of Norse bank (or 3½ m. east of York) and ¼ m. N. of limestone border; 1865, to June, 1874; principally wash ore, in pockets and nests in blue clay which prevailed in the walls beneath the strippings; abandoned, but large quantity of ore at north end reaching nearly to the surface; 40′ deep, partially filled with water (1874.)*

Heidelsbach's bank, ¾ mile further west and 500′ north of the limestone; small; 600 tons; exhausted by 1868; ½ acre, 10′ deep.†

Ebert banks, 1¾ miles north of York (the most northern is sometimes called the *Corr bank*). Operated by Benson & Cottrell, owners from 1866 to October, 1873; ¾+1½ acres, 30′ deep; principally wash ore; 10 tons daily; part filled with water (1874).‡

D. Louck's banks, 1¼ miles northeast of York and ¼ mile north of limestone; two, 100′ apart, with a smaller bank between; 1867; wash ore, some lump; water not quite sufficient to wash; ⅓ acre, 20′ deep, and ½ acre, 25′ deep.§

Thus far the limonite deposits have been either on or just N. of the northern edge of York Valley limestone belt, which edge crosses the Codorus a mile north of York, swings west and north and east to recross the creek two miles lower down, and recrosses a third time 5 miles north

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*Many samples taken for analysis yielded in McCreath's laboratory: Insol. res. 19.750; iron sesquiox., 63.285; alum. 0.765; manganese sesquoix., 2.210; phos. acid, 2.986; sulph. acid, 0.068; lime, 0.196; mag., 0.216; water, 10.880=metallic iron, 44.300; mang., 1.540; sulp., 0.024; phos., 1.303.

† Here a compact bed of quartzite crosses the road, dipping 60° northwest, but there is room for concealed southeast dips between it and the limestone belt.

‡ An interesting bed of compact quartzite, dipping 30°, north 15° west cuts out the ore in the Corr bank. Slates carrying ore much contorted, with cleavage planes dipping 70° southeast. If these be original bed planes then the slates dip beneath the limestone.

§ Rock beds cut are crystalline schists much intersected by veins of quartz.

of York. From this third crossing the limestone edge runs west 2½ miles to Ewingsville, and so keeps on to the north side of the Pigeon hills. It then returns east, south, southwest around the south foot of the hills and runs on into Adams county.

Returning now to the Codorus creek there are several banks in the slate country north of York: Lightner's, Louck's, Benson & Cottrell's, Hake's, west of the Codorus; and Benson & Cottrell's and Smyser's east of the Codorus; all of them either on the limestone border or not more than 1500′ from it. Taking them in the order named will be to follow the edge of the limestone around Pleasureville. (See Report C, 1875, p. 69.)

Banks north of York.

Lightner's bank, 1½ m. W. N. W. of York, on the limestone border; leased by an English company, Sept., 1874.

Louck's bank, 1¾ m. N. of York, ¼ m. from the limestone; open cut 60′ long, 15′ wide, 18′ deep in bluish clay; stripping 5′; yellow clay with ocreous iron, 7′; white clay and chlorite, thin; clay and ball ore 7′; dip of slate 46° N. 23° W.; dip of ore the same.

Benson and Cottrell's bank, near last; 1870; 1000 tons a year; ten per cent. lump; water scarce; ore contains a little sulphur and a little phosphorus; *magnetic sand* and much specular iron intermixed with the ore.

Hake's bank, ½ m. N. of last; clay; not at work in 1874.

Smyser's bank (*Small's bank*), 3½ miles N. of York, on the south edge of the limestone a mile N. of Pleasureville; leased for 20 years (1864–1884) by Ashland Iron Co. 2½ acres, 40′ walls; 15 tons per day of both wash and lump ore of two kinds, one a sandy *manganese* limonite; the other a smooth greyish blue compact ore full of small cavities stained on the edges with limonite; also a white ore looking like a cherty limestone, in fact a spathic or *carbonate iron ore*, suggesting interesting reflections upon the genesis of the limonites. There is on the east side of the bank a limestone bed which dips 18° to the west, i. e *under the ore de-*

posit, and Dr. Frazer suspects it of a greater antiquity than the York valley limestone. (See C, p. 68.)*

Cottrell & Benson's bank, across the road from Smyser's bank; 1871; 10 tons per day, all wash ore, hauled to Emigsville, railroad to Marietta. In 1874 ½ acre, 40′ deep. (C, p. 66.)

Banks west of York.

Eisenhart (*Jac.*), on the Gettysburg turnpike, 2 m. W. of York, has surface wash ore on slate ground; and not far from here near the Carlisle road fork to Emig's Mill in the débris of an old pit was seen a large specimen of *magnetic limonite.* The Beelor trap dyke runs across the neighborhood towards the old—

Kauffman bank, 3 m. S. W. of York on the narrow belt of slate which from here west to Pigeon hills splits the limestone belt into two; 300 tons were taken out; ore so *magnetic* as to disturb the surveyor's compass; ore, mostly *anhydrous*, lay in scales along with mottled red and blue limestone; a mass of ore in place dips 25° S. 10° E.; but the associated slates dip 70° S. 10° E. Beelor's trap dyke runs close by on the east.

Eyester's (*M.*) *bank* (*Smysers's*, *Brillinger's* 3 m. further S. W. along the N. W. edge of the slate belt, along abandoned trench 350′ long, 20′ deep; in fine-grained mica slates dipping 64° S. 20° E.† Ore in nests and lumps of brown and red hematite, but no magnetic visible under the lens; slates almost all weathered into white clay, with

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* Careful sampling, and analyzing by A. S. McCreath, gives the following constitution of *the first kind* of ore:—Insoluble silicious residue, 14.78; iron sesq., 46.28; alumina, 2.67; manganese sesq., 22.89; phos. acid, 1.49; baryta, 1.32; lime, 0.24; magnesia, 0.15; water, 11.20;=Iron, 32.40; manganese, 15.93; sulphur, 0.03; phosphorus, 0.65. Cold short; and unlike any other ore as yet found in York county.—The *Spathic ore*, analyzed by A. Pearce, under Dr. Genth yielded; ferrous carbonate, 77.99; mang. carb., 0.45; magnes. carb., 3.53; calc. carb., 1.43; alum., 2.81; sil., 11.56; water, organic matter and loss 2.23;=iron, 37.65.

† All the dips, slate and limestone in this neighborhood are steep S. E. (See ore map of survey on a large scale, with all the dips marked, in Report C.) If the slate belt be an anticlinal, then the dips next to the northern limestone belt must be *overturned*, and the slates at this mine although seemingly *over* the limestone are really *under* it, where they ought to be.

streaks of irony clay; what is not shows rotten lamination; at northern end of pit compact fine-grained mica slate, over which at the south end are 100′ of the soft clay strata carrying the ore.

Emig's (*Sam.*) *bank*, 3 m. W. of New Salem, near Nashville, near S. edge of slate; opened 1872.

Johnson's (*W. S.*) *pit*, 1 m. W. of last; 1873; ore.

Mengis' (*And.*) *bank*, 1 m. S. of last, near N. edge of southern belt of limestone; 1872 to 1874, 3,772 tons.*

Banks of the Pigeon Hills.

Myers' (*Mich.*) a mile west of last, 1873.—*Roth's* (*S.*) a mile north of last; 1873; 10′ deep; ore.—*Roth's* (*S.*) ¾ m. S. by W. of last; 20′ deep; 7′ stripping. These are a group in the slate belt.—*Miller's* (*J. L.*) ¾ m. S. W. of last; abandoned.—*Bechtel's* (*Geo.*) 1¾ m. S. W. of Myers'; opened about 1868 by Musselman & Watts; abandoned in 1873.†—*Forry* (*G.*) reports ore in mass in his orchard near the limestone, 5½ m. N. E. of Hanover.—*Boyer's* (*Sam.*) *bank*, ¼ m. west of last; 1854; leased 1872; ½ acre, another 1½ acre, both 15′ deep; ores in segregated shelly, friable masses in clays; no unaltered slates seen. It is the first of a series of closely neighboring pits marking the northern edge of the slate belt leaning against the Pigeon Hills and running on to the Adams line.‡

Moulk's (*S.*) *bank*, 5 m. N. E. of Hanover; 1859; in 1870–1874 the Leesport Iron Co. took out 14 tons a day; incline plane 200′ long.§

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* Watts & Sons, the owners, give these figures and an analysis: Iron, 39.640; insoluble, 37.800; sulphur, a trace; phosphorus, 0.080; undetermined, 22.380.

† These last eight banks are disposed around one of the southern spurs of the Pigeon Hills and mark the shape of the spur. (Frazer in C, 55.)

‡ It must be kept in view that this slate belt keeps the limestone belt (to the south of it) away from the Chiques quartzite mass of the Pigeon Hills; therefore *beneath* the limestone.

§ One hundred and eighty to one hundred and eighty-five car loads per day (14 tons) worth $2.50 per ton at Kauffman's siding on Hanover Branch RR., 3 miles distant. One hundred-paddle lump washer and sand washer; 35 horse power engine consuming 1100 pounds coal; 19 men in three gangs; $1.00 per day wages; or $1.50 if paid 7 to 7½ cents per car load; engineer, $33

Moul's (*Sol.*) *bank*, ½ m. west of last; 1854; 2½ acres, 15′ deep; tenaceous clay under stripping; engine house at N. E. end; idle in 1874.

Moul's (*P.*) *banks*, (two,) small.

Bechtel's banks; (1) 4 acres; (2) ¼ acre.

Haldeman & Co.'s bank; near the last; 1870; ½ acre; 8′ stripping; ⅜ wash ore in yellow and blue clays; ore bands 1′ to 3′ thick irregularly running out; used at Chiques to mix with Cornwall ore; 25 tons per day; pit 45′ deep; water supply deficient. Analysis: Iron 43.00; manganese 3.88; sulphur 0.09; phosporus 0.67.*

Miller's (*Ashland Co.'s*) *bank*, 400′ W. of Kaufman's (3 m. N. N. E. of Hanover) and at the base of the Pigeon Hills; 1863; 3¼ acres; 15 men; 18 tons per day without incline plane; all the blue and yellow clay mass contains paying mass ore; mixed with tremonium ores in the Ashland furnace. *Bauman's bank*, not far west of last; ½ acre; stopped 1873. *Miller* (*Widow*) *bank*, near last, small. *Porter* (*Gov.*) *bank;* 1840 to 1862; shut; 1 acre. *Gitt's bank*; several pits in quartzite and sandy slates, 3 m. N. of Hanover; much ore; abandoned.†

Banks near Hanover.

The above-described banks are ranged along the foot of the Pigeon hills north of the York limestone belt. South of the limestone there is no such range of banks in the hydromica slate country; but there are four at Hanover, and two four miles northeast of Hanover of considerable

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per month; foreman $40; 11 working hours; 400 tons a month extracted; two 35 horse-power boilers; 5 cars in use; water for washer pumped from mine; 12 tons of ore per day washed; transport to siding 60 cents per ton, contract wagons belonging to contractor; 9 men always mining; stripping 9′; under this white clay and gravel; then yellow ore clay, no bottom yet. (Report 3, 1874, p. 59, here quoted as specimen of its statistics.)

* See full analysis in C, p. 61. A plate of "red oxide" runs S. W. towards Kauffman's; analysis: Iron sesq., 72.14; alumina, 1.72; manganese sesq., 0.39; phos. acid, 0.43; sulp. acid, 0.12; lime, 0.17; magnesia, 0.33; water, 5.76; insol. sil. residue, 19.09;=Iron, 50.50. This tough, hard siliceous kind of ore is found elsewhere in the county.—*Kaufman's bank*, next the last, started 1874.

† McConaughy's exploitation pits in quartzite, 3½ m. N. W. of Hanover, 1874, has begun to show fairly. This ends the series westward.

importance. The four just south of the village of Hanover, a mile from the Adams line, are

Baumann (J.) pit, first opened a century ago; reopened 1860; then leased by the Wrightsville I. Co., who took out 1000 tons.—*Flickinger's*, 300′ west of last; 500 tons got. —*Delone (Louis) bank*, ¼ mile W. of Baltimore pike; 1867; 2000 tons got in six months, large and small lump ore in slate mouldered to clay; slight stripping; large body of ore seen (1873) in northeast heading.*—*Forney (A. M.) bank*, 400 yards west of last; 1863; 3500 tons got and more in sight, in hole 200′ long by 20′ deep; ore lumps in clay; abandoned.

The two important limonite mines on the *south* edge of the limestone 4 miles N. E. of Hanover, are the well-known Dollinger and Sprenkel banks:—

Dollinger (J. and D.) bank, leased by the Leesport I. Co. and opened in 1873; 180 car-loads a day; 90 per cent wash ore; lumps and nests in the clay of the decomposed slate formation.†

Sprenkle's shafts; ⅓ m. N. E. of last; sunk 1874, north of H. & Y. S. L. RR. Ore in first shaft peculiar, dull brick red, containing masses of specular and some micaceous ore, much mixed with sand and the slate gangue (a fine-grained chlorite hydromica slate *with thin intercalations of limestone*). Two veins struck by the shaft, upper one 1′ thick, with a thin roof of slaty limestone. The N. W. shaft takes out ordinary limonite. Prevailing dip, 50° N. W. *as if going under the valley limestone.* Further west, Musselman shaft struck solid ore.

In quarry 500′ N. of first shaft limestone and slate contact seen, dip of both 48° N. 35° W., slate under limestone. *This is an all-important geological fact, establishing*

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*Analysis: Iron, 33.5; sulp., 0; phos., 1.47; silica, 23; alum., 27.3; ox. org., loss, 14.7. Another: Sil., 8.2; ferric ox., 70.1; alum., .96; mang. ox., 1.75; phos. acid, 2.54; sulp., .03; water, 13.15;=*iron*, 49; *mang.*, 1.21; *phos.* 1.11. Another by F. A. Genth: Sil., 7.55; ferr. ox., 65.6; alum., 2.05; mang., ox., 7.29; ph. acid, 3.05; water, 13.88; mag., .35; *cobaltic oxide*, 0.22;=*iron*, 45.9; *manganese*, 5.07; *phosphorus*, 1.33. (Report C, 1874, p. 41.)

†See statistics in C, p. 55; and analysis: Iron 45.1; manganese, 1.5; sulp., 0.09; phos., 0.60.

the location of the ore in the Primal Upper Slate beneath the Silurian (*Ordovician*) *limestone*, although *the nearest quartzite is a mile southeast from the ore.*†

Banks south of the York Valley limestone.

Before continuing this list of mines into Adams county, we will return to the Susquehanna, and note the ore banks of the hydromica slate belt south of the York valley limestone, beginning with the one nearest the river, No. 15 on the York county map, C, page 16.

Wilton's bank, 1¼ m. S. of Wrightsville; 1850; 1855; 1858; 12,000 tons; abandoned before 1874, but much ore remaining 65′ beneath the surface, in a ravine between high slate hills; limestone seen up the ravine; quartzite marked on map.

Leber (*Dan.*) *bank*, 2 m. S. of last, ½ m. back from the river, on the edge of the limestone; 1872; mostly lump ore, concentric bombs, the shells separated by shells of clay; limestone 1000′ S. 15° W. of the pit dips 40° S. 22° E., therefore the north lip of Cabin Branch Run synclinal limestone basin has *the ore slates underlying the limestone.*

Emig (*J.*) *bank No. 1*, 600′ W. 30° W. of last, on the edge of the limestone; stopped 1867.

Emig (*J.*) *bank No. 2*, ¼ m. W. of last, very old, abandoned 1869; shaft 110′ deep; bottom ore so compact as to require blasting; very little wash ore, mostly lump.

Keller (*Geo.*) *shafts*, 1 m. W. of last, (4 m. S. of Wrightsville); about 1864; 70′ and 30′ deep; almost all lump, requiring blasting, very near surface; in hydromica slate partly in a very sandy slate; many pieces of quartzite; much of the ore *magnetic;* very crystalline limestone close by, dipping 54° S. 22° E.

Burg (*Reuben*) *bank*, at Prospect (Furnace P. O.) 1⅓ m. from Margaretta Furnace; shaft 30′ deep struck limonite charged with magnetic particles.

Small (*J.*) *bank*, ½ m. W. of last; same black ore; lump and wash ore equal; makes foundry iron.

Margaretta Furnace banks, on Cabin Branch Run, 3 m.

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† See the York Co. map published in Atlas to Report C3 on Lancaster county.

from river; Slaymaker sold (1850) to Halm and Himes, who worked them 1867 to 1874 (date of Report) at 200 tons per week; various limonites (*turgite*, *&c.*,) brittle, sandy, shelly grading off into slate rock; the purest ("black ore") analyzing 60° iron seems to have been subsequently deposited in cavities between the mica slate strata, too much decomposed to show true dip; mines on the contact of slate and limestone.*

A mile S. of Margaretta furnace are two banks: *Jas. Curran's*, opened about 1844 and *W. G. Case's*, about 1851, from which ore has been mined, but they have long lain idle.

Keller (*J.*) *bank*, 1¾ W. of Margaretta Furnace; 1866; 1000 tons the first six months; then abandoned; ferruginous slates dip 70°, S. 20° E. This bank is within a short distance of the edge of the phyllite belt, therefore near the bottom of the hydromicas.

Barcoft's (*Butcher's*) *bank*, 500′ west of last and higher in the same hydromica belt; opened 1840; work suspended in 1868; ore cold short, plate-like, hard, flinty, tough, with unusual amount of black glassy coating, and mamillary stalactites, knobs and ridges, which when broken show cross-fiber crystallization (*göthite*). Large masses of lump ore in the clay, regularly arranged; one massive lens dipping 30°, N. 80° E. through the slates, which are more or less completely changed to clay; upper part of mine limonite and turgite. Musselman & Watts took out 10,000 tons at one time.†

Banks in the York county phyllite belt.

Barley bank, 1 m. W. of last; 1868; 400 tons in two years; dark brown hematite in clay, in phyllite slate belt; ⅓ m. from quartzite belt.

Hengst bank, 900′ S. of W. of last; in same phyllite belt

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*See mining statistics, C p. 20. Result of analysis of shell ore: iron, 48.8; manganese, 0.79; sulphur, 0.038; phosphorus, 0.343.

†See mining statistics in C, p. 22; and Watts' analysis: Silica, 26.75; perox. iron, 47.15; alum., 1.70, water, 11.40; undetermined, 13.00;=Iron, 33.00. A low grade ore if this analysis represents the mine; but its siliceous character is due to its place in the phyllite formation instead of in the upper hydromica formation.

and as near the quartzite; 3,000 tons in three years, 1868 to 1871; then idle; 15′ deep; ore a conglomerate of ball ore and ferruginous slate.

Moser's new bank, 3 m. S. W., of last, 2 m S. E. of Longstown, 2½ m. N. of Dallastown, 1 m. from edge of hydromica belt; 1865; abandoned; poor ore.

Ensminger's banks, 1000′ and 1700′ S. W. of last; 1866; 1873.

Moser's old bank, 1 m. W. of last, ½ m. W. of Peach Bottom RR. near edge of hydromica belt; 1820+ worked by York Furnace Co.; then J. A. Wright & Co.; then (1850) Shoenberger, Musselman & Co.; then Musselman & Watts; then Musselman & Sons; 42,090 tons from 1850 to 1873; excavation 250 yards long, now abandoned; ore masses are still visible in yellow, white and blue clays; bottom strewn with lean compact ore; lump and wash ore equal.*

Williams' old banks (*Gladfelter's*), 2 m. E.N.E. of Logansville, was not worked after about 1830, but an immense amount of ore must have been taken from the numerous extensive deep excavations in the phyllite belt within about a mile of the hypothetical limit of the Tocquan schist belt.

Brillhart's bank, 1½ m. E. N. E. of Logansville, has been worked by Kaufman for Columbia furnace, and yielded the same ores as the next.

Feigley bank, the S. W. continuation of the last, opened by Musselman in 1867; up to 1874 (date of report) yielded 50,000 tons of limonite, finely disseminated through clay at least 40′ deep; 10 per cent lump, 90 per cent wash; also a dark-blue compact heavy clay ore; also a peculiar "honey-comb ore," composed of minute plates of limonite knit together like paper walls of a wasp's nest.†

Moser's oldest bank, 200′ W. of last.

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*See statistics in C, p. 24. One specimen was of parallel flat plates, united by one or other edge, space filled with *lepidocrocite*, stalactitic *limonite* and *turgite*. Another was botryoidal coated with black glossy *turgite* (?). A third was compact brown limonite. A fourth (50 pounds) showed all these, and also a peculiar separated structure, the ridges being an inch high uniformly covered with glossy ore. Partial analysis is (Watts): Iron, 40; silica, 32; phos., 1.17; water, 8.

†For statistics of mining see C, page 14, J. B. Britton's analysis of an average sample: Iron, 46.08; ox. 19.74; insol. sil. res., 18.66; water and org.

Banks in the hydromica belt south of York.

Leader's Hill old opening, ¾ m. W. of New Paradise; slates dip 84°, S. 70° E. No ore showing.

Hess bank, 5 m. S. of York, 2 m. W. of Logansville; 150′ long, 15′ deep; 1868; ore too sandy; slates *asbestiform*, vertical, strike N. 20° E.

Falkenstine shaft, abandoned.

Meyer's (B.) bank, 1200′ N. W. of Gladfelter's railroad station; lean ore in vertical slate striking N. 30° E.

Stambach's shaft, ¼ m. W. of station; in dark slates holding crystals of micaceous and magnetic ore.

Gladfelter's bank, ¾ m. W. of station, 10′ deep in vertical slates, striking N. 34° E.

Geisselman's bank, ¼ m. W. of railroad between Gladfelter's and Seven Valley (Smyser's) stations; four small shafts sunk 1870, in hydromica slates impregnated with iron oxide.

Thomas Iron Co.'s banks, ¼ m. S. W. of Smyser's railroad station; two banks and three shafts, ½ acre and ¾ acre, engine house, drifts, etc.*

Walters' bank, ¾ m. N. of W. of Hanover Junction railroad station; 1872; much hard limonite still visible in bunches in clay of decomposed coarse-grained slate; ¾ acre, 40′ deep.

Crout's bank, ⅓ m. N. E. of Strickhauser's station, Han. Br. RR., 800′ along the road, 18′ deep; hard, compact sandy limonite; sometimes operated.

Knotwell's shaft on the York I. Co.'s hill; Aug. 1874, had reached hard ore (at 27′) same as York Co.'s ore.

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mat., 10.94; sulphur, none; phosphorus, 0.69; alum., 1.92; lime, 0.17; magnesia, 0.56; manganese, 0.33; undetermined, 0.91.

A finely laminated bluish limestone containing *white crystalline limestone* scattered through it in spots resembling in certain portions a calcareous conglomerate, in others simply mottled, appears in both banks, and in the run, dips 85°, N. 20° W. In a quarry near by it is so mixed with crystalline hydromica flakes as to mimic hydromica schist, although containing 78 per cent of carb. lime and magnesia; thickness perhaps 400′. This is an important observation. (C, p. 15.)

*Statistics in C, p. 27. Analysis: Iron, 51.7; no sulphur; phos., 0.052; sil., 6.0; alum., 16.4, etc.

Strickhouser's shaft, 1,200′ W. of last; 1860; pit 200′ long (N. 39° E.) 30′ wide and 10′ deep, has shaft in middle 10′ deeper.

Knotwell's bank, 1600′ N. of York Co.'s works; 200′ long; dip 66°, S. 82° E; another slate exposure strikes N. 20° E.

York Iron Co.'s mine, the most widely known bank in York county, yielding the so called "Codorus ore," 2⅓ m. N. E. of Jefferson (Codorus P. O.), ½ mile N. W. of the RR.; opened by Musselman in 1854; worked almost continuously from 1861 to 1874 (date of report) by York I. Co.; a hard, compact slate highly charged with micaceous and some magnetic ore; 10 to 20 tons a day. The slates in Strickhouser's ravine through a ridge 100′ high stand vertical. The back bone of the ridge is Chiques quartzite.*

Sheaffer's pit, ½ m. S. of last; 1867; 350 tons; exhausted.

Thomas Iron Co.'s old pit, 1700′ S. W. of last; 1869; worked one year and abandoned.

Thomas Iron Co.'s No. 2, two banks and a shaft, 2700′ S. E. of last; 1869; 30′ deep, abandoned; layers of mica slate between ore deposits; dips 45° to 90°, N. 45° W.

Thomas Iron Co.'s, No. 3, pits along a 100′ line S. 30° W; outcrops of mica slate further west dip 75°, N. 25° W.

Smyser (E. G.) bank; 1869; ½ acre, 15′ deep; idle.

Hanover Branch RR. open cut yielded considerable ore.

Flickinger's pits along road just west of Jefferson; 1873.

Schumann's pits, 3′ to 18′ deep, through blue clay (decomposed slate), *strike limestone at 17′*.

Meyers' (Matt.) bank, at bend of RR., ⅓ acre, 1871, abandoned; 800′ N. of it sandy slates dip 90°, strike N. 60° E.—*Nes Hill pits*, insignificant.

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*Statistics of mining, C, p. 30. Analyses: (1) Soft ore, iron, 39.280; sulphur, 0.007—(2) hard ore, iron 26.650; sulphur, 0.005. Another analysis: Iron, 26.0; silica, 47.5; alumina, 8.65. Another: Iron, 46.13; silica, 34.10; phosphorus, 0.22. Another (*white ore*): Iron, 46.100; no sulphur; phos., 1.258; silica, 15.000; alumina, 16.000; undetermined, 21.642. Average of three analyses by McCreath: Iron, 34.375; silica, 32.400; phos., 0.378. Average lot of samples sent to McCreath yielded: Ferrous oxide, 0.900; ferric oxide, 50.857; mang. sesq., 0.103; al., 1.630; lime, 0.862; mag., 0.303; sulp. acid, 0.011; phos. acid, 0.513; water, 1.690; residue, 43.425; = iron, 36.3; mang., 0.071; phos. 0.224; sul., 0.004. The long debate over the so called "Codorus silicon steel" deserves no attention.

Forrey's bank, 200′ long, 30′ broad, 15′ deep′; partly washed shut (1874); 800 tons in 1869. Shaft (reported) went through 8′ stripping, 60′ solid ore, bottom still in ore.

Stambach's bank, 1200′ S. W. of last; 200′ long, 50′ wide, 20′ deep; 1869; 800 tons in one summer; ore coldshort.

Trone s trial shafts, 1000′ N. W. of Smith's station; ore found; filled.

Rudesill's bank, $\frac{3}{4}$ m. N. E. of Smith's station; 300′ E. 12° N., 100′ wide, 20′ deep; much washed in.

Mickley's bank, $\frac{1}{3}$ m. E. of last; 200′ long, 150′ wide, 30′ to 40′ deep; $\frac{3}{4}$ acre, abandoned.

Eckert and Kauffman's; $\frac{3}{4}$ m. N. W. of Smith's station; 1869; 29,000 tons up to 1874; ore lean, but works easy in furnace, cold short, plenty still in sight (1874); stripping 0′ to 12′; at W. end *rock ore* 30′ thick exposed, in plates a few feet thick with clay partings, dipping (average) 50°, S. 32° E.; but the general strike of hills and ore banks is more nearly N. 75° to 80° E.*—*Hartman's bank* is a continuation of it eastward, separated only by a road.

Stover's bank is close to the Hanover Branch RR., 600′ N. W. of trial shaft at W. end of last.

Sprenkel's bank, 800′ S. W. of last at York Road RR. station; $\frac{1}{2}$ acre; 1874.

Kraber & Nes' bank, 500′ S. W. of last; 1868; $\frac{2}{3}$ acre; 1000 tons first year; then Thomas Iron Co. (1870) 10 to 30 tons a day.

All these last banks are on a range through the heart of the hydromica belt, near the railroad; but only No. 54 is located on the geological map of York county.

Along the southern edge of the hydromica belt near Xenia and the Maryland are Nos. 13, 14, at the limit of the phyllites:—

Hofacker's bank, a century old, 7 m. S. E. of Hanover, 3 m. from the state line; a quarry of hardened chlorite slates (cut by quartz veins, studded with pyrite and chalcopyrite) nearly vertical, striking N. 20° E.—900′ N. by E. from the old bank is the new Wrightsville Iron Co. bank (April, 1874); ore limonite with some magnetite in a regular bed

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*See statistics in C, p. 38.

hardly needing washing ; dip of schists in cut 50°, S. 70° E., but in the quarry, 90°, S. 70° E.—*Benade's shaft* is ¾ m. S. W. of the bank.

Adams county limonite banks.

McConaughy trial pits, on the H. and C. pike, 3½ m. N. W. of Hanover, for the Lochiel works (1874), is the last ore spot on the Pigeon Hill slate ore range, but in quartzite land. West of this nothing is noted in Report C, 1874, p. 64.

On the York valley belt of slates, the range of banks is continued across into Adams county by the following banks (C, p. 42):

Schwartz (*Sam.*) *bank*, 2 m. S. W. of Hanover ; 1874 ; 1000 tons exhausted it ; machinery standing ; ore in crystalline slates dipping 45°, about south, conformably interleaved, and also cutting the slates.

Schwartz (*Sol.*) *bank*, ¾ m. S. W. of last ; 1855 ; 1 acre, 30′, 40′ deep ; 2000 tons taken out in 1872 to 1874 ; much ore left in floor ; walls full of wash ore.

Boyer bank, on Hanover and Littlestown RR., 3 m. N. E. of Littlestown ; 1856 ; ¾ acre, 15′ deep.

Lefevre pits, 1½ m. S. E. of last. Shaft 20′ deep, caved in, filled up (1874). A sandy yellow ochre ("mineral paint") occurs.

Krumrein's pits, on S. slope of hill, ¾ m. S. W. of last ; 1870 ; 40 tons of 35 per cent. iron ore ; nothing visible (1874) but some Codorus ore slate.

Early and Killinger's mine, 2½ m. E. by N. of Littlestown ; 1874 ; 20, 30 tons per day, one-third lump ore for Keystone furnace, Reading ; 2000 tons to Marietta; foundry iron ; matrix, mouldered clay slate in place, with three cleavage planes, with one of which the ore dips 14°, S. 15° W. Limestone cut 200′ west of bank,* dips 25° S. 36° E., and strikes N. 54° E., both uncertain.

Lefevre's (*Enoch*) *bank*, 2 m. E. of Littlestown ; 1869 ;

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*Said to carry *lead ore* (*galena*). For mining statistics see C, p. 45. Analysis: Iron, 46.9; manganese, 0.815; sulphur, 0.11; phos., 1.224, from average specimen. McCreath.

1200′ long, 2½ acres; a 50 per cent cold-short wash-ore; idle from 1871 to 1874, machinery standing.

Clark (*Widow*) *bank*, 1½ m. E. of Littlestown; pits stripping yellow and white clay; two large pits 1000′ apart, the north one (1868) poorer ore, the south one (S shaped, over ⅓ acre) partially filled, idle (1874), machinery standing; ore shelly like that of the range. Limestone in quarry 1200′ north dips 50° S. 35° E.*

Lancaster county limonite banks.

The Chestnut Hill group of banks on Chiques ridge has been described in the beginning of this chapter. A full description of them will be found in Dr. Frazer's report on Lancaster (C3, 1880, page 208 to 220), as the *Sherk* (No. 6) on the map; the *Coppenhoffer* (No. 7); the *Hertzler* (No. 8); the *Chestnut Hill* (No. 9); the *Silver Spring* (No. 10); and the *Gamber*; all of them in the Upper Primal Slates above the Chiques quartzite. Those which follow are in the chloritic-mica slate or phyllite country of Conestoga, Providence, Eden and Bart townships.

Grubb (*C. B.*) *banks*, a mile N. W. of Colemanville and ½ m. from the river; 1834? The decomposed schists near the river dip 72°, N. 15° W.† Open cut 130′ into the hill; face 50′ high; stripping 6′ to 10′; mostly wash ore, with some lump, very like the York county hydromica belt ores, ball, shell, partly manganiferous limonite with occasional göthite. The ore is in layers between the schists, in the bank next the river; but solid in the heading of the north bank. The three banks range N. 20° W. 650′ long in all. Many bombs filled with steel gray ore.‡

Good's bank, ¾ m. E. of Safe Harbor; abandoned; black *magnetic sand* strewn along the road; as also near the foot of the hill by Colemanville.

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*In Report C2, page C 201, 202, a little further information is given respecting the ore-producing chlorite-hydromica belt south of Littlestown to the Maryland State line.

† Finely laminated gneiss near by dips the same.

‡ J. B. Britton's analysis found: Iron, 53.59; ox., 20.42; water, 11.76; sil. matter, 10.08; soluble, 0.66; sulphur, none; phosphorus, 0.44; ox. with phos., 0.57; alum., 0.64; lime, 0.22; magnesia, 0.04.

Reeves & Co. banks, 330′ N. E. of the first Grubb bank; abandoned, 1866.

Shenk (M. R.) banks; opened before 1840; 4 or 5 acres; abandoned; are lean and shelly; dip in mouldered mica schist and hydromica slate, 50°, N. 15° W.

Peacock's mine, in New Providence, back of Groff's hotel; 1874; 65′ by 50′, and 35′ deep, fallen shut (1877); ore in laminated gneiss full of iron, flat balls, not magnetic.*

Mowzer's mine, ⅓ m. S. W. of last; 1867; cut N. E.—S. W. 500′ long, 70′ wide, 35′ deep; walls of white and red clay; ore, limonite balls in very quartzose gneiss; large lumps of good ore and milk white quartz strewed along the road.

Eckman & Patterson's pit No 2, nearly 1 m. S. E. of last; 1867; new mine worked in 1877 for Port Kennedy Furnace; limestone (struck at 50′) highly crystalline and micaceous.—Pit No. 2, ½ m. E. of last; 1 acre; mass of ore in north end (50′ high); dip, 35°, N. 15° west; ore, as crusts of limonite on prisms of laminated gneiss, filled with grey micaceous sand.

Geiger's bank, not far S. E. from last; 1857; once yielded 20 tons daily, for furnace in Lancaster; ore excellent, thick and compact, in some places loose; was to start again July 1877 (Report C3, p. 228).

Cook, Wright & Co.'s mine, worked before 1776 for the old Mill Valley furnace; bought by Cook & Wright 1867, who took out 20 tons per day, all wash ore but ⅛ lump.—*Geo. Bear's* and *Shenk's* banks adjoin on the west.—*Brooks'*, Montgomery and Reading RR. banks lie still further west. Geiger & Baer took out 40,000 tons; ore in bottom too solid to pick and not solid enough to blast.

Myers (B. B.) bank in Eden township.

Smith (Stewart) bank, ½ m. E. 20° N. from last.

Lefevre (Dan.) bank, ½ m. N. of Quarryville; 20 tons a day; 10 per cent. lump.

Cabeen & Co. bank, just N. of Camargo; worked by Jas. Hopkins for 30 years; 25 tons per day for last two years (1877); ore once hauled 5½ m. to Conewingo furnace; iron

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* Reported, magnetic ore found in pit ½ m. N. E.; gneiss.

greatly praised by Admiral Dalgren for naval ordnance; pit 1000′ long, 100′ broad; full of water (1877).*

Meyers (*B. J.*) *bank*, on Keens run, Eden township; 1835; worked 1873, 1874, at 15 tons a day; ore same as Cabeen's; 25 per c. lump.—*Peacock and Thomas bank.*—*Brooks bank*, old, same range and $\frac{1}{4}$ m. W. of B. B. Myers; 1835±; worked for twenty years.—*Eckert & Co. mine*, 1 m. E. of Quarryville.—*Eckert & Hensel bank*, 1$\frac{1}{2}$ m. N. N. E. of Quarryville; old; 1830± for Mt. Eden Furnace.

Herr's bank, 1 m. N. W. of New Providence, on the edge of the limestone, just north of the Lancaster and Quarryville RR.; 1852; 1000 tons per year for the Phœnixville Furnaces.

Mylin bank, 2 m. N. W. of last in the limestone region. (See C3, p. 236.)

Welsh mountain banks.

In Caernarvon township of Lancaster county just north of the Chester county line, and on the north slope of the Welsh mountain facing the hydromica slate ridge at the south edge of the Conestoga valley, are a row of limonite iron mines, excavations in débris mainly composed of fragments of quartzite, the disintegrated grains of which compose the subsoil, in which the iron set free has collected into brown and red hematite ore in deposits of white and pink clays lying upon the solid quartzite strata, as at the Chestnut Hill mines near Columbia described at the beginning of this chapter. The ores are in the Upper Primal slate formation.

Shirk's bank, 1$\frac{1}{2}$ m. S. S. E. from Churchtown; leased 1872; worked to 1876, at 25 to 30 tons per day;† ore in nests and pockets; in limestone slates, no other rock visible.‡

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*See valuable mining statistics for this and the banks preceding and succeeding in C, p. 231 &c.

†See full account of force, machinery &c. in C3, p. 239.

‡A drift 100′ long driven S. into the mountain filled with water during Sunday; on Monday a hole opened in the floor of the drift 50′ from entrance into which all the timbering fell, apparently into a cavern in limestone. Dr. Frazer supposes the ridge in front of the mountain to be anticlinal making a south dip at the mines. C, p. 240, 241.

McKay's mine, ½ m. S. by W. of last; 1876; small.

Stolzfuss opening, a little S. W. of last; a few tons extracted.—No exposures for 2 miles further.

Shirley's bank, near Shirk's bank; 2 acres; depth 60′ in south heading; stripping 30′ of white and pink clay; in bottom a great square shaft reaches dark brown and black ore like that which at Chestnut Hill immediately overlies the quartzite. Structure obscure, but apparently two synclinals and one anticlinal and half of another in the length of the bank. A pit 20′ deep rapidly filled with water; 30′ of drilling then went through dry black powdery ore.

German's bank, 150′ E. and W. and 50′ broad; clay dipping 20°, N. 16° W.; full of water; much black lump, *manganiferous*, left lying about; soil, clay and quartz gravel.

Smith & Sons bank; 1½ acres; 40′ deep to water; plane steep; machinery standing (1876); dip apparently 45° N. but very uncertain.—*Beartown old mine;* 1861.

Beartown new mine; 1873; 2½ acres; 250′ long (N. and S.) and 170′ broad; S. E. dip in the S. heading soon rolls over to a gentle N. W. dip continuing to N. end of mine.*

Sensinning bank, adjoins last on W.; 1875; 20 tons a day

Russel bank, close to last; 1870 to 1877 continuously at 25 tons per day for Seyfert & McManus (like the last); ¼ lump, ¾ wash ore.

Garman's bank; 1875; Levi B. Smith; 30 to 40 tons of limonite per day; ¼ lump ore.†

Northampton county limonite mines.

The limonite mines of Northampton, Lehigh and Berks have been described by Prof. Prime in his Reports of Progress D, D2, and D3, Vol. I.

In these reports the *Chiques quartzite* is always called *Potsdam sandstone.*‡

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*Copious mining statistics given in C3, p. 244.

†For the Warwick and other mines in N. Chester Co., and the Jones and other mines in S. Berks Co., the reader is referred to a subsequent chapter; as their geological place is not fixed, they shall be grouped with the Dillsburg mines of York, etc.

‡The following description of the rock ought to have been quoted in Chapter XVI, page 179.—The quartzite outcrop extends from E. Penn RR. junc-

The Upper Primal or hydromica slates overlying it are always called by Prof. Prime *damourite slates.* These form the lowest division of the *Magnesian limestone series* (the *Calciferous sandstone formation* as it is known in New York), containing extremely variable percentages of the carbonates of potash, soda, lime, magnesia and iron; and they moulder away at the surface of the ground (and as far beneath the surface as the rainwater penetrates the earth) into white and tinted clays holding the concentrated, oxidized and hydrated iron in the shape of *ball ore*, which at the bottom is often a solid mass, and occasionally crystallized into *pipe ore.**

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tion (with one interruption) all the way to S. Bethlehem. It is a hard compact rock of greyish tint, weathering yellowish from the iron it contains. Small dots and specks of weathered out felspar make it pockmarked. Its total thickness measured at one place is only 21′. At C. Raw's opening (close to RR. track) it *lies conformably on the gneiss*, for a short distance, thus:—sandstone; under this, damourite slate with a little magnetite, only 2 inches; then distinctly bedded gneissic rock, only 18 inches; then, gneissoid rock with mica and partly altered hornblende; then hornblende rock decomposed to a sort of serpentine; then normal syenite..—A little further east, the upper beds are typical quartzite; the lower beds a *conglomerate* of *rounded quartz pebbles* from the size of a man's head to a hen's egg, or smaller, often with fragments of perfectly fresh dark *red orthoclase felspar;* also well preserved *scolithus linearis* (worm-burrow casts).—Eastward, it is typical quartzite, until at S. Bethlehem *red shale* (much like *Trias* shale) takes the place of the quartzite.—Behind the University it is quartzite.—In the RR. cut it dips N. W. *unconformably* over syenite.—East of Lower Saucon church bowlders mark its outcrop, close to syenite.—Further E., on the J. Bergstresser's farm, trial ore-pits struck decomposed sandstone.—Close to the Delaware, it is a *conglomerate* of nut-sized rounded quartz pebbles and small pieces of felspar, graduating upward into sandstone, and still higher beds of the *Calciferous sandstone.*—For its other outcrops in Northampton county see Prime's Report D3, p. 208.—See also his resumé of Fontaine's sections in Virginia, and Safford's in Tennessee, on pp. 211, 212.

*As a pure mineral *damourite* is essentially a hydrous silicate of alumina and potash; and in form it is a hydrous muscovite *mica*, the white (or silver grey) scales of which make up sometimes as much as one-half the body of the slaty rock. One of Dr. Genth's analysis of this slate reads: Sil. acid., 45.57; alumina, 34.83; potash, 10.16; water, 5.30; perox. iron, 2.94; soda, 0.87; magnesia, 0.83; lime, 0.40. (Report B, p. 123.)—In four analyses the damourite mica made up 28.39, 49.70, 53.02 and 55.40 per cent of the slate.—A fifth analysis showed phosphoric acid, 0.102, and sulphuric acid, 0.110, which probably were connected with the iron in the specimen of slate (ferric oxide, 3.79).—Damourite slate has a soapy, unctuous feel, is usually of pale straw yellow to yellowish white, sometimes pinkish, and has a pearly lustre. It

Professor Prime's general description of the limonites of Lehigh county will apply to those of Northampton and Berks as well, and to those of Lebanon, Daüphin, Cumberland, Franklin, which are but local repetitions along the same grand belt of valley limestones, in damourite lower, middle and upper slates. I give it here in a condensed shape, for convenience. He says:

The ore occurs massive, earthy, botryoidal, mammillary, concretionary and occasionally stalactitic. It has a silky, often submetallic lustre; sometimes dull and earthy, color of fracture various shades of brown, commonly dark, never bright; when earthy, brownish yellow, ochre yellow. Stalactites at the bottom of mines are *pipe ore.* Hollow concretions are *pot* or *bombshell ore;* full of water, or of sticky clay; inner walls glazed with oxide of manganese. Solid balls have cracked and honeycombed cores.—With the common limonite sometimes occurs scaly-fibrous or feathery-columnar mica-like *lepidocrocite* of yellow, reddish or blackish brown color, holding about 63 per cent. of iron, but of no money value because in such small quantity.—Most of the ore is in pieces so small as to require washing to carry off the clays in which they are embedded.

Ranges of Northampton banks.

The principal range is along the north slope and foot of the Lehigh mountains facing Easton and Bethlehem. Others are in the small limestone valleys between the mountains. Others are in the limestone country (Formation No.

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can rarely be got in a perfectly fresh condition, except in mines actively worked. On exposure to the weather the slate soon begins to decompose and turns to unctuous clay. This clay is generally brown or yellow at first, but in time bleaches white. The decomposition of the slate is probably due to the presence of the potash and soda, and hastened by carbonic and humic acids in the rain water. The two following analyses of (1) a white and (2) a yellow clay from the same pit are instructive: (1) Sil., 72.2; fer. ox., 1.0; al., 21.8; mag., 0.7; lime, 0.2; soda, 2.1; pot., 3.0; water, 4.7.—(2) Sil., 64.6; fer. ox., 5.6; al., 22.8; mag., 1.3; lime, 0.4; soda, 2.8; pot., 3.25; water, 4.7.—The most notable difference between the slate and the clay is (1) the excess of silica in the clay, on account of the great quantity of free quartz left behind in the mass; (2) the excess of iron; (3) the great loss of potash, proving that the formation of soluble salts of potash is the cause of the destruction of the slate. (D, p. 13, 14.)

II) north of the Lehigh. Others are along the north border of the limestone in a range of damourite slate at the south edge of the great roofing slate country of the Hudson River slate formation (No. III.) There is no essential difference between exhibitions of ore in Northampton and Lehigh counties except in the matter of quantity; Northampton being far behind Lehigh in this respect.

The eight mines at the foot of the mountain from the Delaware river at Easton to the Mary Brotzman mine (No. 47 on the 6-sheet map of the county, in Prof. Prime's Report D3, Vol. 1, 1883) are underground workings, on account of the very heavy stripping ground which would haye to be removed to work the ore in open cuts or quarries.—These underground mines are: Seibert's (*two*); Hess; Lewer; Glendon I. Co.; Woodring (J.); Miller; Sampson.—Then follow on this range: Sampson & Sitgreaves; Heckman; Hahn (Adam); Glendon I. Co.; Woodring (Enoch); Hahn (W.); Boyer; Crawford; Wolf (R.); Nolf (T.); Brotzman (J. L.); Brotzman (Mary, Nos. 44, 46, 47); Jacob; Richard; Brotzman (Mary, No. 48); Richard (T.); Lerch.[*]

In the mountains are:—Walters (worked for the Durham I. Co.); Joy (Nos. 53, 55); Raub & Lerch; Stout & Riegel.[†]

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[*] Of Prof. Prime's notes on the Northampton mines along the foot of the mountain I select the following, from D 3, Vol. 1, p. 194, etc.:

Jacob Crawford, (No. 43) 2 m. S. W. of Easton; shaft 18′ down to 6′; lump ore; interval ? 60′; second bed of ore.—*Mary Brotzman* (No. 44), shaft 64′ to upper ore, 4′.—*M. Brotzman* (No. 46), open cut, no regular bed; alternate beds of dark brown and light yellow decayed damourite slate; flint with the clays; dip, 17°, N. 72° E., perhaps conformable to surface over which the clays have washed.—*M. Brotzman* (No. 48), small open cut; little ore in partially decomposed slate; W. end ore in bottom; thin streaks of *manganese oxide* in the face *prettily crystallized*. (N. B.—The miners were carefully picking this out to throw away, and were much astonished to learn that it was valuable.)—*T. Richard*, 3 m. S. W. of Easton; open cut; ore interstratified between white clays; shaft 107′ down through slate and clay to ore "27′ to 40′ thick" on a floor of "black dirt." (D3, Vol. 1, p. 194.)

[†] *Raub & Lerch* (No. 54), 5 m. S. of Easton; shaft sunk 15′ to ore, and 100′ to ore; 3 beds of ore reported, middle one only minable; partings damourite clays.—*Joy* (No. 55), 2 shafts, 50′ and 75′ deep, to ore in damourite slate and clay.—At *Stout & Riegel's* abandoned mine, 5½ S. W. of Easton, *magnetic ore* occurs near the limonite pit.

All the mines thus far mentioned are on outcrops of the *lower damourite slate formation* at the bottom of the great limestone series.

Mines north of the Lehigh river and in damourite slates of various horizons in the middle and at the top of the limestone series are thus named and described in D3: Biery (Jas.); George (Ab.); Chapman; Lerch; Shimer (No. 5); Ritter (Simon); Goetz; Gernert; Merwin & Shortz; Kohler; Ritter (W.); Schortz (Nos. 12 and 14); Hummel; Beck (W. G.); Beck (J.); Lawall; Woodring; Gernert & Heller; Messinger & Woodring; Moser; Fogel; Young; Schimer (No. 24); Walter; Richard (T., Jr.); Messinger.

Lehigh county limonite mines.

There appear to be four lines of ore deposits across Lehigh county. (*1*) *A southern range* along the foot of Lock Ridge, on a general N. W. dip like the rocks on which the ore (and damourite slate) rests. In this range are the mines of Wagenhorst; Wescoe; A. Hertzog; H. Kaiser; Meitzler; Ludwig, Hertzog and Liess; Kreishman (2); Gaumer; Kerschner (2); Schwankweiler; Crane I. Co.; Allentown I. Co.; Wiand; Laros; Marck; and those at Hunsingerville, which are so grouped together as to constitute one great irregular excavation, viz: Maple Grove pits; P. Kline's mines; J. Barber & Co.'s; Hensinger mines leased by the Allentown I. Co.; Thomas I. Co.'s; Hensinger & Saul's; Mickley's; Hensinger Heirs'; Keifer's; Desh's.*

This southern range is continued eastward across Northampton county along the north foot of the Lehigh mountain as far as the Delaware river opposite Easton, as already described.

The second range lies in the limestone country to the north of the first range, and embraces the mines of Ludwig (2); Butz; Yager; H. Kaiser; Blank; Smoyer (4); B.

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*Many of these mines were stopped in 1874 on account of the depression in the iron trade. Some had been abandoned; some had their machinery standing, ready to be exploited again. They are all located *by numbers* on the sheets of the Lehigh survey map, executed by Mr. Clark under Professor Prime's direction, and published with Report D, 1875. Their descriptions appear on pages 17 to 24 of that report.

Smoyer; J. Smoyer; B. P. Smoyer; Judith Smoyer; T. Smoyer; A. Smoyer; Reub. Romig (2); P. Romig; Werner & Reinhart; and Lauer.

The third range, further north, comprises the mines of Weiler; Crane & Thomas I. Co.; Lichtenwallner; Smoyer; Gernart; Sholl; J. Bastian; E. Bastian; and F. Guth.

The fourth range, further north, comprises the mines of F. Breinig; Moser; T. Breinig; Whitely; Fogel; Schwartz; Bortz; Koch; Grammis; Gackenbach; Fischer; J. & D. Smith; Haines; Miller; Scholl & Co.; Steininger; Moyer; Stein; J. Laros; Levi Lichtenwallner; Krœmlich and Lichtenwallner; and the trial pits at Chapman's station; and the mines in the Fogelsville Cove, although these lie really further north next the slate region.

Ninety-eight (98) mines, mostly open quarries, large and small, shallow and deep, are named, enumerated and located on the first map of Lehigh county, published with Prof. Prime's first report of topographical work done in 1874 (D, 1875).

One hundred and three (103) others were in 1875, 1876, named, enumerated and located on the four-sheet colored map of the county published with Report D2 in 1878. These are classified geographically thus:

In the first range, along the foot of the South mountain:—Reder; Desh; Shelly; Daney; Schwartz (Dan.); Emaus I. Co.; Bader; Trexler & Kline; Kline (H.) *three;* Kline (Jessie); Kemmerer; Keck & Ritter; Kline (G.); Stein; Hottenstein; Apple; Kipping & Holsbach; Seam; Whitman; Spinner.

North of the Little Lehigh:—Reinhart; Jobst; Wenner; Kemry & Carbon I. Co.; Smoyer; Steiner & Kehm; Woodring; Roth; Glick (L. and C.) *two;* Acker; Reinhart.

In the middle of the limestone country:—Schadt; Rush; Ritter; Sheirer; McIntire; Miller; Biery; Wennor; Roth; Butz & Belden; Singmaster; Butz; Walbert; Descher.

Northern edge of limestone:—Barber & Aimy; Marck; Scherer; Jobst; Kratzer; Crane I. Co.; Wenner; Guth (D. A.); Thomas I. Co.; Weaver; Klein; Sieger; Crane I. Co.; Gackenbach; Blank; Guth (C.); Guth (H.); Henry; Boyer; Balliet; Levan; Henninger; Schadt; Baer.

Mines at Ironton:—Kennel (Ironton RR. Co.); Mickley; Ironton Co.; Balliet Bros.; Balliet heirs; Brown; Ritter; Steckle (P.); Steckle (D.); the last two east of Ironton.*

Berks county limonite mines.

The Lehigh ore belts are continued westward towards the Schuylkill; but most of mines named, enumerated and located on the map of Mr. d'Invilliers' Report D3, Vol. 2, 1883, chapter 10, are next to or not far from the Lehigh county line. The limestone valley (between the South mountains and Hudson River slate edge hill) is narrowed down in Berks county to about 2 miles, then widens to about 4 miles and so continues to the Schuylkill. The narrowness of it just at the Berks-Lehigh line is brought about by a jog in the South Mountains and two extensions of the slate hills southward toward the jog; the slates, of course, overlying the limestone. It is remarkable that just here have been made nearly 40 excavations, and that scarcely any ore has been found, or at least mined, in the limestones for the 15 miles west to the Schuylkill; the two Moselem banks being the solitary noted exceptions, and these lie at the edge of the slate. These facts make it likely and in fact almost certain that the ore deposits on the limestone surface near the county line owe their origin to the damourite slates at the top of the limestone series, which once bridged the

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* The great Ironton, or old Balliet mine, is one of the geological wonders of the State, an excavation 2000′ long, 800′ broad and 90′ deep, worked for more than half a century. But as the damourite slates of this mine are of an entirely different, higher horizon and later age, namely at the top of the limestone series, it does not properly come into this chapter on the *lower damourite slate belt (primal) of limonite ores at the bottom of the series.* I have found it impossible to avoid reference in this chapter to all the limonite mines of the valley, because of the difficulty of selecting out those which are exclusively confined to the lower outcrop of slate. Some of those in the very center of the valley may be in the lower, or in the upper slates, or in slates of some intermediate horizon. The valley limestones are excessively compressed and crimpled; so that on lines of *anticlinal* the lower slates may appear at the present surface (although that is not at all probable except in rare cases); while on lines of *synclinal* the upper slates may be and probably sometimes are preserved at the present surface. I was also anxious to give in this chapter a general view of the iron ore wealth of the region. The description of the Ironton mines is therefore postponed to a following chapter.

valley, and still bridges it half way. And, if this be so, then it is possible that *all* the 200 and more mines in the limestone belt of the three counties must be referred to the top damourite slates, and not to the *Primal* at the bottom. It is an additional testimony to this, that the two greatest limonite mines of the region, the Ironton in Lehigh and the Moselem in Berks, are in the upper damourite between the limestone belt and the slatebelt.*

The lower damourite (Primal Upper hydro-potash-mica slate) lying upon the Chiques quartzite, follows the northern foot slope of the South Mountains around to Reading.

A group of ten limonite banks are located in the cove at the head of the Little Lehigh, south and west of Shamrock (S. E. of Topton). A mine is just south of Topton; another, 1 mile S. E. of Bower's station; two more a mile S. W. of Lyons station; five more S. of Fleetwood station; another (Shaefer's) ½ m. S. E. of Blandon station.

In Oley Valley.

In the Oley Valley, Hunter's & Weaver's mines are 2 m. S. W. of Friedensburg; and these are the only limonite banks in the body of the highlands in Berks county except the Bittenbender and Gehman banks 5 m. S. of Alburtis.

But there are indications of a siliceous hematite connected with the Chiques quartzite beds in many other places. The ores of this formation where exploited have been found not only silicious, but so phosphatic and with so little alumina, magnesia and lime as to make cold short iron invariably. These ores however seem in all cases to be the product of the overlying damourite slates, the iron of which set free has found a home in the quartzite, especially where this is in a sandstone condition.†

The *Udree ore bank* in Ruscom Manor on the N. flank of Furnace Hill, 1½ m. S. W. of Pricetown, was the largest producing bank in the mountains in 1882; belonging to

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*In a following chapter this famous Ironton mine will be described in detail (from D2, p. 39, &c., as examined and mapped by the survey in 1875), because it is the best and most typical deposit of limonite in this region of the state, and the most instructive for the elucidation of the structural relationship between the limestone and slate formations of the Great Valley.

†See D3, p. 361.

the Clymer I. Co., and located in the sandstone close to the gneiss ; worked since 1871 by the Clymer I. Co. for Mt. Laurel Furnace ; mostly wash ore ; some bombs ; handsome specimens of concretions and stalactites ; varieties of göthite, lepidocrocite, turgite, red and yellow ochre ; too cold short for the neighboring Oley furnace ; cheaply mined as an open cut, 70′ deep ; ore dipping 70°, N. 20° E., 20′ thick ; 300′ along outcrop ; horses of clay ; 18 to 20 tons per day ; analysis by McCreath :—Iron 40.05 ; manganese 3.314 ; sulp. .003 ; phos. .522 ; sil. matter, 22.44.

The Warner mine, 1¼ m. S. E. of Friedensburg, at the junction of Oley slates and limestone, the line of contact crossing the open cut ; Clymer I. Co. for Oley furnace ; damourite slate (turned to white and buff clay), largely used for excellent building brick ; wrought for 18 years ; 10 to 15 tons per day ; ore dips 30° to 50° N. W. (away from slate hill), as a bed 2′ to 8′ thick underlaid with clay ; shaft sunk (1878) 49′ to 2′ hard ore bed ; at 56′ another 8 foot ore bed (50 per cent. lump); clay between the two beds, but second bed nearly flat, etc. See interesting description of efforts to get water at this dry mine on page 365.*

The Hunter mine, 300 yards N. W. of the last (Weaver), was abandoned when visited in 1882, and is accounted almost if not quite exhausted, being wholly in the limestone. One shaft was sunk 90′ through yellow clay, to a 1′ bed of white kaolin, under which lay 1′ or 2′ of limonite ore ; under this a little *black clay* holding *concretions of carbonate of iron* (siderite); under this a thin bed of mixed *black clay* and limonite.†

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* *Carbonate of iron* (*siderite*) has been seen here, but apparently in no great quantity. It is important for the genesis of limonite.

† This shaft section is extremely interesting, as there can be no doubt that the black clay must have held pyrites and siderite, and by the decomposition of these the limonite was produced, precisely as in the case of the Devonian *Marcellus ore mines* of Mifflin county on the Juniata river, which will be described in a future chapter.

The *kaolin* in this mine has been a good deal mined. The best quality, No. 1 white, used to be sold at from $7 to $15 a ton to Connard's paper mill at Pleasantville, and Burgess's paper mill at Spring City. Opposite Royer's Ford, No. 1 was a deposit 30′ by 20′ under 6′ of cover, pinching out all round. Of the three grades there were about 800 tons. (See four comparative analyses by McCreath, D3, p. 368.)

The Manwiller mine, 1¼ m. W. N. W. of Griesermersville, Oley township, entirely in the limestone, was started in 1873 and abandoned in 1878; there was a fair showing of lump, but the whole was merely a pocket like so many of the smaller limonite banks of the region. About 2000 tons were got.—Ore can be seen cropping out in the little Dale Forge limestone valley in Washington township.—5000 tons were taken from the *J. Rush bank* in Hereford township, now filled with water.—5000 tons were got from one of the Bittenbender banks (in the same township) during 5 years work; greatest depth of open cut 50′, in limestone and clay; great quantity of flint mixed with the bottom ore.—1000 tons were mined from the adjacent *Gerham bank*, but condemned for its excess of silica.*

Schweitzer & Kurtz bank, 1¼ m. N. E. of Pricetown, and *Schaeffer's* at Fleetwood, were new mines in (1882), in limonite which belonged to the quartzite beds. (D3, p. 371.)

The Muhlenberg (*Beidler*) *bank*, W. of Reading, in limestone, an open cut 30′ deep, shows much siliceous limonite, with slate and clay holding the ore.—*Seitzinger bank*, a mile nearer Reading, has limestone outcrops east and west of it.—*The Eureka bank*, 3½ m. W. of Reading, a 40′ cut, yielded cleaner cellular ore, with little or no pyrites, but some oxide of manganese.

Cumberland County limonite mines.

The limonite mines of Cumberland and Franklin, along the foot of the South mountains, as far as Mont Alto, are described in a special report of the Iron Ores and Limestone Quarries of the Cumberland Valley by Mr. E. V. d'Invilliers.†

Beginning at the east end of the South mountains, 12

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*These banks run parallel to and 800′ S. of the *magnetic ore* workings higher up the hill in the gneiss, and have nothing to do with that ore. The magnetite mines of Berks will be described elsewhere.

† Annual Report of the Geological Survey for 1886, part IV with two maps. They were also described by me in a private report, with illustrations, published in the proceedings of the American Philosophical Society of Philadelphia, Jan. 3, 1873.—Mr. McCreath's analyses will be found in Report M3, 1881.

miles west of Harrisburg, we have (going west) the following limonite mines:*

Leidig & Hoffer (30); Beltzhoover (29); Ege (28); Pepper (27); Strickler (26); King (8); Pepper (7); Grove, or Peach Orchard (6); Big Pond (4); G. H. Clever (5); Clever Mammoth (3); Muslin (39); Chestnut (38); J. H. Cressler (37); J. Bridges (36); all in Cumberland county and south of the Yellowbreeches creek and Harrisburg and Potomac railroad.—Then in Franklin county Ahl (27); McHose (28) on the railroad; Cressler (29); Koser (30); Southampton (23); Ruby (24); Gochenauer & Rohrer (25); Means (26), all in the ravine of Furnace Run.—Then along the Mont Alto railroad Stephen's Pond (8); McNeal (7); Roth (5); Pond No. 1 (9); Pond No. 2 (10); and the group back (E.) of the Pond banks, viz: English (11); Promise (13); Hope (12); Wiesling (15); Limekiln (16); White Rock (18); Calliman (17); Guilford (14); then again on the railroad. J. Rock (6); No. 32; George (20); No. 8; No. 5; No. 4; No. 3; No. 2; No. 1, of the Mont Alto (1); Mill Bank (3?); Smith and Avery (2); Wythe Douglass (22); Pass Orchard (21); G. Rock (20); and lastly R. McCreary (19); on the Baltimore and Cumberland Valley road.

Leidig & Hoffer's bank is a small abandoned digging in the cove between two of the end spurs of the South Mountain, 3½ m. S. E. of Boiling Springs.

Beltzhoover bank, 1350′ long, 180′ wide and 30′ deep, on the north west side of the spur; open cut to south separated from main ore by 200′ of yellow clay; ore body not more than 40′ thick; 60,000 tons won.†

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* On the small maps in Ann., 1886, part IV, p. 1437, the mines are *numbered*, and the *names* are given in the columns at the bottom of the maps; but on the larger maps in the Atlas to the volume (part IV) the *names* alone are given. It is a pity that no geographical arrangement of mines according to numbers was possible; but I here endeavor to diminish somewhat the embarrassment thus produced for the reader by taking *the mines along the foot of mountain* in order first, especially as these are certainly in the Primal hydromica or lower damourite slates beneath the limestone.

† Here the ore dips distinctly 40° to 50° N. and N. E. *away from the mountain.* Variegated clays overlie the ore on the north, and are manganiferous Ore rests on reddish sandy slate, beneath which no ore is found. The old *Crockett bank* is further west up the hollow. The *Siplinger bank* is also long abandoned. Trial pits sunk westward found no ore, at least for 30

Ege bank (*Big bank*) of Phila. & Reading I. Co. 2 m. S. of Boiling Springs, an immense excavation, practically abandoned (in 1886) and the shafts and faces fallen in ; 1500′ long, 250′ wide, 70′ deep at south end. At the west end the ore was drifted on and found always dipping steeply *S. E. into the mountain.* thickening and thinning but "with an average thickness of 25 to 40 feet."

Pockets of manganese-iron ore edge the main body, and weathered into sooty clay masses or large spots in the white clay mass. The wash ore is mostly removed ; the remaining solid bottom ore is of poorer quality, and expensive to mine. The greatness of this mine may be judged from the fact that the lease called for 50,000 tons per annum ; but it never actually yielded more than 35,000 tons in any one year.

Pepper, or *Old bank*, near the head of a little limestone valley extending around a finger of the mountain 2½ m. S. W. of Boiling Springs ; trench 375′ long, 150′ wide, 45′ deep ; east end wall, buff clay and sand, wash ore ; west of plane, white clay streak 12′ wide ; balance, good and poor ore ground mixed ; many black manganese blocks ; abandoned (1883). In 1873 I saw a stope 70′ high, showing 25′ wash ore above, 45′ solid ore below, arranged in fine anticlinal arch;* shafts from the floor down went through 35′ more of solid ore, making 100′ of ore ground in all. At least 100,000 tons

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beneath the surface. A low tunnel was driven in white clay along the N. edge of the ore body to keep it in sight, and the tunnel doubled on itself N. W. showing an anticlinal structure, such as I saw in the heading. See foot note to d'Invillier's, p. 1468. Toward the east end the ore body swelled to 400′ broad. No. 3 tunnel 775′ long, from the RR. to the ore, was cut to avoid a plane. It was driven 650′ before the ore was reached, proving again the strange S. E. dip of the damourite slate formation here. See many other interesting details in d'Invillier's report; among them that the manganese deposits limit the ore in this as in other banks in this vicinity. Eastward the ore shelves up and covers a wedge of limestone 160′ thick. Trial shafts eastward have not been very satisfactory; but it is supposed that the ore is practically continuous to the Beltzhoover bank, 3700′ distant. There is a considerable amount of *shot ore* largely mixed with quartz. The trial pits were usually in a greenish talcose slate (*soapstone*) of the miners.

*See my pen and ink sketch of it in Amer. Phil. Soc. Proc., Jan. 3, 1873, page 9. I estimated a possible 9,000,000 tons along the little valley leading up to the Strickler mine; but it must have been an overestimate.

of ore were taken out prior to its abandonment; ore excellent for gun metal; used at Boiling Springs furnace 75° to 85° per cent. to 15° to 25° per cent. limestone ore, hematite or magnetic.*

Strickler bank, on the high divide back of the finger mountain and at the head of the vale of the Old mine (¾ m. W. S. W. of it). It is a mile E. of Mt. Holly Springs (paper mills). The bank in 1883 was 200′ long by 120′ wide and 15′ deep to level of water; the mine having been long abandoned after yielding possibly 40,000 tons.†

The ravine descending from the high divide at the Strickler bank *west* down to the Mt. Holly banks corresponds to the ravine descending from the Streckler bank *east* to the Old bank; and the line continued west past Mt. Holly banks is straight up Mountain Creek valley to the Pinegrove Furnace banks, in the heart of the mountains. Why Mountain creek did not keep on and issue at the Old bank is an interesting structural (and erosion) question. No ore has been found in the test pits along the ravine.

Mountain Creek limonite banks.

The first two banks ascending the valley are the *Mt. Holly mines*, 1 m. S. of Mt. Holly Springs, on the south side of the creek, 150 yds. up the slope at the foot of the mountain. They were both abandoned when visited by

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*Carlisle Iron Works property on which all these banks stand is 10,000 acres. Furnace recently (1883) improved, with hot blast, &c.—Analysis of large sample by McCreath: Iron, 45.1; mang., 0.23; sul., 0.20; sil. matter 21.02; phos., 0.176.

† The road over the divide runs along the N. side of the bank above it, and under a remarkable cliff of quartzite, or sandstone beds, descending (south) from the top of the mountain at an angle of 20° or 30°, as if to go under the ore, but broken off at the bank, as if it once overlaid the ore. A curiously interesting exhibition of erosion, with or without faulting, I know not which. I saw in 1873, 20′ of lump and wash ore then worked, and a sump of 26′ deep sunk in solid ore in the floor of the bank. About 20,000 tons had been already removed, and the rate of shipment then was 18 tons a day. McCreath's analysis of his own samples was: Iron, 43; mang., .01 sulp., 0.3; sil. mat., 19.0; phos., 1.4. All the ores of this range contain much manganese and phosphorus.

Mr. d'Invilliers in 1886. Dr. Frazer describes them in his Report C2, 1877, thus:

Thomas Iron Co.'s bank; 225′ long; 225′ wide; begun about 1872; average production 30 tons per day; nearly exhausted and half full of water in 1876. In the southeast heading the edges of the slates, converted into ore bearing clay layers, dip visibly 55°, N. 60° W. Bands of limonite concretions are interbedded with pink, white and yellow clays much crumpled with N. W. and S. E. dips. Red oxide stains some of the clays a bright red.*

Medlar and Saylor's bank,* 200 feet S. W. of the last, is an open quarry (about 2 acres), 600′ long by 200′ to 300′ wide, and 20′ to 30′ deep; begun by Geist & Krauft in 1840; first really worked by Medlar & Saylor in 1870, on a 4000 ton per annum lease at 75 cents royalty; daily average 70 to 80 tons in 1876.†

Grove bank, Hunter's Run station, 2 m. above Mt. Holly, south side of the creek, just above the mouth of Hunter's run. Opposite to it, north of the creek, and up the foot slope of the north mountain, are the four following banks in a row:

Lehman bank, opposite the Grove bank, idle in Oct., 1886 for want of water; a bore hole went down *through ore for 340′;* then through blue clay, 40′; then white clay, 30′; then "mountain clay," 25′ to "Potsdam sandstone" (Mt. Holly quartzite)=435′.‡ In 1887 mining recommenced; pit then 250′ long, 50′ wide; ore excellent; ½ ore in places; but average of mine ore to clay only 1:8 or 1:10; no solid ore; dip very irregular.

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*No. 159 on the map of York and Adams Co. in C2. *Medlar bank*, on map to An. Rt. 1886, iiii, p. 1463.

†It is said 1000 tons a month was mined out; and that much good ore remains; but the ore of both these pits is rankly cold short, and mining costly. At least 100,000 tons have been taken from the two pits to mix with Cornwall ore in the Harrisburg furnaces. Analysis of McCreath's sample of mixed lump and ball: Iron, 38.25; mang., 2.73; sulp., 0.005; sil. mat., 23.55; phos., 1.37.—Of dark brown cellular lump: 48.50; 0.73; 0.006; 11.27; 1.62. (d'Invilliers, 1886.)—See statistics of wages and machinery in 1874, in C2, p. 240.

‡These figures must be very misleading considering the *steep dip* of the quartzites at Mt. Holly, and consequently of the slates, which have decomposed into ore bearing and other clays.

Crane Iron Co. banks, $\frac{1}{4}$ m. W. of last; open cut 250′ long, 50′ wide; tunnel driven in at lower level from washer; bottom of cut being sloped down to tunnel; stripping 20′ at the least, and up the mountain (over the best ore) "enormous," mostly of sandy blue and white clay; output, 1886, 30 tons a day for Columbia, Pine Grove, Dunbar and Newport furnaces; afterwards increased. East of pit a shaft went through 50′ ore; cross cut through 50′ ore and clay.*

Dunbar (*R. Boyer*) *mine*, $\frac{1}{4}$ m. W. of the Crane; new in 1887; shaft 60′ deep; main gangway (northward) through 140′ ore clays, then 80′ through barren clays; drift westward 150′ in ore clay, lean, 1:10; two drifts (eastward) meeting irregular and thin deposits of ore.†

Chestnut Hill bank, adjoining the last at the west end of the row, $\frac{1}{2}$ m. N. of the railroad and $1\frac{1}{2}$ m. W. of Hunter's Run station; ore crops abundant; tunnel to take the ore beneath heavy stripping commenced in the autumn of 1886; ore body tested to depths of 30′ to 40′, E. and W. of tunnel; large pump on the creek for water supply; tunnel mouth 110′ above RR. grade; strikes ore clay at 130′ in and keeps 230′ further in; ore ground rich and lean alternately; most of the lump ore next the mountain; wash ore on varigated clays in front of it towards the valley; average ore to clay, 1:10; ore rich (47 to 49 per cent.) low in phosphorus (.08 to 1.0); 3000′ of outcrop tested by trial pits and shafts; ore for Chestnut Hill furnaces.

Koontz & Meyers bank, opposite last on south side of creek; small; abandoned for years.

Divens bank, just west of last; small; abandoned.

Henry Clay bank, west of last; 150′x60′; full of water in 1886.‡

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*The *stratification of ore and clay in bands* and irregular masses is very marked in this bank; but *so wavy* as to prevent any theory of general dip structure. There has been a vast deal of settling and sliding and compression during the process of slate mouldering and ore concentration.

†The main tunnel seems to have gone through *three distinct ore beds*, 2′ to 3′ thick each, separated by barren clays, in the first 140′, as described in the text; all the ores and clays *standing vertical*, i. e. varying between 70°, N. and 70° S. In strong contrast to this the ore overhead at the end of the west entry *dipped very gently south.*

‡ In all these banks the best ore is now (1886) entirely covered up, the openings having been abandoned when the lump ore was met with. They

Seyfert & McManus bank; 150′ W. of last; abandoned, but not exhausted.

Lanigan bank, 300′ W. of last; 120′x90′, 30′ deep to water; sides covered with wash of sand and stone and yellow clay; 15,000 tons mined out, and good show of lump ore in floor when abandoned.

Laurel No. 2 bank, nearly 3 m. W. of last; 200′x100′; vigorously worked from 1878 to 1881; neutral liver colored limonite in yellow clays.*

Laurel No. 1 bank, ⅙ m. W. of last, close by Pine Grove Furnace RR. station (2½ m. N. E. down stream from Pine Grove); on N. slope of terrace; small cellular lump, easily picked, and hard lump bottom ore, blasted; chief dependance of the furnace, mixed with Lehman bank ore; output running nearly up to 150 tons per day; heavy ore to clay 1:1; wash ore much less; dip S. E., wavy, sometimes N. W.; tunnel from W. end N. W. towards RR. through 50′ "top clay" into higher ball ore clay. Another tunnel S. E. 230′, mostly in ore ground, with blue clay intervals, rising S. E. but wavy, most of the ore to the west of it; ore very dense with much flint.†

Pine Grove No. 1 bank; 1½ m. W. of last, and ½ m. E. of the furnace (opposite the limestone quarry on the north

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all occur on the flat plateau gently rising southwards up the flank of the main mountain, and are largely accompanied by quartzite and sandstone; *no limestone showing* anywhere." D'Invilliers. Analysis: Iron, 35.85 (lump ore, 50.25); Mang., 2.25 (0.07); Sulp., 0.03 (0.007); Sil. mat., 31.89 (10.65); Phos., 0.18 (0.51); McCreath.

* The mountain spur, coming from the west, south of Pine Grove furnace, on which this opening was made, ends here, and the mine is well round its N. E. end, on nearly flat dips, probably a dying anticlinal. Top wash ore 12′ to 20′; clay 4′; lump ore masses in bottom of bank very compact. (Report 1887, p. 1453.)

† May 16, 1887, of 76 car loads got 46 of clean ore, but this was from the bottom of cut. Output in May, 50 to 60 tons per day. Water tunnel 300′ entirely through wash ore N. under RR. to creek. But this indicates synclinal with flat S. dips on the northern (creek) side and very steep *overturned* dips on the southern (mountain) side. Analysis of lump ore: Iron, 42; Mang., 3.5; Phos., 0.15. Pine Grove furnace depends largely on this mixed ½ and ½ with softer non-manganesian limonites from Hunter's run to make its neutral pig. An average mix of ⅔ Laurel + ⅓ Crane (or Lehman) gave carwheel pig (⅝ in. chill) analysing: Silica, 1.426; Phos., 0.305; Sul., 0.009; mang., 2.722. McCreath.

side of the creek); not in work in 1886; 1000′x200′, and 60′ deep; output from 1879 to 1885, 75,000 tons; prior to 1879 (in company with other pits) perhaps 150,000 tons of wash ore; originally 10′ clay and sand stripping, then 25′ wash ore clays, then 25′ solid soft lump; at W. end 60′ stope; drift S. W. from here 200′ and cross cut 150′ to left, all in ore ground (largely neutral ore from surface to bottom solid lump) probably continuous ore ground to *Old bank*; southern face fine show of lump ore; another drift from E. end 200′, largely brown cellular ore, with a large dome horse of white clay.* Northern face poorer ore, and much *black clay.*†

Old bank, just W. of last; large excavation, long abandoned. All dips of ore and limestone seen in these banks are S. E. No N. W. dips observed; perhaps S. E. dips are overturns.

Red bank of the Thomas Iron Co. (abandoned) lies nearly a mile south of the furnace; opened in 1874; general dip S. E.; area a fifth of an acre; 25′ to 30′ deep; ball ore in clay, and a good deal of red hematite; yellow and white clay beddings in natural position in the walls apparently dip N. W. but may have crept over from a S. E. dip.‡

Two large *quarries of limestone* lie 1000′ S. E. of the village of Pine Grove, area of both 8 acres, dips 30°, 40° and 45°, S. 30° E. Limonite ore has been taken from one of these limestone quarries, a single block of ore weighing 30 tons. The limestone is whitish, bluish, yellowish, very pure and good flux.§

Wild cat pits of the S. M. M. and RR. Co., 2½ m. S. W. of the furnace, shows that the limonite deposits continue up the valley towards Adams county; for, a large number

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* Another dolomitic limestone crops out S. of this clay mass; dips obscure.

† The lump ore mining has been suspended because it averaged 2.25 mang. and 0.225 phos. and yet gave 40 to 42 iron. Analysis of McCreath's samples: Iron, 42.15; sulp., 0.028; sil. mat., 20.9; phos., 0.275.

‡ Dr. Frazer remarks on the not unfrequent occurrence of this tendency of the inward dipping clay walls of limonite mines to settle and reverse the dip. To an observer facing the stope the bedding appears leaning towards him; but the removal of a few feet of wall will suffice to show them dipping away, (CC bottom of p. 246).

§ Limestone also reported seen half a mile up the mountain side.

of these trial shafts 30′ to 40′ deep passed through ore ground; but the 50 per cent ore held an excessive (1.3) percentage of phosphorus, which deterred the company from mining.

Of course the valley must be a synclinal of Chiques sandstone (the débris from which largely covers the surface), supporting the Primal Upper (hydromica) slate formation (furnishing the ore ground) and that supporting the lower beds of the Great Magnesian limestone (formation No. II*a*), remnants of which have been left by erosion, as shown by the quarries opened for flux for the Pine Grove furnace.

We return now to the north foot of the mountains, to the banks along Yellow Breeches creek.

Limonites along Yellow Breeches creek.

Mullen (*King*) *bank;* 2 pits in front of Mount Holly gap, 1 m. W. of Papertown, 600′ S. of road up the flank of the mountain; full of mountain wash; ore largely mixed with chert and cobbles of sandstone; white clay 20′ wide crosses the mine; long abandoned; ore reported good, but hard to wash; borehole record: Surface clay, 8′; ore clays, 128′; on limestone.* Shipments of uniformly good ore to Steelton, Newport, etc. A good deal of lump ore. Ore largely confined to the ravine and not extending far east and west.

Peffer old bank, 2 m. W. of Papertown, ½ m. S. of Barnitz RR. station, 1000′ S. of RR. towards the mountain, close to the junction of limestone and sandstone; good ore; abandoned for many years; say 5000 tons won; surface all around pit strewn with ore over 5 or 6 acres.

From this southwest for seven miles there are no mines.

Then the isolated *Grove*, or *Peach Orchard bank*, 2½ m. E. of Jacksonville, close to the mountain, 1 m. S. of the creek on small run; long ago abandoned; but Augusta and Cumberland furnaces ran many years mainly on this ore, using, say, 50,000 tons.

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* This is very interesting. The limestone so high up the mountain face with ore slate clays over it can only be explained by either (1) a universal overthrust and overturn; or (2) a fault, of which there is no evidence except in the valley of the creek; or (3) a descent of the limestone southwards under the quartzite mountain, which is inadmissible.

Big Pond banks, 3 m. S. W. of the last, 2½ m. S. S. E. of Jacksonville, on the last head brook of Yellow Breeches creek issuing from the South mountain; in the slates beneath the limestone; abandoned long since, although furnishing small shot and some bomb-shell neutral ore.*

Clever bank, 2 m. S. W. of Big Pond; 100′x100′x40′ deep; stripping 10′; white, yellow and red ore clays in lower part of limestone formation.

Clever Mammoth No. 1 bank, 1¼ m. S. of last, on first head brook of Conococheague creek issuing from the mountain; once important; abandoned long before 1886; 200′x 60′x 30′ deep to standing water; solid mass of ore reputed to be in the floor still; ore costly and of uncertain quality.†

The *Chestnut bank* and the *Muslin bank* lie between the G. H. Clever bank and the railroad.

The *Coffee bank* and the *Peacock bank* hold the same relative position to the Clever Mammoth; about ¼ m. E. of Cleversburg; in the Primal Upper slates (damourite). The Coffee was abandoned Oct., 1886; stope 40′, exposed to mountain side wash; ore in tough yellow clay, wavy, not rich. The Peacock was full of water. Stripping heavy, ore phosphorus (.535).

The *Cressler mine*, 1 m. S. W., and the *Bridges mine*, 1½ m. W. of Cleversburg, are in the limestone country southeast of the railroad.

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* This stream sinks in the limestone. In 1872 I sketched this range of pits (see Fig. 13, Amer. Phil. Soc. Proc., Jan. 3, 1873). Ore at creek level down stream, and 75 feet above stream to the south; only one bank then active; surface clay, 22′; wash and lump ore 20′; clay in bottom. Elsewhere stripping 6′ on solid ore. In uppermost (south) bank *limestone crops out at surface dipping 8°, S. 20° E., i. e., into the mountain;* S. of which a shaft went down through 52′ of ore and clays and *struck limestone at bottom. This limestone is very ferruginous* and makes excellent flux. Ore admirable, neutral, always worked alone in the Big Pond furnace, ½ m. S. E. of bank. Output between 75,000 and 90,000 tons between 1836 and 1868, making 800 tons of pig per annum (but d'Invilliers estimates it between 100,000 and 150,000 tons). Analysis: Iron, 44; sulphur., .03; sil. mat., 20.5; phos., 0.318.

† As I sketched it in 1872 it showed 8′ surface stuff; 12′ wash ore; 6′ ore with some clay; 9′ solid lump ore and still in floor; but clay bottom at W end; 40 tons output per day, very cold-short; output 20,000 tons.

Franklin county limonite banks.

Shirley's run is the county line between Cumberland and Franklin. Furnace run, a mile further S. W., flows parallel to it, out of the South mountain down to Shippensburg. *Means' bank*, *Rohrer's bank*, *Gogenhauer's bank*, are three small abandoned ore pits 4 m. up the run from the railroad.

The *Ruby* (or *Plaster*) *bank*, *Southampton bank* close to Southampton furnace, *Koser bank*, and *Cressler bank*, are ranged along the run westward, down stream. The *Ruby bank* is about 1200′ W. of the foot of the mountain, in the slates.

The old *Southampton bank* is in the slate range; abandoned since 1865; 150′x50′x20′ deep to standing water; cold-short ore.*

From the last (Furnace run) group of mines southward (six miles) to the Gettysburg-Chambersburg turnpike there are no mines. Here the face of the mountains is set back (first) four miles, and then runs on to Mont Alto furnace, 4½ miles. The first (northernmost) mine of the Mont Alto group is 1½ m. S. of the pike; the rest of them occupy the remaining 3 miles.

The west face of the South mountains south of the pike is called the White Rock mountain. In front of it, south of the pike, standing out in the limestone valley, is a low ridge, a mile long, called Little mountain, and between the two is a narrow, shallow vale (opening southward) called English valley; six mines are behind Little mountain, two on its slopes and five in front of it, at its west foot.

Little mountain is an anticlinal of Primal Upper slates, on sandstone, sinking west beneath the limestones of the valley towards Chambersburg, and east beneath the limestone in the English vale (which is synclinal) to rise again at the foot of White Rock mountain. This accounts for the arrangement of this Pond Bank group.

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* Iron, 45.55; mang., 0.73; sulp., 0.013; sil. mat., 16.46; phos., 0.69. The Ruby analysis reads: 37.2; 1.64; 0.03; 24.25; 0.61.

Mont Alto limonite banks.

Pond bank, a large abandoned open mine 80′ deep, ore superior, under 10′ to 30′ stripping. A shaft north of it went through the following: Earth and white clay, 10′; sand, sharp, light colored, 5′; clay, sand and pigment, 25′; *black clay*, fine-grained, 1′; *lignite*, 4′; clay, sandy, grey, 1′; *lignite*, 18′; sand, 1′; clay, variegated, 6′. (Wiestling's report to d'Invilliers, 1886.)*

Little Pond bank, 600′ N. of Mont Alto railroad, close to base of Little mountain, formerly an open cut, afterwards won by under-ground gangways driven S. from the shaft to the railroad, and curving round the Little mountain anticlinal on a very flat dip; also northward under the old open cut (which was 35′ deep.)†

English mine, a little higher up the W. flank of Little mountain; open cut, 200′x150′x30′ deep to standing water (1886). More lump ore was got from this than from any other of the Mont Alto mines, but it carries more phosphorus than any other, and so work was abandoned when Bessemer pig came into demand, as so many others of these limonite banks have been for the same reason.‡

Hope trial pits; 1200′ N. E. from last and rather on the E. slope of Little mountain. Ore found to be phosphorous (0.464).

Promise bank, in the vale on the White Rock mountain foot slope; actively worked in 1886 for Mont Alto furnace; first by open cut, 125′x125′x40′ deep; then central shaft

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* I saw *lignite* in this bank in 1872, and reported it to the Amer. Phil. Soc. Proceedings Jan. 3, 1873, comparing it with the well known *lignite mass* in the Brandon iron mine in Vermont, and arguing from it the *tertiary age* of all the limonite deposits of the Atlantic, so far as they were *cavern deposits in Silurian limestone valleys*. This assigned age, however, does not in any way conflict with the theory of the genesis of the limonite from the damourite or hydromica slates of the Primal series.

† Two analyses: Iron, 50.55 (48.60); mang., 0.300 (2.154); sulp., 0.054 (0.048); sil. mat., 11.52 (11.68); phos., 0.157 (0.059). McCreath.

‡ Dip of ore gentle but decidedly S. E. *into* Little mountain, which, as in other such instances, requires explanation. Ore covered with *black clay*, over which is 6′ to 10′ of stripping. Plenty of ore left in this mine. Analysis: Sulp., 0.015; phos., 0.849.

70′ deeper through wash ore, and 5′ into bottom lime stone.*

Guilford mine, active in May, 1887, 1 m. S. of last; same relative position. Between them are the abandoned *Westling* (1), *Limekiln* (2), and *Calliman* (3) *banks*. The *White Rock banks* (4) is high up the mountain slope, and does not belong to the slate range, but to the underlying sandstone, and *consequently shows the highest percentage of phosphorus;* whereas the *Limekiln ore was almost free from phosphorus.*†

The Guilford bank was (in 1887) 150′x100′x20′ to 30′ deep; ore found on top of flat ridge a little W. of the base of the mountain, and consequently has little stripping, say 4′ to 10.′‡ Ore stopes largely cut up with lean clays. More *bombshell ore* has been got here than anywhere else.§

The line of ore ground described above extends S. to the RR. 1200′ and crosses it into the B. George land.‖

The *Jacob Rock bank* here is worked solely underground for Mont Alto furnace.¶ *No. 32 bank*, on road, 1½ m. N. of Mont Alto; worked in 1887; ¼ acre; small lump and wash ore plenty; much free silica to be picked out from ore near surface; none in the deeper ore, where clay takes the place of sand; 15 to 20 tons (washed) ore per day.

Ruth shaft. A ridge ½ m. N. W. this last bank (32) and a

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*Two tunnels diverge into the mountain, from which gangways branch in various directions. (See description by d'Invilliers in An. Rt. 1887, p. 1432.) In one, two beds of ore 27′ and 40′ thick are separated by 13′ of barren clay Total proved thickness of good wash ore ground in cut and under-ground works about 100′. The wash ore turns out a percentage of *sandstone fragments* about as large as the largest ore lumps. These are hand picked and thrown aside. Analysis: Iron, 54.6; mang., 0.336; sul., 0.037; sil. mat., 5.775; phos., 0.104.

† Analysis show phosphorus in (1) .087; (2) .040; (3) .070; (4) .109.

‡The heavy stripping ground has had as much to do with the abandonment of our limonite mines as any variety in the quality of the ore; most of them still retaining large quantities of ore which the iron market will not pay to uncover. It is this that has driven the miners into the new style of underground driving.

§ These bombs are very rich in iron, but hold so much clay that they have to be smashed to pieces and washed.

‖ To the northward the abandoned *McNeal bank* and *T. Stevens' Pond bank* carry the ore to the turnpike.

¶Analysis: Iron, 47.35; mang., 0.75; sul., 0.066; s. m., 16.02; phos., 0.197.

mile from the mountain, and in prolongation of Little mountain (southward), is largely slate carrying a good deal of surface ore. A dry shaft on the crest of this ridge went down in ore (with a few pieces of limestone and clay) 120′. The ore crop traced north is 150′ wide, almost all wash ore. Want of water has prevented the establishment of a mine on this ridge. *Limestone*, *vertical* (slightly S. E., *i. e.*, overthrown), crops out a short way from the crest down on the N. W. flank of the ridge; which fixes the geological place of the slates.

The *Mont Alto banks*, 1, 2, 3, 4, 5, are almost a continuous open cut, 9 m. S. E. of Chambersburg on the west foot slope of the White Rock mountain; served by a RR. siding from the Mont Alto RR. which runs from near Scotland, south, past Mont Alto furnace, to join the Baltimore and Cumberland Valley RR. near Waynesborough.*

No. 1, near the furnace, long abandoned; now used as a *sand quarry*, the outcropping sandstone (to which the ore belonged) disintegrates and falls to sand.—No. 3, a little further on (N.) close to W. side of terrace; 400′x300′x60′ to 100′ deep; "worked to 120′ deep;" now abandoned.†—No. 4, next it, along the terrace; 60′ deep; output (of 15 years) 100,000 tons, all neutral ore, the main reliance of the furnace formerly; not very rich, but very free from siliceous stuff.—No. 8, 1 m. N. of furnace, on the same terrace; crescent shaped, 500′x150′; everywhere 20′ to 30′ of stripping; stopped in 1883; shaft passed through 30′ stripping and then 70′ of ore. No limestone seen here; but *the dip is S. E. into the mountain.*

Smith and Avery bank, 1 m. W. of Mont Alto, W. of RR. *in limestone land;* 1 acre, 15′ to 30′ deep, increasing northward; idle in 1887; too much phosphorus for the Mont Alto charcoal iron (0.415).

Mill bank; RR. cuts (25′ deep) through it, 500′ long,

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* For description of furnace see An. Rt. 1887, p. 1422; and interesting details in Frazer's Rt., C2, 1875, p. 257, *et seq.*

† A dome-shaped outcrop of *limestone* shows in it *apparently dipping S. E. into the mountain*, around which the ore was quarried. A shaft 50′ deep wholly in lump ore, *dipping steep towards the mountain*, pinching out E. and W.

with nests of ore in decomposed lime shales; too much phosphorus (0.439); abandoned.

G. Rock, *Pass orchard*, and *Douglass banks* are small deserted pits at the base of the mountain, 3 m. S. of Mont Alto and ½ m. E. of Quincy station. They belong to the Primal Sandstone range.—The *R. McCleary bank*, 2 m. W. of them is in the open limestone country; 150′x50′x15′ deep, with limestone in its center dipping 25°, S. 70° E. Four shafts in it (now all shut) showed that the ore was chiefly *pipe ore* finely *disseminated* through yellow clay.

There are no mines further south to the State line, but the same kind of ores follow the foot of the Blue Ridge through Virginia and Tennessee; as in the opposite direction similar large limonite mines range northeastward through New Jersey and New York to the famous Salisbury mine at the N. W. corner of Connecticut, and the Brandon mine in Vermont; and it is not to be doubted that if the damourite slates had been brought to the surface anywhere in Middle Pennsylvania similar deposits of limonite would have been created from them in recent times; but the general erosion has not gone deep enough for that, and the slate formation has been as yet protected from decomposition, so that it seems useless to bore or sink for the limonite beneath the surface.*

Path Valley limonite mines.

The Richmond, Carricksfurn and Fannettsburg ore banks in Path Valley, northern Franklin county, are perhaps an exception to this statement. They are situated along a great fault, which is not perfectly well understood, and which may possibly bring the Primal slate to the surface, in which case the mines would belong to the *lower damourite* range. But the fault more probably merely throws the *upper damourite* slate against the Medina sandstone on the slope of the Path mountain. The first theory is made

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* In none of the middle counties of Pennsylvania do the Primal slates rise to the surface except perhaps at the Tyrone forges on the Little Juniata in Huntingdon county, where no limonite deposits appear. If present they would greatly assist in identifying the Tyrone beds, over the precise horizon of which hangs some obscurity.

a little less improbable from the general absence of heavy limonite deposits along the limestone-slate contacts of Cumberland and Franklin counties, and also in the back valleys except at Leathercracker in Blair county.*

The two Virginia ranges.

In Virginia there are recognized two distinct ranges of limonite deposits : (1) A lower, massive and dense, dark and often pitchy black ore, in the body of the Primal sandstone ; (2) An upper, richer, more cellular, brown or liver-colored ore, in the overlying slates.

The lower ores are usually more cold-short. Both the Virginian ores seem to be richer in iron with less silica than the general average Cumberland county ores in Pennsylvania. The lower range is scarcely recognizable in Pennsylvania ; but Mr. d'Invilliers, who is well acquainted with the Virginia ranges, refers to the lower range the ore in Thad. Stevens's bank, north of his furnace on the Chambersburg pike, and the ore opened in the face of the mountain opposite the pike W. of the furnace. These I have already placed in the South Mountain quartzite formation, over the conglomerate beds, and they can have no near relationship to the hydromica (damourite) slates at the bottom of the limestone, nor to the Chiques quartzite under the slates.

But quartzite beds occur in the body of the chlorite slate formation in York county south of Wrightsville, on the Susquehanna ; and there may be other such horizons of quartzite older than that of the Chiques Rock. (Frazer in C, p. 202.) *Codorus ore* (No. 43 of the York Co. map) in North Codorus township, may be of this case.

Grubb's Cadorus ore in quartzite.

The Grubb ore (No. 110 of the map, also called the "*Codorus ore bank*") on the Codorus furnace lands 5 m. N.

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* The Path Valley fault discovered and studied by Dr. A. A. Henderson of the First Survey in 1839, 1840, is described, from his notes, by Prof. Rogers, in Geo. Pa., 1858, Vol. 1, p. 322, where Henderson's sections make the first theory almost a certainty. I therefore postpone the description of this ore range to its geological place in a future chapter.

of W. of Wrightsville is remarkable for belonging to the Chiques (Hellam) quartzite formation itself. Discovered and opened in 1866, this iron-bearing sandstone, quarried to the extent of 2000 to 3000 tons per annum for St. Charles Furnace above Columbia, to mix with Cornwall ore, holds its iron in the shape of $\frac{1}{3}$ *magnetite* and $\frac{2}{3}$ *red and brown hematite;* and having no sulphur and very little phosphorus helps to make excellent bessemer pig.*

The following description of what Dr. Chance considers a Potsdam sandstone ore mine is very interesting and geologically useful.

Lehigh Mountain Mining Co.'s limonite mines, 2 m. E. of Emaus, Lehigh county, and next E. of the Kemmerer mine; shaft 85′ deep; cross cuts at 55′ and 85′ south to ore body dipping steep (45°±) N. W. away from the mountain towards the edge of the limestone (200′ to 500′ distant); ore bed varies in thickness from 40′ to 5′; sometimes pinched out altogether; hanging wall clay having layers of flint and sometimes large masses of quartzite: foot wall also clay; mine down 130′ (1885); ore 40 to 50 per cent iron, rather high in phosphorus and silica; probably an altered pyrite: alteration may not descend beyond 300′ where the drainage level of the Little Lehigh creek will be reached. Outcrop line of 2 miles proved by 15 to 18 old surface pits, abandoned because of continual sliding into them of large quantities of quartz fragments and sand from mountain slope above, making it impossible to get clean ore for market. Now only the clean ore mass is taken out. The ore bed seems to be faulted at intervals so as to present a number of short S. S. W. crop lines arranged in echelon

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* The Grubbs wrote that a mixture of $\frac{1}{7}$ this Codorus ore with $\frac{6}{7}$ Chestnut Hill and Cornwall ores made a soft, strong and very fluid iron. Cornwall ore contains too little silica (6 per cent alumina to 15 per cent silica), whereas J. B. Britton found in this Codorus ore: Iron protox., 4.13; sesquiox., 36.08; (=iron, 28.46); ox., 17.16; sil., 33.80; al., 4.61; lime, 0.05; phos. acid, 0.158. For description of mine and mining statistics, see Frazer, Report C, p. 64, 1874.

along the S. W. normal line of the mountain slope rocks, viz: quartzite lying on gneiss. The gangway levels also are not straight but curved, the dip changing from steep to flat. Exceptions to the N. W. dip have been reported. (Letter of Dr. H. M. Chance, Nov. 3, 1885.)

Copious and precise descriptions of the various Primal (Potsdam) quartzite, sandstone and slate outcrops, exposures and cuts will be found on pages 99 to 135 of Chapter IV, of D'Invilliers' Report on Berks county, D3, Vol. 1.

CHAPTER XXI.

Magnetic limonite mines doubtfully referred to the Primal slates, or to the Gneiss, or to the Trias, in York, Chester and Berks counties.

The wording of this title is not intended to express more than the fact that the magnetic limonites of York, Chester and Berks are so curiously many-sided in their relations to the rock formations in and upon which they lie, that it is in the case of most of them impossible to prove satisfactorily that they have originated from the decomposition of iron-bearing shales of a particular age. They have all been changed from the condition of a hydrous peroxide to that of an anhydrous sesquioxide by the heat of trap dykes. How far the trap has introduced iron (with copper) from below, or how far the action of the trap has been limited to segregating the iron distributed in the sedimentary strata, cannot be dogmatically stated. The prime fact is that the region of these mines is a belt of country covered now, or once covered, by the Trias formation, the special (but not exclusive) region of trap outflows.

In York county.

The Dillsburg magnetic mines, situated in the northwestern quarter of York county, two miles from the foot of the South Mountains and a mile more or less E. of Dillsburg, in the Trias belt, form a group over which has been some geological contention as to what formation they belong to, whether to the South mountain cambrian rocks, or to the Trias new red sandstone and shale. All the mines yield about the same kind and quality of ore, magnetic, sulphur and copper bearing, like the Cornwall, Jones and Warwick ores. It is a country of trap, and dykes of trap adjoin the ore ; which accounts for the copper, sulphur and magnetite. But the Valley limestone No. II is close at hand on Yellow Breeches creek, overlaid by Trias ; and a belt of Hudson

River slate No. III, in Cumberland county, points directly towards Dillsburg, not 3 miles distant. The country north of the Trias in Cumberland has parallel synclinal basins of III separated by anticlinals of the underlying II. There can be little reason to doubt that the Trias in York county covers other and similar parallel rolls of II and III; and therefore it is entirely proper to suppose the existence of the lime shales between II and III (the upper damourite slates) beneath the Trias at and around the Dillsburg mines.

The situation then would be precisely that of the Cornwall mine, except that at Cornwall the great fault has let the Trias down against the II–III slates. But there may be faults at Dillsburg also; and indeed both the great abundance of trap and the general north dip of the Trias presuppose them.

On the other hand, between the Dillsburg mines and the mountain slope (covered with hydromica slates and fragments of Chiques quartzite) the Primal upper slates should exist beneath the Trias, and should furnish Chestnut Hill ore, turned by trap into Jones Warwick ore.

The limestone dips being all steep, the cross section distance between the upper and lower slates need nowhere be more than a mile (on a monoclinal); and, therefore, if the Dillsburg ore be transformed damourite slate limonites they may belong to either the upper or the lower slates; and in either case the trap would make them copper-bearing magnetic red-short ores.

But as most of the numerous mines are to all appearance in Trias rocks they have been assigned to iron-bearing slates of Trias age, altered by trap. If the McCormick boreholes near Dillsburg furnish accurate data they make it certain that some at least of the Dillsburg ore-masses are true ore-beds lying between variously colored sandstone strata, and not far above and below beds of limestone and sheets of so-called white, grey and black trap.* If these rocks be of Trias age it seems quite impossible to assign the ores of

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* See borehole records (condensed) in foot note to page ; and in full in C2, p. 216.

the Dillsburg district to the Primal slates. The most important mine for this side of the argument is that of the Altland shaft or Schoolhouse mine. The most important for the other side are the Bender and McCormick banks.

The central figure of the Dillsburg group is the—

Underwood slope (formerly *Mumper mine*), opened 1848; slope 290′ long, 28° (average) due N.; at 26′ struck ore 18′ thick; followed it dipping more steeply; roof trap; floor "*sandstone intermixed with limestone*"; distance from wall to wall "averages" 5′; but ore 6′ to 30′ thick met with; 8 side drift levels averaging 70′ in length; 3 shafts, deepest 140′; output (1875) 40 tons per day, total output to date (1875) say 10,000 tons; ore solid and hard, blasted, very little of it crystallized magnetite.*

Underwood's new mine; 200′ S. of old slope; one pit 10,000 square feet, 15′ deep; a derrick shaft went through 25′ (20′?) trdp and then 28′+ (30′?) ore; E. and W. level; slope from bottom of shaft 50′ long, gentle N. dip in ore; 6 tons a day. "*A layer of limestone was passed through.*" Ore needs no washing. South of derrick shaft, 70′, another shaft through 2′ trap, then 10′ ore.—E. N. E. of derrick shaft, 100′, a third shaft, same record.—New pit sunk through soil and gravel 30′ to ore.—A large pit S. W. of main pit exhausted a pot of 5000 tons of surface ore.—E. of S. 300′, a third pit (3500 sq. ft.) abandoned.

Logan's mine, 500′ E. by N. of Underwood's slope; opened in 1874; shaft 50′ deep; slope from bottom of shaft 28°, due N. 80′ long (1815); output 25 tons per day for H. McCormick furnaces at Harrisburg; ore magnetic, not washed; section, soil and gravel with some bowlders of trap, 28′; sand, 6′; ore 20′; floor rock 2′.†

King's mine, 3300′ E. of Underwood's slope; shaft sunk (1876) through soil and loose trap, 6′; hard trap, 17′; ore, 9′. A level driven 20′ E. in ore wedged between trap below and hardened sandstone above, dipping (elsewhere) 23°, N.

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* Lowest gangway 110′ long E. and 120′ W. See full description of working and statistics of cost, etc., in Frazer's C2, p. 208.

† Statistics, etc., in C2, p. 211.—A trial shaft 2400′ N. proved some ore; ground strewn with large bowlders of trap.

40° W. As this mine was advanced (spring of 1876) the ore steadily improved in quality downward, pyrites diminishing, lime and magnesia increasing, and vein more solid. The vein is 9½′ thick, viz: bottom ore, 1½′; rock, 1′; top ore, 7′. Output 25 tons per day.[*]—Other old pits are to be seen in the neighborhood (exhausted ore-pots) one of which is said to have given 2000 tons of surface wash ore, with some N. slope ore. Massive trap is still visible in the pit.

McCormick & Co.'s old mine, 500′ E. of the Underwood slope; 12,000 square feet area; begun by Mumper in 1850; shaft (in bottom of pit) 140′ deep; ore exhausted. A slope 100′ N. of pit, 20°, 60′ long, abandoned.

McCormick's long cut and slope; the mine furthest north in this group; open cut along ore crop 500′; roof trap, dipping 27° to 34° (20°, Altland) N. Westward. Abandoned (1875).[†]

Smyser's open cut, 1000′ S. E. of Underwood slope; ore like that of the other mines; total yield, 3000 tons; pit 30′ deep in sand and gravel (no rock visible), abandoned.[‡]

Bell's shaft, 33′ deep, not far from bore hole No. 3.[§]

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[*] Mr. King's letter, May 22, 1876. He explains that the "fault rock" is "a mixed up, broken up mixture of sandstone and trap rock," and that immediately behind it (S.) is a ridge of dark green rock. See contents of letter in C2, p. 213.

[†] Bore hole No. 1, 160° N. W. of middle of this cut, went down through clay, sandstone and clay, 14′; *bastard limestone*, 9½′; sandstone, 9½′; *trap*, 9′; unknown and brown sandstone, 32′; *ore*, 6′; sandstone, 4′; *lean ore*, 4′; total, 88′.—Bore hole No. 3; white and red sandstone, 17′; *trap*, 17½′; black, green, brown and white sandstones, 14½′; total, 49′.—Bore hole No. 4, 150′ S. of E. end of cut; various colored sandstones, 50′; *trap* (black), 16′ and (white) 6½′; *ore*, 1½′; white, green and red sandstones, 42′; total, 116′.—Bore hole No. 5, sunk in the old bank: soil, &c., 9′; *ore*, ⅙′; sandstones, 22′; *trap* (black), 23′; sandstone, 3¼′; *ore*, 3¼·; white sandstone, 5′; *ore*, 1⅓′; white sandstone, 11′; *limestone and flint*, 6′; *limestone and fireclay*, 10′; sandstones, 30′; *ore*, 2′; sandstone, 2′; sandstone and *ore*, 3′; *limestone and flint*, 6½′; *ore* and sandstone, 0½′; sandstones, 17′; *trap* (grey), 2′; white sandstone, 2′; limestone, 3′; variously colored sandstone beds, 25′; total, 191′. See these records in more detail in C2, p. 216.

[‡] One report says that the lessees sank 45′ to ore 25′ thick dipping S. E. Another report makes the ore dip S. W. on a saddle of trap. Ore used unwashed; scattered through the bank; costly mining. Two observers could get no dip for the trap in this bank. C2, p. 217.

[§] These works were new when visited in 1875. See details in C2, p. 218.

Grove's mine, ¾ m. S. E. of Underwood slope; worked for 2 years previous to 1875*.

Price's open cut, a mile S. E. of Underwood slope; 350′ long by 125′ broad, abandoned about 1860, after yielding a large amount of magnetic ore; said (in 1875) to have still a 6′ ore bed within 14′ of surface; sandstone appears in the N. side.

Fuller mine, 3½ m. N. E. of Dillsburg; begun 1863; worked in 1875, 15 tons per day; ore strongly magnetic; tunnel adit from railroad on bank of Yellow Breeches creek, 200′ due S. and two drifts E. and W. under roof of trap, dipping 24°, N. W.; foot wall greenish altered sandrock.†

Porter's bank, near the last; worked by Gov. Porter five years (from 1850 + ?) and by A. Price for eight years; ore magnetic; pit, 40′ deep (14′ below creek level); ore dipped 30° towards and under the creek; *limestone beds in RR. cut close by dip 30°, S. 10 E°.*‡

Shelly's mine, near the last, yielded 300 tons of magnetic ore, 10′ thick, under 20′ of trap, and lying on Potomac marble. Another shaft went through 30′ of trap to ore.§

A group of pits and shafts S. W. of Dillsburg, includes *Heiges' shaft*, very little ore;—*Filler's trial pit; Berghart's pit*, a layer of ore between red sandstone (Trias);—*H. Heiges' trial pits*;—*A. Heiges pits*, ore and trap;—*G. Heiges' shaft*, 30′ through trap and green sandstone; *ore* 4′ thick. All these are scarcely more than unsuccessful prospecting holes. Trap is abundant; the surveying needle is deflected; Primal slates appear from beneath the Trias.

Another group of pits of small size range irregularly past Wellsville (6 m. S. E. of Dillsburg) in the heart of the Trias

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*See details in C2, p. 219.

† Details and statistics in C2, p. 220. Analysis (in C, p. 74): Iron oxides, 62.0; phos. oxide, 0.05; manganese sesqui oxide, 0.352.

‡The ore bed is reported to have been 6′ thick, and opened for 25′ along the crop. Dr. Frazer thinks that by "magnetic" is not meant ore of the Dillsburg type, but the "magnetic" ore of the York valley, and probably belonging to the older (Primal) rocks; Yellow Breeches creek being practically the dividing line between these and the Trias. (C2, p. 221.)

§ Such is the report of Mr. Shelly to Dr. Frazer in 1875. C2, p. 222.

country, with abundance of trap: *Lichty's*, *Meyers'*, *Elicker's*, *Kimmel's*, *Cooper's*, *Morganthaler's*, *Wiley's*, *Brenneman's*, *Griest's*, *Harman's*, *Gerber's*, *Altman's*, *Comfort's*, *Cadwalader's*, *Bent's*, *Marshall's*, *Schluthauer's*, *Cookson's*, *Smith's* (*W. R.*), *Smith's* (*J. T.*); but they all belong to the Trias, and not to the Primal slates; as is best shown at the *Schoolhouse mine* or *Altland shaft*, where the micaceous magnetic ore bed is seen regularly interbedded with the Trias sandstones, dipping 35°, N, W., and both sandstones and ore cut off by a vertical trap dyke, only 4′ thick. Over 5000 tons were won previous to 1875.*

There remain to be noticed here a group of three mines undoubtedly of Primal age, at the foot of the South Mountain in York county:

Bender's magnetic ore mine, 1½ m S. W. of Dillsburg, on and near the edge of the Trias; open cut; 1849, 200 tons; idle until 1873, 300 tons, a pocket of ore 5′ thick; other such shallow pockets near by; ore magnetic.

Bender's limonite bank, ¾ m. W. by N. of last, in the decayed Primal slate clays which form the south flank of the mountain range; open cut, ½ acre; 1874; output 2000 tons in 1½ years and abandoned; stripping 12′ to 20′, over a mass of small wash ore and streaks of shell ore, 23′ (and more) deep; one of the ore layers dipped 56° S. †

McCormick's bank close to the last; a century old; worked by many successive parties; wash ore; very few large masses; dip of richer streaks same as in Bender's bank; pit 35′ deep to water; no rock seen; ore left in floor; abandoned.

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*This is the best example of indubitable Trias magnetic ore I know, and deserves careful study. The gangway in ore from the shaft east shows the ore bed varying between 1′ and 6′, and sometimes penetrating one side of the trap, for a few inches only. The trap has developed ore on its N. W side, but not worth mining. (See picture section in C2, p. 235; mine plan, p. 237.)

† But the decayed slate rock layers can be easily followed by the eye, in both banks dipping 30°, S. 30° E. Many of the leaves of clay are encrusted with limonite; many of them are twisted and bent in common with leaves of hard brittle ore; showing plainly that the segregation of the ore followed the decomposition of the clayslate. (C2, p. 229.)

In Chester county.

Pickering creek heads at Windsor in Upper Uwchlan, and flows eastward through West Pikeland (past Marisville), East Pikeland, Charlestown and Schuylkill, to the river two miles below Phœnixville. The Pickering Valley RR., 10 miles long, brings down the ores to the Phœnixville furnaces.

The country is gneiss, undoubtedly once entirely covered, as it now is partially, with Primal slates and sandstone; and these of course with the limestone, slate and sandstone formations of the Palæozoic series up to the coal measures. If all these were removed by erosion, or nearly all of them, before the New Red series was laid down upon the country, the interval of time between the Carboniferous and Trias required for such erosion would be incredibly great. And yet we see the Trias resting on the gneiss along French creek, with no appearance of a fault at the contact. The eroded edge of the Trias across Chester, Montgomery and Berks counties is sufficient proof of the former extension of the Trias southwestward over the gneiss region, no doubt over the whole of it.

This is the foundation of Prof. Rogers' theory of the Pickering Valley limonite deposits, and of others north and south of them in the gneiss country. He supposed that iron-bearing Trias sandstone beds caught in faults in the gneiss deposited their iron in ores left after the general erosion of the Trias had been accomplished.*

But it is admissible to suppose that portions of the iron-bearing Primal sandstone and hydromica or damourite slate formation have escaped erosion from the surface of the gneiss and have produced limonite ore deposits here as elsewhere. Although there are some serious objections to this hypothesis (for the whole subject of the erosion of the gneiss region of N. Chester is full of difficulties) it has some advantages over the other; one of which Mr. Rogers himself furnishes, when he says: "It is an interesting fact, having

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*Geol. Penn. 1858, Vol. 1, pp. 83 to 90, with diagrams of faults and ores; copied into Report C4, 1883, p. 168.

some bearing perhaps upon the question of the origin of the iron ores . . . that several of these deposits adjoin, if they are not closely connected with outcrops . . . of *limestone*," as at the *Lewis bank* and the *W. Parker bank.* A still more important support to the theory is lent by the fact reported by Dr. Frazer (C4, p. 231) that exposures of *azoic slate* occur in the *Harvey* (or *Latshaw*) *mine.* The large *Worth mine* of surface limonite in W. Caln, 1½ m. N. of Sadsburyville, lends some support to this view, as agreed by Dr. Frazer in C3, p. 261. The slate partings in the limonite magnetite ore mass at the Warwick mine are decidedly friendly to this view.

A group of old mines around Yellow Springs were described by Prof. Rogers as seen by him in 1853:

Lewis bank, still worked in 1853, 1½ m. N. E. of Yellow Springs; in narrow trough (fault?) between steep gneiss, and gently pitching altered red sandstone and shale (on N. W. side); white granite near south wall; ore a loose sandy mass; bank N. E. and S. W. 40′ deep; altered red rock holds many spangles of graphite and magnetite crystals; the unaltered red rock quite like Trias. *A narrow strip of limestone is said to have been encountered in this mine.*

Fegley's bank, ½ m. N. E. of Yellow Springs, separated from the Lewis by a gneiss range; two excavations in line, between contorted steep gneiss and altered red sandstone (on N. W. side) dipping 40°, S. E.; granite veins in gneiss wall; ore mingled in a confused mass of rotted gneiss and granite; but main body of ore (40′ thick) is in loose earth resting on the red rocks. Fegley bank (1853) 200′ × 100′ × 50′ deep; ore in bottom. Another large pit, just N. E. of the other, has a 12′ ore bed on a floor of red sandstone.* Annual yield of the two banks in 1853, 2400 and 2000 tons. Leased to the Phœnix I. Co. in 1865. Abandoned.

Latshaw (later *Harvey*) *mine*, ¾ m. S. W. of Yellow Springs, on a fault between steep gneiss and S. E. dipping red rocks, but decomposed granite in the south wall; ore

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*The strip of red rock makes a low ridge 600′ wide and half a mile long, and the ore seems to have come from it. Mr. Rogers had no doubt of its Trias age.

mass on and in crushed and crystalline red rocks, full of graphite scales and mica, looking like gneiss. Output in 1874, 2000 or 3000 tons (Rogers).—Output in 1881, 1000 tons. *Exposures of azoic slates dipping S. E. occur in this mine* (Frazer).

Steitler bank, ¾ m. S. W. of the Latshaw, and on the same fault, between a vertical granite dyke and S. E. dippings crushed red sandstone.* First worked about 1800; annual continuous output for 8 years (1845 to 1853) 3000 to 5000 tons of rich good ore; a little manganese oxide; a little pyrites; beautiful masses of fibrous and pipe limonite frequent; unusual abundance of bombshell ore, often holding feathery-white mica (Rogers).—In 1879 this excavation was 900′ long, 600′ wide; had sometimes yielded 8000 tons in a year; but was then abandoned. (Frazer, C4, p. 231.)

Raby mine, in E. Pikeland, 1 m. S. W. of Kimberly; still worked in 1882, 6 tons per day.—*Orner mine*, ½ m. W. of old Fegley in W. Pikeland; worked by the Phœnix I. Co. in 1883. Shows graphite.—*Fussel* (*Morris*) *mine*, 1 m. W. of Yellow Springs, exhausted in 1880, after an output of 250 tons.—*Tustin* (*Isaac*) *mine*, ¼ m. S. of Chester (Yellow) Springs; opened 1851; leased to Monocacy Furnace Co.; then in 1864 to the Phœnix I. Co.; shallow ore; abandoned.—*Prizer mine*, 600′ S. W. of the last; worked by Phœnix I. Co. from 1856; then by Monacacy F. Co.; large output; heavy stripping; abandoned.

Acker (*E. Jones*) *mine*, ¼ m. S. of Latshaw (Harvey) mine, was worked from 1863 on by Phœnix I. Co. with a large output; afterwards for Monocacy furnace; output in 1882, 20 to 30 tons a day. It was opened about 1853, on a different fault line (600′ S. of) the Latshaw fault line, between steep gneiss and S. E. dipping altered crystalline red sandstone beds full of mica and specular iron crystals; it was at that time a mass of fragments of white granite, gneiss, and red rock pervaded and cemented by limonite. See diagram section in C4, p. 171, borrowed from Rogers' Geol. Pa., 1858.

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* See diagram cross section on plate, Report C4, p. 171, copied from Rogers' Geol, Pa., 1858.

Mosteller mine in W. Vincent, 1 m. E. of Pughtown; Phœnix I. Co., 1880, 15 tons a day. Analysis of ore: Iron 41.64; silica, 23.07; phosphorus, 0.46 (J. C. Smith).—*Stauffer mine*, ⅜ m. S. W. of last; Phœnix I. Co., 1880; after 4000 tons output, abandoned.—*Green's mine* in W. Nantmeal; Eckert & Co.; two large excavations, ½ and ¾ m. N. W. of Barnestown station, E. Brandywine and Waynesburg RR.

The Warwick Groop.

The famous Warwick township mines of northern Chester, in the trap district on the edge of Trias, are among the most interesting and obscure of all our ore deposits, both in respect of their relation to the rocks, and in respect of the chemical changes which have produced the ore. The felspathic granite or conglomerate rock at the Hopewell mines is very interesting.

The *Hopewell Furnace old mine*, 1½ m. N. W. of St. Mary's, was abandoned (1878); but the *new mine*, 150′ deep, was worked by drifts and slopes, at four levels; shaft sunk in 1877–8 to ore 40′ thick and no bottom, but said to average only 10′; ore between a hanging wall of *conglomerate* (with blue or amethyst quartz) and a foot wall of syenite or dolerite trap ("blue rock"); ore much like Cornwall ore; ore lying in veins or bands, dipping 35°, N. 70° W.; open cut 200′ long; old shaft abandoned; new shaft 150′ to a 12′ ore dipping 35°; exhausted, for in 1882 they were robbing the pillars at the rate of 30 tons a day (Frazer). The mine is near the contact of the Primal sandstone with the gneiss. Shaft sunk through trap, struck two veins of *magnetic ore* dipping 30°, N. 25° W., the upper one 15′ to 25′ thick, the lower one 7′. The trap runs N. W.–S. E., cutting and shifting the ore (Rogers).

Warwick mine, at Marysville, a very large old work in limonite and magnetic ore, no doubt orginally all limonite, concentrated from ore-bearing rocks obscurely related to the upturned gneiss, on the eroded edges of which lies the ore in a sheet varying from 2′ to 17′ in thickness.*

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* As shown in the diagram section in C4, p. 239, borrowed from Rogers' fig. 572 in Geol. Pa., as seen in 1854. The ore is a mixture of limonite and

This large Warwick mine is in a gravel mass made up of loose fragments of syenite, quartz conglomerate, and mud rock, mixed with sand and clay. A public road runs through the mine.

The new *Smith's Warwick mine* was opened in 1879. In 1882 the Brooke I. Co., the principal operators, were taking out 20 tons of magnetic ore per day.

Steele's mine, ½ m. N. of Marysville, abandoned long before 1850, seems to have been on a magnetite vein in gneiss near a trap dyke. (C4, 241.)—*Leighton's mine*, S. of Marysville, just outside the edge of a patch of Trias basal conglomerate, was largely opened on the outcrops of two magnetite veins dipping 33°, N. W.; the upper, 15′ thick, pinching in 25′ of depth to only 15 inches; the lower (two or three feet beneath the upper) 10′ thick at the surface, dwindling to 4′.* Length of crop 1500′; length of pit 200′; depth of open cut 40′; total output 20,000 tons; abandoned before 1853.—*Knauertown mine*, on S. edge of tongue of

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magnetite, the agent of change being a wide trap dyke which passes across the ore mass and throws it up on one side. The ore lies in several nearly flat waves. The edge of the Trias new red sandstone formation laps here over the gneiss and the iron ore. At one place the Trias conglomerate is baked and altered, holding round bunches of various crystalline minerals, hollow spaces (geodes) and vein strings. The geodes are lined with beautiful crystals of epidote, etc., and bunches of large fine garnet (melenite). Injections of *serpentine* occur in the mine. The greatest depth of the ore below the surface was 60 feet; over much of the ground the ore was but little beneath the surface. Average richness 45, rising sometimes to 50 per cent; somewhat sulphurous. The mine has been wrought for 160 years, with an annual output for 15 years of 4,000 tons; for the next 20 years 6,000; in 1853, 12,000. The changed ore is grey, crystalline, magnetic; the unchanged ore is a compact closely cemented brown hematite (limonite) as in other mines described in this chapter.

Interstratified minutely with the ore are plates of earthy hardened slate or shale, which sometimes swell to considerable thickness and separate the ore mass into distinct ore beds. An intimate mixture of fine-grained ore with the clay stuff makes the lower grades of ore. What are these slate layers? The resemblance of Warwick to Cornwall ores suggest that we have at Warwick as at Cornwall a mass of hydromica slate, or rather of lime-shales, decomposed into limonite and then partially converted by trap into magnetite. But at Cornwall the lime shales are those at the top of III, as at Ironton and Moselem. It is impossible to imagine any slate at Warwick except the Primal; and this if present will explain the "injections of serpentine" mentioned above.

* See diagram section, Rogers' fig. 571, in C4, p. 239.

Trias; small; ore and situation precisely like Warwick.—*Crossley's pits*, 1 m. N. of Knauertown; abandoned before 1854; between walls of gneiss in a low ridge, at the W. end of which a large vein of magnetite rapidly pinched out downward.*—*French Creek magnetite mines*, ½ mile S. of Harmonyville at the end of the St. Peters branch of W. & N. RR.; two shafts 250′ deep (with hoisting and pumping engines at both); capacity for output, 15,000 tons per annum. Ore holds sulphides of iron and copper.†

In Berks county.

The Jones (*Warwick*) *mine* in Caernarvon township, Berks county, 3 m. N. E. of Morgantown, and 12 m. S. of Reading, worked by the Phœnix Iron Co., was opened by David Jones in 1735 on a 1000 acre tract sold as mineral land by Wm. Penn to Welsh iron masters as early as 1686.‡ It was known as a *Warwick mine*, because worked for Warwick Furnace at Pottstown. It is however 5 miles W. N. W. of the *Warwick mine* in Chester county. It is situated at the head of the Conestoga valley, where the Lancaster limestone narrows to a point between the Trias belt and the Chiques quartzite lying on the Welsh mountain gneiss. An open quarry of 5 acres (in 1857) has a N. wall of (20°, N. 30° W. dipping) magnesian limestone beds *under which are the ore-bearing Primal-slates* turned into a limonite and magnetic ore mass by a trap dyke on the southern side of the mine (next the quartzite). The purest and richest ore is next the trap. Copper sulphide, carbonate and silicate occur in the ore (as at Cornwall). The total output has

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*Close by is the Knauertown (or French Creek, or Elizabeth) Copper mine, in gneiss, but with a granite S. wall, dip steep to N.; width of lode 45′; shaft 140′ deep vertical, and 45′ more on the dip, to a star of short gangways in three directions; abandoned May, 1854. Massive dyke of trap just south of the mine, at the north edge of the tongue of the Trias. Gangue largely calc spar, through which are scattered crystals of magnetite, pyrite and chalcopyrite, the last most abundant at the N. wall. (Rogers, in C3, p. 243.

† E. B. Harden, 1882, in C4, p. 244.

‡ See Mrs. James' Mem. of T. Potts, Jr.; Swank's Statistics for 10th census; Lesley's Iron Man. Guide 1859, p. 561; d'Invillier's Report, D3, p. 226. Rogers' Geol. Pa. 1858, Vol. 1, p. 182. An. Rt. Geol. Survey Pa. 1840.

been very great, as the mine has been wrought ever since the Revolutionary War; in 1853 it was 7,000 tons; average for the year 1850 to 1854 (during which a futile attempt to mine it for copper also) 10,000 tons.*

The *Dotterer red hematite mine* in Earl township is a remarkable instance of the uncertain relationships of some of our ores. It is the only mine in Berks county showing plainly, *i. e.*, in workable mass, the two varieties of specular iron ore, viz: (1) massive, crystalline, steel gray, weathering reddish; and (2) earthy, uncrystalline, blood-red to brown; evidently grades in the change from hydrous limonite to unhydrous specular, with or without the production of magnetite.

The bed, 44′ thick, stands nearly vertical (80°) between a foot wall of conglomerate and a hanging wall of chlorite slate; and is itself merely a deep red ore-charged portion of this chlorite slate formation. The conglomerate made up of pebbles of gneiss and quartzite, runs along the east flank of Saw Mill Hill (near the summit of which the mine shaft is sunk) while the crest and west flank are made by the primal quartzite. The ore, therefore, seems to belong to the *lower primal slate formation*, overturned slightly beyond the vertical.†—Some excellent red hematite has

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*The geological position of this body of ore is unmistakably the same with the whole range of Primal limonite deposits of the south edge of the Great Valley; and yet the ore is classed (and very properly) with the magnetic iron ores. There is less reason, therefore, to doubt that the Warwick and Pickering valley ores of Chester county belong to the same Primal hydromica (damourite) slates. The magnetite, the copper and the trap seem to go always together, in the case of those limonite deposits which have been wholly or partially changed into magnetic ores; whether as, in this instance of the Jones mine, the slates are at the bottom of the No. II limestones, or in the case of the Cornwall mine where the slates seem certainly to be at the top of them. *Where there is no trap there is no magnetic ore, and no copper.*

† See description, vertical section and mine plane by Mr. D'Invilliers in Report D3, Vol. 1, 354, etc. In the extreme north of New York State red hematite is mined beneath Potsdam and over slates. In Berks, Pa., the Lock Ridge magnetic range (p. 253) seems to occupy this position. In Virginia the red hematites occur in the lower, and the limonites in the upper primal slates; ores however being also mined in the intervening sandstones and conglomerates. (A. S. McCreath's Mineral Wealth of Va., p. 9.) In New Jersey the red hematite comes in between marbles and gneisses;

been won from *Kaufman & Spangler's old mine* in Furnace Hill, Earl township, long abandoned, apparently in quartzite.*—Red hematite was got close to limonite in Brumbach's ore holes in quartzite on the hill 1 m. W. of Green Hill tavern near the old Rockland forges.†

For the *magnetic iron ore mines* of Berks county I must refer the reader to Mr. D'Invillier's Report D3, Chapter VIII, pp. 237 to 351, where he will find described in detail the interstratified magnetites of the Mesozoic conglomerate; the Rittenhouse Gap district, Thomas I. Co. mines, Tunnel mine; Gap Mine range, Moll & Geary, Conrad slope, Ginkinger, Weller, Wetzel, Miller, Dunkle, Gardner station, Marstellar, new and old Mickley, Finlay, Fegley (S. Boyer & Co.), Frederick, Fritch, Tutham mines; the Rockland township mines, Beitler; Ruscombmanor mines, Clymer, Tunnel, Schittler; Oley township, Tulley; Alsace township, Reading old banks; Hartford township, Siesholtzville, Bittenbender, Gehman, Shimersville; Washington township, Landis, Barto, Stouffer, Gilbert, Gilberg; Pike township; Earl township, Phœnixville and Warwick mines; the Gabel mine; the Fritz Island mine; the Raudenbush; the Wheatfield;—and the Ruth.

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but in Berks county no such alliance is known. The only instance of *micaceous red hematite* known in Berks is an unworkable vein on Fritz Island below Reading. The Dotterer mine is 2 m. due W. from Hill church; had 3 shafts 66′, 61′, and 50′ deep, with cross cuts, etc., described in D3, p. 356. The foot wall for at least 75′ along strike is everywhere a clay slate, rich in alumina, poor in iron, carrying 5 per cent titanic acid; used at Phœnixville, at Pottstown, and (1882) at Norway (old Lawrence) furnace to mix with more refractory magnetites, but no limonite. (See statistics of charge, analyses, etc., on pp. 356 to 359.)

* The ore was hard, compact, lustrous, what there was of it. Here occurred also magnesite (carbonate of magnesia). See Genth's Report B, p. 157.

†The hill is riddled with trial shafts which yield very little of this rich and desirable ore.

CHAPTER XXII.

On the Great Valley.

The earliest settlers of Pennsylvania soon learned to recognize the superior fertility of limestone land.

While one stream of immigration from Philadelphia followed the line of the Chester county valley, occupied the plain of Lancaster, and spread itself along the Lebanon, Harrisburg, Carlisle and Chambersburg belt, two other streams ascended the Schuylkill, Delaware and Lehigh rivers to take possession of the Easton, Bethlehem, Allentown and Reading portions of the same belt.

The distinction was then made in the markets of Philadelphia between the wagons which came from the *Little valley*, and those which came from the *Great valley.* The Little (Chester, Downingtown) valley was near at hand; the Great (Lehigh, Berks county, Lebanon, Cumberland) valley was far away in the interior of the State, among the Indians and the mountains.

The Lancaster plain was popularly called the *Conestoga valley*, of which the *Pequea valley* was a subdivision, and was known to extend beyond the Susquehanna river as the *Codorus valley* of York county.

These were the gardens of the new State, which made the market of Philadelphia the finest in the world.

The *Great valley* of Pennsylvania derives its name not only for its unusual width but for its extraordinary length. Whereas the *Little valley* is confined to two counties, Chester and Montgomery, is nowhere more than three miles wide, and is bounded by ranges of land scarcely 300 feet higher than its floor—the *Great valley* has an uninterrupted course of 1000 miles, from Canada to Alabama. In Pennsylvania it has a course of 150 miles, is in some places 20 miles wide, and is bounded by mountain ranges 1000 feet high.

Levels above tide of the water ways.

It is transversely crossed by all the principal rivers of the middle Atlantic seaboard—by the Hudson at Newburgh, by the Delaware at Easton, by the Schuylkill at Reading, by the Susquehanna at Harrisburg, by the Potomac at Harper's Ferry, by the James in middle Virginia, and in southern Virginia by the New river, which flows the other way, westward, under the name of the Great Kenawha, into the Ohio.

These rivers enter the valley by gaps in the North mountain, and leave it by gaps through the South mountain ; and while crossing it are bordered by hills two or three hundred feet high; or in other words, the water channels of the rivers are sunk that much beneath the average level of the general floor of the valley, showing a remarkable uniformity in the structure of the valley for several hundred miles. It is only towards its far northern end that it is cut through down to tide level, by the Hudson river.

The *Delaware* enters the valley at the Water Gap at 300′ A. T. and leaves it at Easton at 150′ A. T.

The *Lehigh* enters it at about 370′ A. T. and then flows sidewise eastward into the Delaware at Easton.

The *Schuylkill* enters it at Port Clinton at 400′ A. T. and leaves it at Reading at 180′ A. T.

The *Swatara* enters it at about 450′ A. T. and then flows sidewise westward into the Susquehanna.

The *Susquehanna* enters it four miles above Harrisburg at about 300′ A. T. and leaves it at Columbia about 250′ A. T.

The *Potomac* enters it at about 300′ A. T. and leaves it at Harper's Ferry at about 250′ A. T.

To put this in tabular form :*

	Potomac.	Susquehanna.	Swatara.	Schuylkill.	Lehigh.	Delaware.
North Mountain, ...	300′	300′	450′	400′	370′	300′ A. T.
South Mountain, ...	250′	250′	. . .	180′	. .	150′ A. T.

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* For all these levels see Report on Levels, N, 1878.

It is plain to see that the three great rivers which drain a large portion of four states, Virginia, Maryland, Pennsylvania and New York, have cut the deepest channels; and that all three enter the Great Valley at exactly the same level, 300′ A. T.; while the smaller intermediate rivers, Lehigh, Schuylkill and Swatara, have cut down only to 370′, 400′ and 450′.

From the Delaware to the Susquehanna water gaps in the North mountain the distance (in a straight line) is just 100 miles.

From the Susquehanna to the Potomac water gaps (in a straight line) is 75 (but by the curve of the North mountain 85) miles.

From the Potomac to the James river water gaps, the valley of Virginia is straight for 160 miles, and instead of being crossed by intermediate rivers, is drained lengthwise, northward, into the Potomac, by the Shenandoah river 120 miles long.

The various sections of the Great Valley are drained by large streams flowing from divides both ways to the transverse river channels; thus: (1) The Little Lehigh *eastward* into the Lehigh and so into the Delaware; (2) Antilauna (Maiden) creek *westward* into the Schuylkill; (3) Tulpehocken creek *eastward* into the Schuylkill; (4) Swatara creek *westward* into the Susquehanna; (5) Connedogwinit and Yellow Breeches creek *eastward* into the Susquehanna; Conecocheague creek *westward* into the Potomac.

Kearneysville, B. & O. RR.	Potomac at Harper's Ferry.	*Divide* near Shippensburg.	Susquehanna at Harrisburg.	*Divide* at Prescott, near Lebanon.	Schuylkill at Reading.	Schuylkill at Maiden Creek	*Divide* on Lehigh Co. Line.	Lehigh at Allentown.	Delaware at Easton.
589′	250′	783′	310′	501′	200′	270′	485′	230′	150′

The divides at the heads of these lateral or in-valley streams represent the *general level of the whole floor of the valley* across the state; and the levels of these divides are indicated by the summit stations of the various railroads which, together, make a continuous line of traffic from end to end. See table at the foot of last page.

By this showing the floor of the Great Valley is lower between the Delaware and Susquehanna, than between the Susquehanna and Potomac. But it must be remembered that railroads follow depressions, and seek the lowest place on a divide; and that from Harrisburg to Newville (30½ miles) the Cumberland Valley railroad grade reads: 322′, 357′, 436′, 427′, 458′, 477′ (at Carlisle) and 533′, mostly on a pretty level limestone plain. In the next eleven miles it rises to 654′, and suddenly then to the "summit" 783′; falling again at Chambersburg to 618′ and at Greencsstle to 585′. So that in reality we may feel safe in assuming a general level of the floor of the valley across the whole state, as traversed by the lines of railroad, at about 500′ A. T.*

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* A line of levels carried along railway lines from Sandy Hook via Hagerstown, Md., Grafton, Va., Athens, O., Mitchell, Ind., to St. Louis (published in Coast Survey Report for 1882, page 521+, with a map of the route, page 557), fortunately for our present purpose, follows the Great Valley from Easton, through Allentown, Reading, Lebanon, Harrisburg, Carlisle and Chambersburg to Hagerstown, and then ascends the valley of the Potomac on its way west.

Easton. (No. XIX) Cut on one of the central piers of the RR. bridge across the Lehigh river, 214′ above mean sea level.

Easton. (XX) Cut W. corner of jail, on foundation stone, 357.5′.

Easton. (H) Sill of blind window, E. side of court house, 363.5′.

Allentown. (I) Cut on sill of basement window S. side of front entrance of jail, 321′.

One and a half miles W. of Allentown. (XXI) Cut on N. W. corner RR. bridge over wagon road, 295.5′.

One-half m. W. of Macungie station. (XXII) Cut on top stone, N. side RR. bridge over small run, 383.5′.

Reading. (J) Cut on coping stone, E. abutment of N. E. RR. bridge at RR. depot, 264′.

One-quarter m. E. of Shamrock station. (XXIII) Cut on N. E. corner RR. bridge, 424.5′.

One-eighth m. E. of Robesonia station. (XXIV) Cut on pier of small bridge, 432.5′.

But the lines of railroad connect the principal towns of the valley; and these have all been built on the most fertile and smoothest part of the valley floor, viz: its southern belt composed of limestone soil; and it is to this belt alone that the above average of 500′ A. T. applies; its northern belt is rougher and higher.

The two belts.

The Great Valley is divided geologically lengthwise, from end to end, into two belts of country; one, next the North mountain, a *slate belt;* the other, next the South mountain, a *limestone belt.* The line of separation in some places runs for miles remarkably straight; in other places it is remarkably crooked; but along the whole course it may be called the middle line of the valley; the slate region being to the north and west of it; although occasional streaks of limestone appear in the slate belt, and occasional patches of slate in the limestone belt; but the relative proportions in width vary, the slate belt being nearly everywhere the wider of the two, and in parts of the valley twice or even three times as wide as the limestone belt. In Cumberland county, however, the limestone belt is a little wider than the slate belt.

One and a half m. W. of Womelsdorf station. (XXV) Cut at E. end of base of N. wall of overhead bridge RR., 483.5′.

Lebanon. St. Mary's Catholic church. (XXVI) Cut on S. side of southernmost front entrance; centre of cross, on white marble block, 474.5′.

Lebanon. (K) Bottom of square hole in top of marble post in ground of Mr. P. L. Weiner, S. E. corner Eighth and Chestnut streets, 465.5′.

One and a quarter m. W. of Annville. (XXVII) S. W. corner RR. bridge over Joe Crider's dam, 405′.

Swatara bridge (RR.) (XXVIII) Cut on stone parapet between Beaver and Hummelstown station, 367.5′.

Harrisburg. (XXIX) Centre of top surface of monument in capitol grounds, marking astron. stat. coast survey, 356.5′.

(L) Cut at base of pillar at S. E. corner capital building, 367.5′.

Carlisle. (M) Cut on base of column at W. side of jail entrance, 472.5′.

Shippensburg. (XXX) Cut on water table of house and store of W. C. J. Reddig, N. W. corner Main and Railroad streets, 654′.

Chambersburg. (N) Cut on pedestal at base of N. pillar of court house front, 620.5′.

Greencastle. (XXXI) Center of cross cut in stone in front wall of RR. depot, 7″ above sidewalk, S. of entrance, 588 5 .

Hagerstown. (A) Cut on water table of court house, corner Washington and Jonathan streets, on Jonathan street side, 552.5′ = 168.3402 meters, The *Slate belt* has an average general level about two hundred feet higher than the limestone, say 700′ A. T. This is strongly marked all the way from the Delaware river at Belvedere, to the Schuylkill river at Leesport, by a steep hill-slope down from the higher slate floor of the valley to its lower limestone floor; and this step in the surface is made more remarkable by narrow openings or ravines from which issue numerous small water courses heading in the recesses of the slate land, and at the foot of the North mountain.

This elevated terrace-like edge of the slate belt continues, although in less regular style, through Berks into Lebanon county; can be recognized in Dauphin and Cumberland counties; but gradually becomes less conspicuous in Franklin county. There is no mistaking, however, the greater relative height of the slate belt everywhere along the Great valley.

The distinction is emphasized moreover in all cases where *limestone coves* invade the slate belt, and where *slate ridges* traverse the limestone belt. It is evident to the most indifferent spectator that the surface of the limestone land lies naturally lower than that of the slate land,* but a clear exhibition is made of it by the contour-line maps of Lehigh and Northampton counties published with Reports of Progress D, D^2 and D^3. These maps show the relative levels of the whole limestone belt of the valley, of the edge of the slate belt, and of the slopes of the South Mountains, all the way from the Delaware to the Schuylkill rivers.†

No *contour-line surveys* of the Slate belt have been made anywhere along the valley; and until such surveys have been made and a continuous contour-line map of it has been

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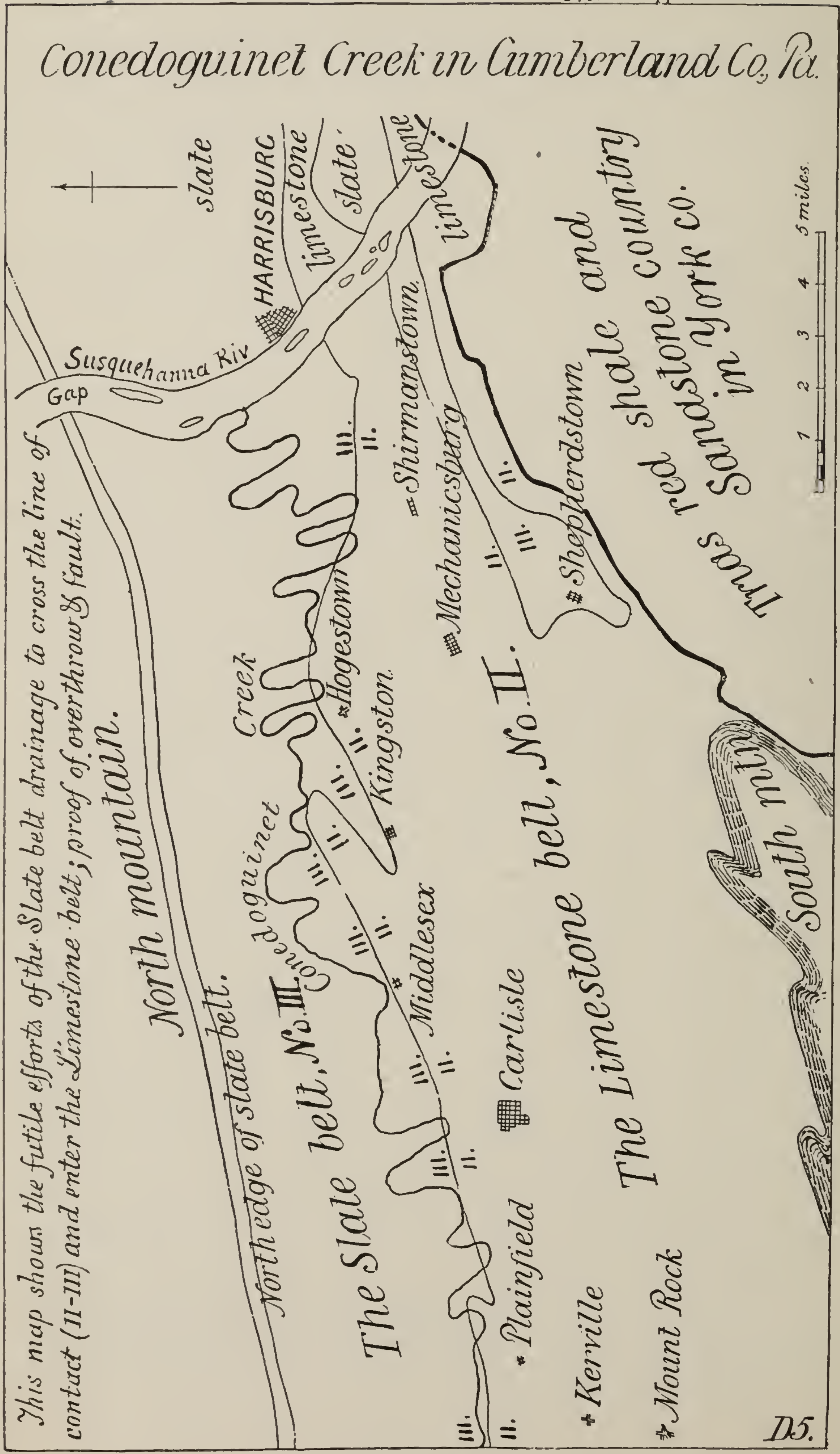
* The reason for it will be given further on, in connection with the underground cavernous condition of the limestone belt.

† It is evidently desirable that the Legislature should provide means for continuing this topographial survey westward across the Susquehanna river to the Maryland line.

In Franklin and Cumberland counties the South Mountains have been elaborately surveyed in the same manner, and down their western slopes to the south border of the limestone belt; but the means of the survey were to olimited to bear the expense of carrying the work across the limestone land to the edge of the slate land.

Ch. XXII, plate 1.



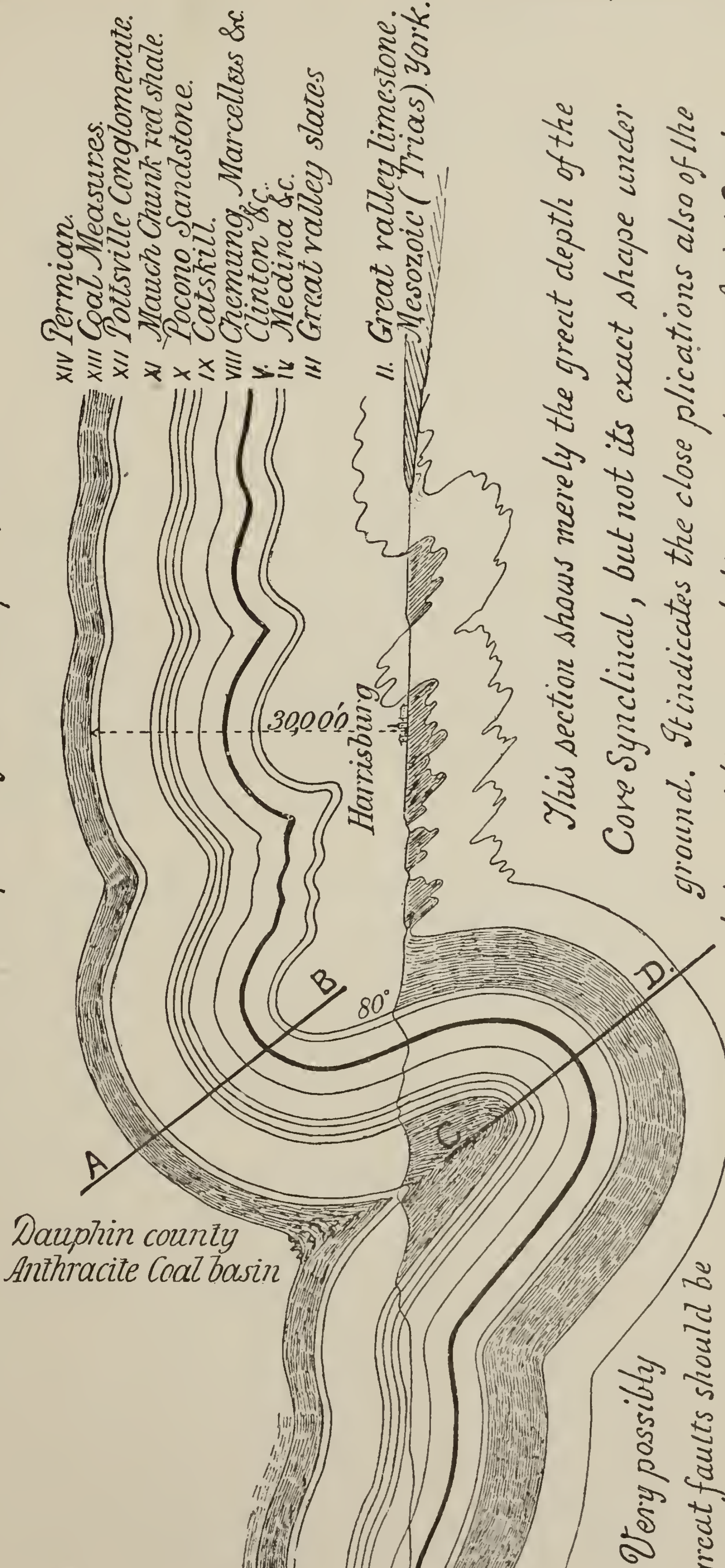
Conedoguinet Creek in Cumberland Co, Pa.

This map shows the futile efforts of the Slate belt drainage to cross the line of contact (II-III) and enter the Limestone belt; proof of overthrow & fault.

Ch. XXII, plate 2.

Hypothetical Palæozoic Section across the Great Valley at Harrisburg.

To illustrate Chap. XXII of Final Report, 1891.



This section shows merely the great depth of the Cove Synclinal, but not its exact shape under ground. It indicates the close plications also of the slate and limestone belts; and the vast Aerial Erosion.

Very possibly great faults should be placed along lines AB, CD.

D5.

executed, no entirely accurate knowledge of its geological structure can be obtained. We know, however, that it is everywhere very much crumpled into narrow folds; and that some of these folds are so sharp that the limestone formation everywhere underlying it comes occasionally to the surface.

The north edge of the Slate belt is high up on the slope of the North mountain; in fact the outcrops of the top layers of the formation run only one or two hundred feet beneath the crest of the mountain.

Synclinal mountains of IV in III.

The upper part of the Slate formation is coarser or more massive than the lower part, and in some places contain pebbles in such abundance as to become conglomerate rock. Therefore, as in some places along the south edge of the slate belt the underlying limestone comes to the surface along the middle line of an uncommonly sharp and strong *upfold*—so in some places along the north edge of the slate belt the upper and coarser slates have been preserved along the middle line of an uncommonly sharp and deep *down-fold.*

In two notable cases even the Medina sandstone No. IV has been thus preserved; and this is the explanation of *Hole mountain* in Lebanon county, and *Parnell's Knob mountain* in Franklin county—both of them standing out in front of the North mountain. (Plate, page 285.)

Hole mountain in Lebanon county is a ridge five miles long ending at the Swatara river. Its top is a V-shaped pinched stripe of the sandstone No. IV, held in a vice of upper slates. Along the banks of the Swatara the slates can be seen going down in front of it and coming up behind it, and then going down again under the North mountain.

Parnell's mountain, in Franklin county, is of precisely the same character, but longer, and produced by a deeper down-fold (synclinal) of the slate belt. It is 10 miles long and entirely cut off from the North mountain behind it by the narrow straight upfold (anticlinal) of Bear valley. The down-fold is so deep that a regular canoe of the sandstone

No. IV has been preserved, its two crests being separated by a middle groove in which lie some of the lowest soft layers of the Clinton red shale formation No. V.

In studying *Hole mountain* we make a first step towards understanding the geology of all Middle Pennsylvania; in studying *Parnell's mountain* we make a second step; and if we consider Jordan's Knob behind it, we take the third step. For the North mountain here (at Loudon) doubles back upon itself (see page plate) and after zigzaging around Horse valley, Amberson's valley and Path valley, comes back to Loudon and runs on, as if nothing had happened to divert it from its course, into Maryland. But all these zigzags represent high upfolds and deep downfolds in the slate formation No. III which underlies the mountain everywhere; and not only in the slate formation No. III, but in the limestone formation No. II which lies still deeper everywhere under the slate; for along the middle of *Amberson's valley* and *Path valley* the underlying limestone has been brought up and bared at the surface; while the steep, dipping slates are confined to the side hills and to the steep mountain slopes.*

Anticlinal belts of limestone in the slate.

The great upfold (anticlinal) of *Path valley* runs on from Loudon southward bringing to the surface in front of Cove mountain a narrow belt of limestone.

The upfold of *Bear valley* runs on also, by Bridgeport, Mercersburg and Simpstown, and brings to the surface another long narrow belt of limestone. Between these two parallel limestone strips runs a strip of slate, preserved in the downfold (synclinal) of *Jordan's Knob.* The Loudon and the Mercersburg strips of limestone terminate in two coves at the Maryland line, the Punchbowl (or Corner), and Blair's valley; and these two coves lie between Cove mountain and two mountain spurs in Maryland (Two Top mountain and Casey's knob) which exactly correspond to Jordan's knob and Parnell's knob

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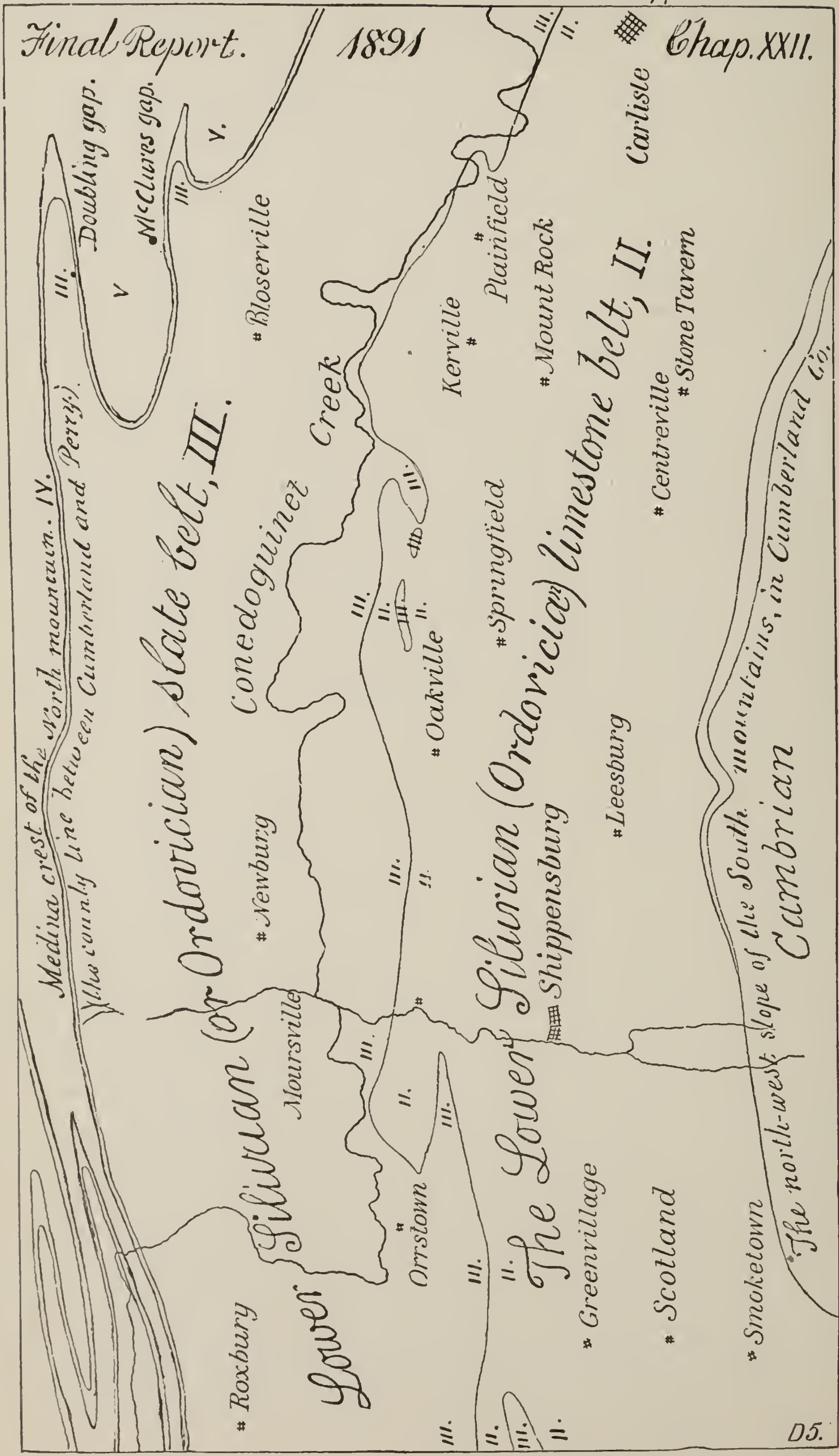
* Along the north side of Path valley runs a great fault, so that the underlying limestone has slipped up against the upper slates on the mountain side.

Ch. XXII, plate 3.

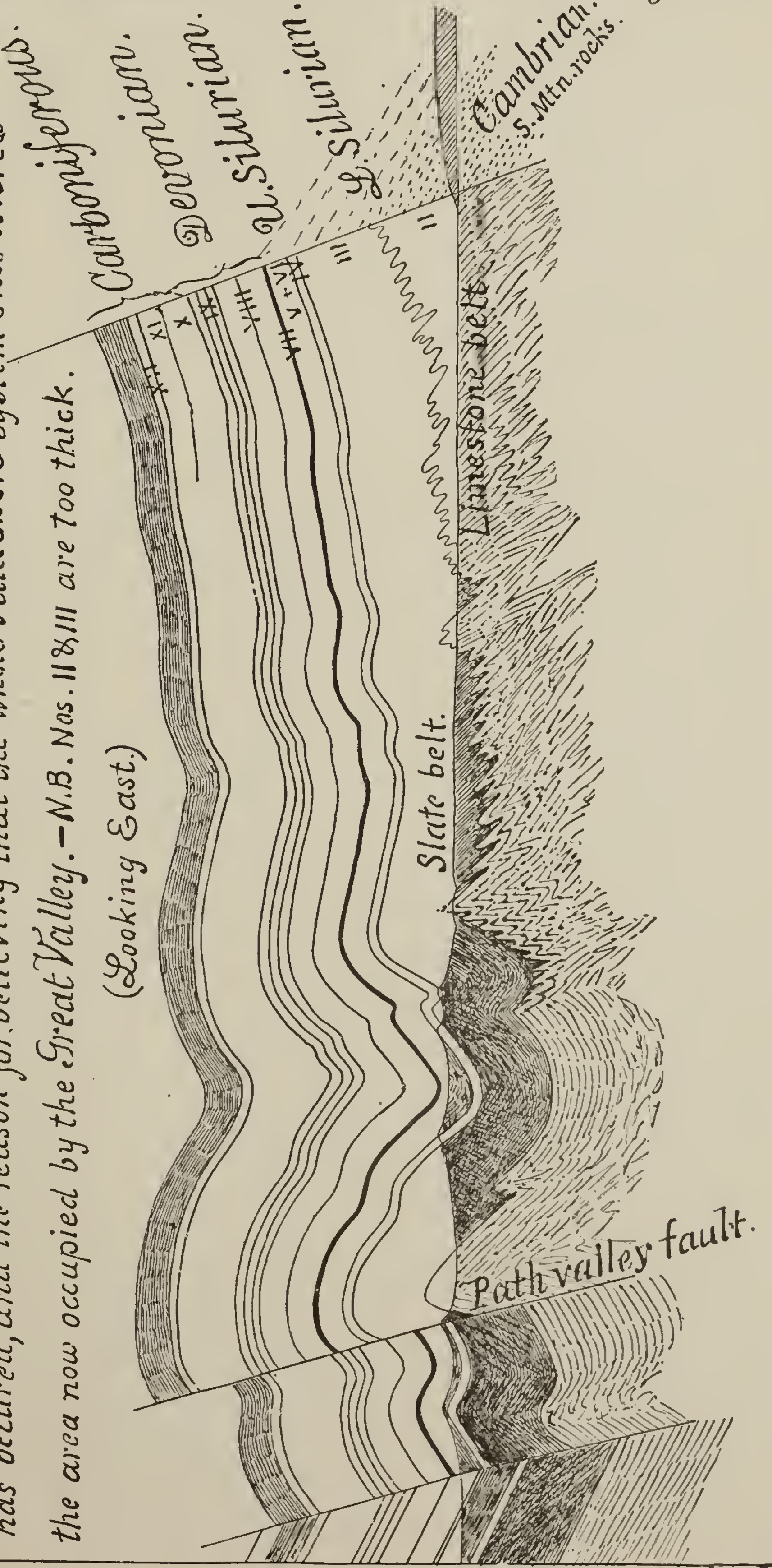


Ch. XXII, plate 4.

Cross section of the Great Valley from near Cowan's Gap south through Scotland to the South Mountain in Franklin County, Pa.

This cross section is geographically accurate; the topographical elevations are on a true scale; but the geological Subdivisions are merely indicated to show the amount of Erosion that has occured, and the reason for believing that the whole Palæozoic System once covered the area now occupied by the Great Valley. —N.B. Nos. II & III are too thick.

(Looking East.)



D5.

towards which they look, the distance being about 14 miles. Blair's valley is the easternmost of the two coves, and corresponds in all respects to Bear valley between the Jordan and Parnell's knobs.

The geology of this part of Fayette county is beautifully simple, symmetrical and instructive. It is rendered still more instructive by the following particular:

A third upfold (anticlinal) runs in front of Parnell's mountain, and brings to the surface *in the slate belt* the underlying limestone in a third long narrow slip, which starts at a point at Strasburg, and is crossed by the Chambersburg pike just west of St. Thomas, where it is 1½ mile wide. After passing St. Thomas southward this strip of limestone becomes nearly 5 miles wide at the Greencastle-Mercersburg pike, and so passes on into Maryland. The slate belt, which is seven miles wide at Newville in Cumberland county, 6 miles wide at Chambersburg in Fayette county, is thus narrowed to 3 miles at Welsh run and the Maryland line; the main limestone belt 13 miles wide bordering it on the east, and the Welsh run limestone belt 4 to 5 miles wide bordering it on the west.

This widening of the *Welsh Run limestone belt* southward from St. Thomas might have been produced in two ways; it was actually produced in a third way exactly consistent with all that has just been said. (1) It might have been produced by a swelling upward of the *Strasburg anticlinal* after passing south by St. Thomas; or (2) it might have been produced by a flattening out of its dips on both sides; but it actually was produced (3) by two other additional anticlinals running alongside of (in front or east of) the Strasburg upfold;—one, which may be called the *St. Thomas anticlinal*, brings up a strip of limestone south of St. Thomas;—the other, the *Rock Spring anticlinal*, which brings up a little prong of limestone 3 miles S. of St. Thomas, and after crossing the slate belt obliquely produces the Rock Spring limestone cove 3 miles N. of Chambersburg.

These three up-folds in the slate belt of middle and northern Franklin combine to keep the limestone up to the surface along the *Welsh run belt* near the Maryland line.

Limestone coves in the slate belt edge.

The limestone indentation in the edge of the slate belt at Rock Springs is about 3 miles deep. (Plate, page 285.)

Another similar indentation of limestone in the southeast edge of the slate belt occurs at Fairview and Middle Spring on the Cumberland county line (page plate). Both these indentations point southwest, showing that the *anticlinals* which upheave the underlying limestone through the slate *sink in that direction.*

Another indentation is shown upon the map at Newville in Cumberland county, but it points northeast. Newville is built in this little limestone cove and has slate hills all round it except to the west. The outlines of slate show a downfold (synclinal) running just south of the village.

Another very little indentation in the south edge of the slate belt is made at Plainfield, 4 miles west of Carlisle, and the arrows on the map along the creek here show that the prong of slate is a true synclinal.

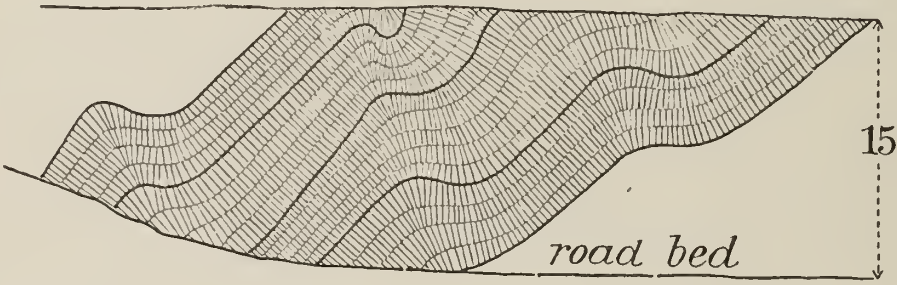
Another very pretty indentation of limestone in the slate belt, two miles long and pointing (like the last two) eastward, lies back (north) of Kingston, six miles east of Carlisle. Here the arrows on the map instead of explaining the facts are very confusing, all of them pointing south at various angles. The cause of this will be explained hereafter, but it may as well be mentioned here that most of these upfolds (anticlinals) and downfalls (synclinals) are not only squeezed tightly together, but so bent over northward (as if by a pressure from the South mountains) that the strata which *ought to dip north* dip south, and cannot therefore be easily separated from those which *ought to dip south.* In other words, one-half of the south dipping strata are in reality *overturned* and lie with their upper faces downwards.

Another limestone cove in Cumberland county runs up into the south edge of the slate belt in the opposite direction (northeast) behind the long prong of slate which points out half a mile west of Kingston along a deep downfold (synclinal) in the limestone belt. (Plate, page 276.)

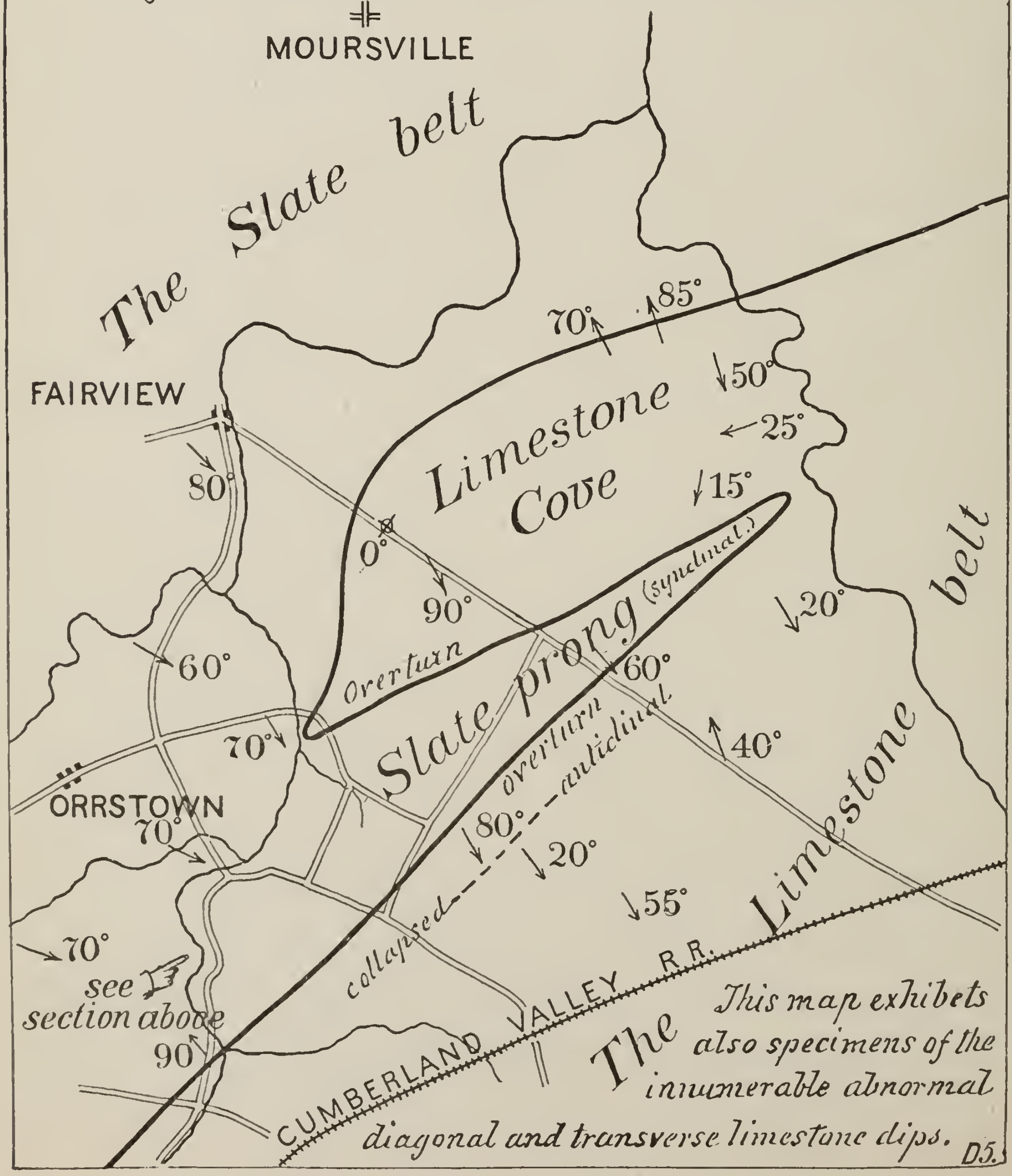
No such interruptions of the south edge of the slate belt

Ch. XXII, plate 5.

Specimen section of waves in Great Valley limestones.
To illustrate Chap. XXII of Final Report, 1891.

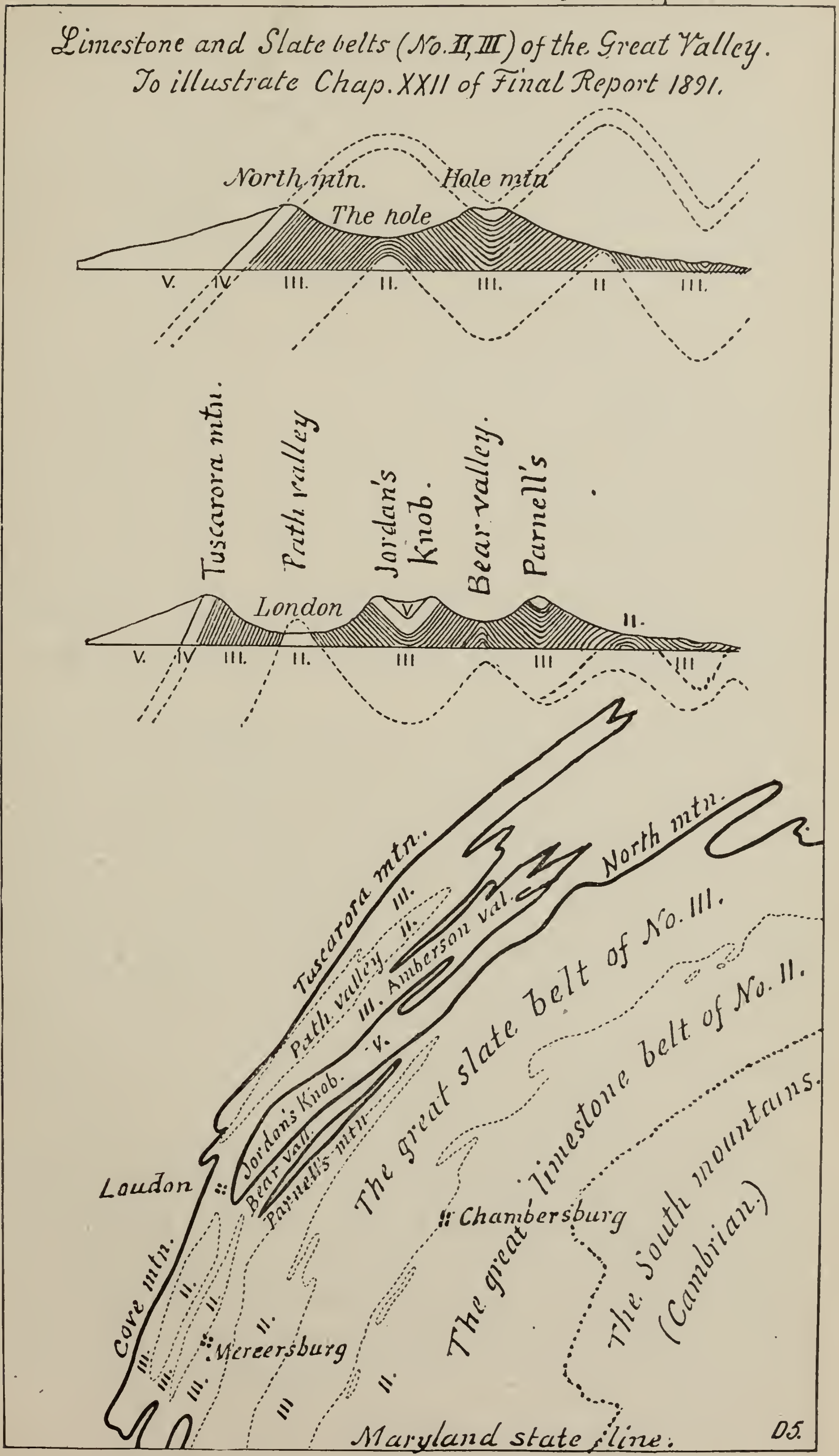


Specimen of anticlinal Coves of II, and synclinal Prongs of III, along the center line of the Great Valley, Cumberland.



This map exhibets also specimens of the innumerable abnormal diagonal and transverse limestone dips.

Ch. XXII, plate 6.



Limestone and Slate belts (No. II, III) of the Great Valley.
To illustrate Chap. XXII of Final Report 1891.

occur in Dauphin and Lebanon counties. In Berks county, approaching the Schuylkill, they become very numerous, but produce a state of things geographically so curious and important as to require a special description. East of the Schuylkill the edge of the slate alternately advances upon the limestone and retreats from it in a series of small irregular curves which scarcely disturb the straight line of the contact; but there is a decided cove at Moselem, and another at Kutztown, both pointing west; and together they broaden the limestone belt and contract the slate belt a trifle. At Monterey near the Lehigh county line, a cove points northeast.

In Lehigh Co. limestone coves back of slate prongs play a great *rôle* in the geography. One is produced by an anticlinal passing Trexlerville; another deeper one lies north of it; a third and very large one is that of Jordan creek; a fourth is the Ironton cove. All these point west, and have the effect of reducing the breadth of the slate belt on the Lehigh river to one-half of the breadth it has on the Berks-Lehigh county line.

In Northampton county the many irregularities in the face line of the slate belt are all of the nature of coves; but in no case are they shut in behind synclinal prongs of slate. But on the other hand we have here small *circuses of limestone completely enclosed in the slate belt, back of its edge*, anticlinal in their structure, and teaching the same lesson as the coves, viz: that the limestone formation No. II passes down (northward) underneath the slate formation No. III, and is here and there brought up through it to the present surface by upfolds or anticlinal waves.

Synclinal belts of III in II.

Prolong two limestone coves (one pointing east the other pointing west into the edge of the slate belt) until their opposite points meet, and you will have a strait of limestone between the mainland of slate and a long narrow island of slate in front of it; the strait of limestone being an anticlinal or upfold, and the island a synclinal or downfold, or basin.

Such basins of slate in the limestone belt are numerous enough to prove that the slate formation No. III originally entirely covered the limestone formation No. II.

In Franklin county one commences 3 miles South of Chambersburg and runs 4 miles, crossing the South Penn. RR. ½ mile from the Marion junction. The arrows near Marion point the limestone going down very steeply under the east edge of the slate strip. This slate strip is undoubtedly a closely folded downfold (synclinal).

The other is a similar little strip of slate half a mile west of Greencastle, a few hundred yards wide, a mile or so long, and separated from the edge of the slate belt by a strip of limestone only a few hundred yards wide. An arrow at its north end pointing east and three others along the railroad pointing west show that this little strip of slate also lies in a closely folded trough in the limestone.

Returning now to the eastern end of *Cumberland county*, the map shows the slate belt suddenly widening from 3 miles at Kingston and Hogestown to 5 miles at the Susquehanna river. Its edge makes a beautiful curve to the river at Bridgeport and Harrisburg. Part of this curve is a great fault, of which more will be said hereafter, the limestone country has been elevated and the slate country depressed; so that the Connedogwinet creek, however often it tried to break through the wall, was never able to do more than scoop little semi-circles from it at various points along the line; and this explains the remarkable loops of the creek.

In Dauphin county the edge of the slate belt runs on east nearly straight for seven miles to Beaver station on the Lebanon Valley railroad, the railroad between Harrisburg and Beaver keeping on the limestone. From Beaver across to the North mountain is all slate, and the belt is 8 miles wide and continues of that width into Lebanon county, its south edge being a very even line and nearly straight.

But between Beaver and the Swatara river towards Hummelstown there is a space of about a mile where the slate belt throws a projection southward over the limestone; and this projection turns west and forms a belt of slate land in the heart of the limestone belt, a mile or two wide, extending back 6 miles past Churchville to the Susquehanna at New Cumberland. The river flows across this slate belt 3 miles below Harrisburg.

At New Cumberland (on the west bank of the river) this slate belt is scarcely half a mile wide ; but it keeps on west, in a trough of the limestone, 8 miles, and ends in two blunt prongs one to the north and the other to the south of Shepherdstown. Before coming to an end it broadens out to a width of two miles, with such varieties of dip as to baffle all explanation. Only it is evident that this belt of slate overlies the limestone, and runs east and west about 12 miles, splitting the limestone belt into two ; just as the three slate belts of Southern Franklin county split up the limestone belt into four.

In Lebanon county the slate belt is unbroken by the appearance at the surface of any large appearances of the underlying limestone. Its width from Lebanon to the Swatara gap in the North mountain is 9 miles. Its south edge is quite straight as far as Lebanon ; there bending a little it runs almost straight into Berks county. The Union canal on the north side of Lebanon marks the contact of the limestone sinking beneath the slate. The line passes one mile north of Myerstown.

The limestone belt is 1½ miles wide on the Dauphin-Lebanon county line ; 5 miles wide at Lebanon ; 6½ miles wide at Shafferstown; and 6 miles wide at the Lebanon-Berks county line.

No strips of slate have been preserved on the limestone belt, except at its southern edge, where large tracts of slate may be supposed to overlie the limestone where everything is covered up by the comparatively recent Mesozoic Trias red shale formation, to be described further on.

The edge of one of these slate tracts extends for 4 miles at Cornwall, and is visible for a mile in width along the railroad to the mines.*

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*There may be some doubt about these slates being No. III. They may be the slates *beneath* the limestone.

Another semi-circular slate tract 2½ miles long (E. and W.) and 1½ broad (N. and S.) appears at Shaefferstown. The limestone dips beneath it all around its eastern, northern and western sides, there can be no doubt about its being a preserved portion of the slate belt, now separated from it by an eroded interval of just 5 miles. The south border of this patch is overlapped by the edge of the great Mesozoic (Trias) red shale formation of Lancaster county. How far south the slates extend under the red shale is not known; but no slates appear on the limestone in the Manheim, Ephrata and Conestoga valleys in Lancaster county south of the red shale.

In Berks county the slate and limestone belts of the Great Valley are so intermingled that no general description would be understood.* While the northern or main part of the slate belt runs to and across the Schuylkill, long prongs and strips of slate cross the limestone belt in the triangular enlargement of the Great Valley between Womelsdorf, Leestown and Reading; and long strips of limestone traverse the slate belt north of Womelsdorf and Bernville on the Union canal.

Southern edge of No. II.

Having thus traced the contact of the limestone and slate belts along the middle line of the great Valley from the Maryland state line to the Schuylkill river in Berks county, and pointed out the streaks of limestone coming up through the slate, and the prongs and ridges of slate still left uneroded on the limestone, in all four counties, it will be proper to describe the southern edge of the limestone belt, and show how essentially different it is in Franklin and Cumberland, from what it is in Dauphin and Lebanon.

The southern edge of the limestone belt in Franklin and Cumberland counties runs along the foot of the South mountains to their eastern termination 11 miles west of the Susquehanna river. Here it turns round the end of the

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* It can only be understood by an examination of the colored geological map of Berks county, made to accompany Report D3, Vol. III, which remains unpublished, except as one of the maps in the Hand Atlas Report X.

mountain southward and is immediately lost beneath the *Mesozoic Trias red shale.*

It is evident that the limestone of eastern Cumberland county and the limestone of middle Lancaster county are connected underneath the Trias red shale belt which separates them at the present surface by a breadth of more than 10 miles measured along the river.

Whether the Cumberland county limestone and the York county limestone are also connected underneath the Trias red shale directly across a distance of 17 miles, is less certain. The doubt arises from the possible underground connection of the South mountain rocks beneath Dillsburg, Rosstown and Liverpool with Chiques rock at Columbia.

If such be the case, we must draw *the edge of the underground limestone belt* from Yellow Breeches creek (2 miles north of Dillsburg) to New Holland at the bend of the river, and so on towards Lancaster city.

But, on the other hand, as we do not know what has caused the depression in which the Trias red shale was deposited, we cannot tell how deep it may be; consequently, we cannot tell whether or not the limestone in York county covers the South mountain rocks under the Trias red shale.

The main point is that, when the South mountains come to an end, *the limestone belt* becomes covered with *Trias red shale*, the north edge of which is of course the south edge of the *surface limestone belt* in eastern Cumberland, across Dauphin and nearly across Lebanon county. Not until we reach the eastern corner of Lebanon does the southern edge of the *surface limestone belt* rest again against South mountain rocks.

Here a small isolated mountain mass called *South mountain* in Lebanon county and *Mulbaugh's hill* in Berks county, separates the limestone belt to the north of it, from the red shale belt to the south of it in Lancaster and Chester counties.

East of Mulbaugh's hill the red shale laps around and again covers the south edge of the limestone as far as to the Schuylkill river below Reading.

East of the Schuylkill river the South mountain gneisses rise in the range of highlands, with the great valley of limestone at its north foot, and so continues through New Jersey and New York into New England.

Mulbaugh's hill at the corner of Lebanon, Berks and Lancaster counties is therefore an isolated piece of the highlands about 2 miles broad and 10 miles long, surrounded on the north by limestone and on the south by red shale; but *underground* no doubt entirely surrounded by limestone; for the limestone is seen going down under the red shale at both ends of it; and there is every reason to believe that the Trias belt south of it, which is not more than 6 miles broad at the west and 10 at the east, occupies a *buried limestone valley* of unknown depth.

We have then in Cumberland, Dauphin, Lebanon and Berks counties an extraordinary phenomenon, which has a most important bearing upon the river drainage of the whole Atlantic coast. The great range of the South mountains which otherwise extends continuously for many hundred miles, from its southern end in Georgia to its northern end in New England, is here broken by a gap 60 miles wide, *i. e.* from Dillsburg in York county to Reading in Berks county. A great gateway through which the greatest river of the coast (the Susquehanna) drains the back country into the greatest bay of the coast (the Chesapeake); and the breadth and depth of the bay correspond to the area and volume of the river, which has been filling it during all the ages since the Coal. And in this gateway stands a pillar (Mulbaugh s hill) to mark the continuance of the range *underground.*

Relation of the South Mountain uplift to No. II.

Had it not been for this remarkable break in the South mountain-Blue Ridge-Highlands range of the Atlantic seaboard region of the United States, it might have been supposed that the limestone formation No. II was deposited in a sea, the southeastern shore of which lay at the northwestern foot of the South mountain range, then in existence. But the South mountain range was *not* then in existence.

The sea extended to that part of the surface of the globe now covered by the Atlantic ocean.

This fact is made known in several ways:—(1) By the great thickness of the formation at the foot of the mountain range; (2) by the existence of faults along the foot of the mountain range; and of course faults presuppose the spread of the formation southeast of the faults; (3) by the appearance of the limestone formation in valleys between the parallel ridges of the mountain range; for such limestone valleys can only represent fragments of the general limestone outspread preserved in deep troughs; (4) by the appearance of the limestone along the southeastern foot of the mountain range; as, for example, in southern Berks and Northampton counties, in New Jersey and New York; (5) by large areas of the limestone formation between the South mountain and the present Atlantic coast; as, for example, in York, Lancaster, Chester and Montgomery counties; but chief (6) by the great expanse of the formation (both covered and not covered by Trias red shale), through the 60 mile opening in the range above described, far away towards Maryland.

The numerous relics of the limestone formation No. II, preserved as small isolated areas, in southeastern Pennsylvania, taken in connection with the isolated areas remaining in the heart of the mountain range, suffice to prove that it originally extended in an unbroken sheet, and probably in a nearly horizontal attitude, over all the United States and Canada; and that it probably now underlies the Cretaceous and Tertiary belt of the Atlantic and Gulf States, and perhaps the whole of the Atlantic ocean, the Gulf of Mexico and the Caribean Sea, covered of course by less ancient Palæozic, as well as by Mesozoic and Kainozoic formations.

It follows that the uplift of the South mountain must be later than the limestone and slate formations of the Great Valley. The date of the birth of the range can even be fixed with a near approach to truth. Its upheaval seems to have been in some sense the cause of the folding of all the formations of middle Pennsylvania of the more gentle waves in western and northern Pennsylvania, and southern New York, and of the great faults of Virginia and Tennessee.

Now, as these foldings and faults affect the Coal measures No. XIII at the top of the series, just as seriously and in precisely the same manner as they affect the lowest formations of the series, the sandstone No. I, the limestone No. II, the slate No. III, the sandstone No. IV, &c., the folding action must have taken place after the Coal measures had been deposited. On the other hand, the Mesozoic (Trias) red shale formation next following in age the Coal measures lies quietly, as we have seen, over the upturned edges of the older series, and therefore the folding action must have begun and ended in the interval of time between the deposite of the last Coal measures (Permian of Green county) and the first or bottom beds of the Mesozoic strata which we see lying sometimes upon the gneiss, sometimes on No. I, sometimes on No. II, along a line east and west of Norristown in Montgomery county and elsewhere.

If the folding action was produced by a push of the whole Atlantic coast region northwestward—as it evidently was—for there is a general overturning of the tops of the folds in that direction—the push must have been connected with the rise of the whole range of the South mountains from its northern to its southern end; for the folded country is a thousand miles long by five hundred broad; and the immense height of the upfolds (anticlinals) and depth of the downfolds (synclinals), *amounting variously to 5 miles vertical*, shows that nothing less happened than a *shifting back of the whole Atlantic belt of the earth's crust northwestward a distance of at least 40 miles.*

The mountains thus created were evidently as grand as any more recently produced in any part of the world, the Andes and the Himalayas for example. But these consist of the last deposits of the ocean, and have so lately ascended into the air that, although their destruction is going on with great rapidity, many of their summits are still more than five miles high. Whereas, a like process of destruction has been diminishing our old Pennsylvania mountains for many geological ages, so that not a trace is left of their original magnificence; the edges of a few of the harder formations make continuous ridges and these not more than 1000 or 2000 feet above the general surface of the low lands.

CHAPTER XXIII.

Why is there no coal in the Great Valley?

The answer to this often asked question is easy, short and practical:—*No coal beds can be found in the Great Valley because the Coal Measures which once covered the region have all been swept away into the Atlantic Ocean.*

The geological structure of the Great Valley, taken as a whole, is simple and easy to understand. It has large features not to be misunderstood; in fact visible at a glance upon the colored geological map of the State, where a band of blue (limestone) and a band of gray (slate) run side by side its whole length across the State.

I will recapitulate in a few short sentences the principal points of the last chapter so that they may be kept in mind.

1. The *South Mountain sandstone* (*No. I*) is older than the limestone formation in the valley, and passes down under it to make a foundation for the whole valley and for all Pennsylvania, New York and Ohio to the northwest of it.

2. The *limestone strata* (*No. II.*) are older than the slates of No. III, and of course underlie the slate belt; except where the slate belt is thin and worn away, letting the underlying limestone appear in the coves. The whole limestone belt was once covered by the slate formation. As the cleaning away of the slate from off the limestone belt has been always going on, and is still going on, only isolated patches of the lowest part of the slate formation remain here and there on the limestone belt.

3. The *slate formation* (*No. III.*) is older than the North mountain sandstone and passes under it northward.

4. The North Mountain sandstone (No. IV.) descends in its turn, northward, beneath the formations of Pike, Monroe, Carbon, Schuylkill, Perry and Fulton counties.

We shall see in suceeeding chapters how formations II, III, IV rise several times to the surface in middle Pennsylvania; every time making a limestone valley surrounded by a slate belt and by a mountain like the North mountain. Then we shall see them plunging vertically to a great depth beneath the Allegheny mountain, along the top of which runs the first bituminous coal basin. Here we see all the formations from IV to XIII piled upon them. In Huntingdon county all the formations from IV to the Broad Top Coal measures (XV) are piled upon them. Even close by the Great Valley, in Dauphin, Schuylkill and Carbon counties, all the formations from IV up to the top of the Anthracite Coal measures (XVII) remain piled upon them ; the limestone No. II lying at the enormous depth of 30,000 feet beneath the city of Pottsville.

Just as we see along the Little Juniata all the formations from XIII in the Allegheny mountain to IV in Bald Eagle mountain rising (southeastward) one after the other to make an arch five miles high in the air over the Nittany limestone and slate valley, and then descending (southeastward) one after the other in Tussey and Terrace mountains beneath the Broad Top coal field—just so we see the whole pile of formations from XII to IV coming straight up from the underworld in the Sharp mountain, Second mountain and North mountain to make a similar great arch in the air over the slate and limestone belt of the Great Valley .

But as the great arch over Nittany Valley has all been swept away, and it is useless to seek for coal at the present surface anywhere between the Cambria and Clearfield coal mines and the Broad Top coal mines, so the arch over the Great Valley has been swept away and it is useless to seek for coal south of Sharp mountain in Schuylkill and Dauphin counties.

The coal measures have been swept away from the Great Valley many geological ages ago ; and we know by long experience that there are no workable beds of coal in any of the pile of formations beneath the coal measures, except one bed in No. X at Duncannon, and that is worthless, and has been swept away (with the rest of the rocks) from the Great Valley.

To illustrate what has been stated above in a few words I insert two cross sections which will speak to the eye better than any words :—

Section through Harrisburg (page 277, plate 2) from Duncannon at the mouth of the Juniata, down the Susquehanna to Columbia; and

Section across Franklin county (page 281, plate 4) from Path Valley mountain, through Scotland to the South mountains.*

The practical importance to the farmers of the Great Valley of knowing these facts and understanding the above statement is evidently considerable. Why should they waste time and money in digging for coal where it cannot possibly exist?

There is not a trace of a coal bed left at any point in any county along the whole course of the Great Valley between the Hudson and the Potomac; nor in Amberson's valley and Path valley which lie behind the North mountain in Franklin county; nor in the Fishing creek Trout run Pine Grove valley in northern Dauphin and Lebanon counties.

All reported discoveries of coal beds are mistakes which a few words will suffice to explain.

Along the center line of the Great Valley, between the limestone belt and the slate belt, the black *Utica slate formation*, *IIIa*, crops out, always thin, and often absent. In other words, the bottom rocks at the southern edge of the slate belt are often as black as the black slate of a coal bed, and have deceived many persons into digging for coal. When weathered down they make the black clay which is so conspicuous in the great Ironton iron mines of Lehigh county, and the Moselem mine of Berks county. They make a black soil at other places along the lines of junction of the slate and limestone lands. But no impressions of coal plants are ever seen in these Utica black slates. But occasionally impressions of *graptolites* may be observed on them, looking like lead pencil marks on paper; some of them are merely forked lines; some of them look like the

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* These sections have been carefully constructed on a scale of 4 miles to 1 inch from observed outcrop dips in the Great Valley and to the north of it so numerous that no material error can be imagined in the general shape of the arch in the air over the Great Valley.

edge of an open umbrella; others like holly leaves. They are the remains of curious little animals which swarmed at the surface of the ancient sea; and they were so numerous that their dead bodies darkened and even blackened the mud which afterwards was hardened into slate rock. These graptolite slates are exposed to view in the horse shoe bends of Connedogwinnet creek in Cumberland county.

Discoveries of coal are reported from time to time by people living *in front of the North mountain*, on its foot slopes. Pieces of *so called coal* are frequently found lying on the surface or are knocked out of the exposures of dark slate; for example, near Mercersburg and Loudon in Franklin county. But these pieces are not indications of the existence of a workable coal bed. They are merely black shale layers in the upper part of the slate belt (*Hudson river slate formation IIIb*,) charged with the animal carbon of dead *graptolites* and *trilobites* (water bugs) which lived in immense numbers in the waters of that age.*

Discoveries of coal have also been reported from *behind the North mountain* in Lebanon county, along a narrow belt of the Marcellus formation (VIII*b*) which runs entirely across the state into the southern states, and zigzags through many of the valleys of our middle counties. It is a narrow belt of outcropping black-slates very much resembling the black-slates which cover coal beds in the coal regions. But it is *slate* and not *coal*. People who see it in a hillside in the form of a regular bed, and very black, looking a good deal like the outcrop of a coal bed, think that it is merely the bad edge of a good coal bed. They who try to burn a piece of it in a blacksmith's fire find that it will blaze a little at first and then remain red hot and throw out a good deal of heat; but when they take the piece out of the fire, it is nothing but a stone. This however does not discourage them; there are plenty of wandering miners seeking a job who assure them that if they will "go down on the bed" it will turn to good coal. In almost every county in the state

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* The chemical analysis of a specimen of this deceptive kind of coal, found back of Mercersburg in Franklin county, will be given in a subsequent chapter, where the rocks of the slate belt are described.

lying between the North mountain and the Allegheny mountain considerable sums of money have been wasted in sinking shafts and drifting tunnels into this belt of *Marcellus black slate* during the last fifty years, but no valuable coal bed has ever been obtained.*

CHAPTER XXIV.

The Great Valley Limestone No. II.

Having described in the last chapters the general topographical and geological features of the Great Valley, I shall give in this and following chapters descriptions of its two principal formations in sufficient detail to make them understood :—(1) the limestone beds in the Lehigh region; the quarries between the Schuylkill and Susquehanna; the quarries west of the Susquehanna;—(2) the slate belt with its roofing slate quarried in the Lehigh region; and its clay-limestone beds on the Susquehanna.

The reader will thus be prepared for a description of these formations where they have been preserved in synclinal basins in Chester, Lancaster and York; and where they are brought up to the present surface by anticlinal waves in Fulton, Perry, Juniata, Mifflin, Bedford, Blair, Huntingdon, Centre, Clinton and Lycoming counties.

The exhibition is so great, the wealth of observations so over-abundant, that the most condensed summary of the facts published in the reports of the survey will seem to need some apology for its length. But it is an embarass-

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*In Perry and Juniata counties thin streaks of very slaty Marcellus coal cross the bed of the Juniata river, and much money was formerly wasted in following them into the hillside; all money thrown away. Peoples' experience of Marcellus black slate mining in other states has always been the same.—I have added this instance of deceptive coal prospecting, because it is of importance to the citizens of Lebanon and Dauphin counties in the Great Valley. It will find its place again in a future chapter on the Marcellus formation.

ment of riches. I can only strive to classify the subjects properly, and avoid repetitions.*

Subdivision of No. II.

In New York state No. II is subdivided into (1) *Trenton, Black river* and *Bird's-eye limestone* at the top; (2) *Chazy limestone* in the middle; and (3) *Calciferous sandstone* at the bottom, resting on the Potsdam sandstone. †

In Pennsylvania along the Great Valley belt the only distinct division of it that can be made is into upper purer limestone beds, and lower magnesian cherty and sandy beds; that is, if the New York names are to be used, into *Trenton limestone* on top, and *Calciferous sandstone* for all the rest of it down to the bottom.‡

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*The detailed descriptions of quarries may seem needless; but they are only specimens on a large scale of the economical geology of the state, and teach the structural geology in a better manner than it could be taught by verbal general statements. It is a kind of object teaching. It shows the difficulties and the successes of field work. It points out localities for study. Above all, it has a business value. The quarries of the Great Valley are selected because they are a numerous, connected and typical series, and have played a master role in the history of the growing wealth of Pennsylvania.

†The discussion on the "Quebec group" of the Reports of the Canada Survey do not concern us in Pennsylvania; but any geologist who desires to know the last word on it will find it in two short communications in Science, Dec. 26, 1890, page 359;—one by R. W. Ells, repeating his opinion (published in the Canada Survey Report of 1887–8, pp. 83, 84, K) viz.: "That these [Quebec] rocks represent a peculiar development of strata of Trenton age, and probably even down in that formation," sustaining Logan's old view;—the other, by Alfred R. C. Selwyn, the Director of the Canada Survey, opposing W. Ami's views, and repeating his own opinion (as against Logan) published in 1876–7, that the Quebec city rocks are certainly of Hudson river (Lorraine, Cincinnati) age, overlying the Trenton.—I may be permitted to add here that neither my conversations with Logan while he lived, nor the study of his written statements of the case, removed my objections to what I regarded his extraordinary and improbable theory of an expansion of a part of formation No. II eastward into a great local formation named by him "the Quebec group."

‡Writing of the magnesian part of the formation in the Lehigh region, Prof. Prime says: "Lithologically it seems to be impossible to make any distinction between the limestones which must belong to different geological horizons; for limestones from the top of the series, close to the Trenton limestone, look quite as much like those from just above the Potsdam [Chiques]

Even in the back valleys of Middle Pennsylvania no better sub-division of the whole formation can be made; although the unbroken, uncrumpled condition gives a chance to put its beds in vertical order which is not possible in the Great Valley. For we there see only a gradation from the purer beds at the top downward into middle cherty beds and lower sandy and cherty beds, without any strongly marked *general* horizons of change.

Prof. Stevenson's railroad section of 4519 feet of it in Bedford county, Snake Spring township (Report T2, p. 93) will illustrate the fact.

420′ of *Trenton* blue flaggy limestones, II*c*; succeeded downwards by thicker beds of light blue or bluish grey; mostly not silicious; many yielding superior lime.*

1351′ of *Chazy beds, in part* II*b*; highest beds hardly silicious; *white chert balls* begin to appear (descending) 600′ below the top; next 400′ cherty limestones; further down more and more silicious; *black chert* appears at 1200′ from top; streaks of chert so numerous that the weathered surface is fretted with ridges.†

420′ of concealed measures.

419′ of limestone, mostly silicious.

400′ (estimated) concealed measures.

175′ (exposures imperfect) limestone, silicious.

150′ concealed measures.

300′ (*Calciferous in part, IIa*) beds of cherty calcareous grit; fretted weather surfaces show the abundance of thin chert layers.

90′ concealed measures.

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sandstone (No. 1) as do specimens taken from two beds in the same quarry not ten feet vertically apart. No traces either lithological or palæontological have been found by which the Calciferous sand rock (said by Rogers to occur near Easton) can be recognized or differentiated from the other formations." (Report D2, page 11.)

* The line of separation of the *Utica slate No. III* from the underlying *Trenton limestone No. II*, is almost abrupt where well seen in Milligan's Cove (T2, p. 93). Fossils rare; *Calymene senaria* and *Strophomena alternata*, obtained from one of the highest beds. *Columnaria alveolata* was seen in Morrison's cove (p. 94).

† Cyathophylloid fossils got near the base of this subdivision along the Juniata.

620′ of limestone beds *sandy* but with very little chert; most of them might be called a calcareous sandstone.

175′ concealed measures—Total, 4519 feet.*

No one can doubt that the uppermost beds of the limestone belt represent the *Trenton* outcrop on the Mohawk river. We can therefore safely use that term in Pennsylvania; and typical Trenton fossils occur in sufficient numbers to justify its use.

Chazy fossils occur sparingly in the middle magnesian beds, and I see no objection to retaining that name.

But *Calciferous sandstone* was from first to last an unfortunate New York term and ought to abandoned. The beds are limestone, not sandstone beds, although they are often sandy, and have an abundance of silica in the form of chert; but many of the lowest beds are nearly pure magnesian limestone layers.†

Chapter XXV.

No. II in the Lehigh region.‡

The beds of limestone along the Lehigh river, where they have been exposed to special view in very extensive quarries worked for the Allentown, Crane and Thomas furnaces, are seen to vary much in texture, color, hardness, structure and chemical composition.

Some beds are compact, others crystalline.

Blue and dove colors prevail; but some beds are almost white, others nearly black; and the blue limestones are of all shades from lightest to darkest blue.

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* It is quite probable that towards the northern edge of Bedford county a greater thickness of this formation is brought to the surface; but no details were obtained there. (T2, p. 94.)

† I am unwilling to add another name to our already copious nomenclature by calling them the *Allentown*, or the *Easton*, or the *Reading*, or best of all the *Bethlehem formation*, which last would be unexceptionable, if distinct limits could be assigned to it, which cannot be done. I prefer therefore to distinguish vaguely the lower, middle and upper portions by the old numbers, II*a*, II*b*, IIc.

‡ I take the substance of this chapter from Prof. Prime's report, D, D2, D3.

The hardest beds are commonly those of dark blue color; others are soft, disintegrating to ⅛ or ¼ of an inch on a weathered surface so that they can be rubbed to loose sand between the fingers. Groups of the harder beds make little ridges which determine to some extent the direction of brooks and streams on the surface.*

The softer beds give lines of sink-holes leading down to caverns through which subterranean streams flow, sometimes reappearing at the surface in large springs, at other times emptying into the larger river valleys. Many of the longitudinal vales are ancient caverns which have lost their roofs.

Two different kinds of structure are well known to the farmers: *rock limestone* and *slaty limestone.* The massive beds of rock limestone are accounted to make a better farm lime, or stronger manure; and this is probably a correct opinion, for the slaty limestone owes its structure to its greater percentage of silicate of alumina, which does not act as a manure. Some very pure lime or lime-magnesia (dolomite) beds with a very slight percentage of silica are extremely thin-bedded, slaty looking, and ringing when struck.—Some shaly beds have so large a percentage of alumina that they decompose to clay.

A very strange, peculiar and entirely mysterious feature of some beds is a structure resembling a mass of clam shells closely packed together with their round sides uppermost.

The chemical composition varies between a pretty pure carbonate of lime, and a nearly correct dolomite (half lime, half magnesia), but always with some amount of silica, alumina, iron, phosphorus, carbon and water of crystallization. And it seems that the *lower* (more southern) beds of the formation are more magnesian (on the whole) than the *upper* (more northern) beds.†

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*Well exemplified in the steep bluff of hard limestone, bounding the Jordan, ¼ m. N. W. of the Thomas I. Co.'s mine, No. 149 of the map. Extensive quarries of good curbing and crossing stones are worked on the N. bank of the Jordan, ¾ m. E. of Orefield.

†Such is the opinion of Prof. Roepper of Bethlehem, and Mr. W. Firmstone of the Glendon I. Works, whose analyses have been numerous and intentionally directed to the discrimination of the beds as fluxes. It is cer-

The *dolomite beds*, however, are distributed among the limestone beds in a curiously capricious manner, showing no kind of order or system anywhere throughout the formation.[*] This is the case high up in the series; as appears from analyses of 10 of the beds of Grove quarry in Black Log Valley, made for Orbisonia furnace in Huntingdon county; where the Trenton formation is exposed, about 500′ thick, dipping about 60°, and composed of dark blue and gray soft argillaceous limestones alternating with blue lime shales (more abundant toward the top); the quarry being opened in lower beds, measuring 22, 20, 10, 24, 18, 21, 20, 32, 30, and 72 inches thick respectively; and the respective percentages of carbonate of lime being (in whole numbers) 90, 85, 90, 74, 81, 83, 81, 82, 85, 47, the last and lowest a dolomite. (F, p. 260.)

Damourite (*hydromica*) layers only half an inch or more in thickness part the limestone beds from one another all through the formation, and in such numbers that a hundred of them have been counted in a single outcrop. They are regularly interstratified with the limestone beds, and are decomposed by the weather into clay.[†]

But the damourite is sometimes seen as leaves thinner than paper, completely intermingled with the limestone and so thoroughly incorporated as to make a separation of the two impossible. The flakes of the mica in this latter case cross the body of the limestone in all directions.[‡]

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tain that the *cement beds*, so rich in alumina, are at the top of the magnesian series, or in the *Trenton formation II c*.

[*] Of this more will be said in describing the McCormick quarries at Harrisburg. Here I will merely give Mr. J. B. Britton's analyses of nine beds in Troxell's quarry, Jordan Bridge of the C. & F. R. R.; A. the lowest bed; I. the highest; A. to E. worked for flux for Crane I. C. furnaces, F. to I. rejected.

Carb. lime, ...	85.2,	76.8,	78.2,	61.5,	70.1,	63.9,	71.9,	58.3,	89.5;
Carb. mag., ...	5.9,	17.0,	14.5,	26.8,	20.1,	3.1,	8.3,	2.3,	0.6;
Silica, ...	7.1,	4.1,	4.7,	7.3,	6.1,	27.7,	14.6,	33.2,	8.2.

For the percentages of phosphorus, alumina, iron, etc., and for many other similar limestone analyses, see Prime's Report, D2, 1878, page 16 to 20.

[†] Hydromica is a hydrous silicate of potash and alumina.

[‡] Prof. Prime adds that this may excite a suspicion that the damourite has been a subsequent production, although the limestone rock is fresh and hard and shows no sign of water percolation, or mineralogical change of any

The great mass of damourite slate (primal slate) at the bottom of the formation, with its line of limonite iron ore banks, has been described in a previous chapter. A large quantity of damourite slate appears at the top of the formation also in some places along the line of contact with the slate belt; and in this upper outcrop occur the great *limonite mines* of Ironton in Lehigh county, and Moselem in Berks county; also as I believe, the Cornwall magnetic iron ore mine in Lebanon county; and the Path Valley limonite mines in Franklin county.*

Chert is abundant in the lower portion of the great limestone formation No. II, both in scattered balls, and in lens-shaped masses. The chert is sometimes honeycombed, or contains cavities from which rhombohedral crystals of dolomite have been dissolved out.

Sandstone beds are sometimes met with between the limestones; and they help much to prove the mechanical deposit of the whole formation. A few only have been noted; the largest not 2′ thick; all in the magnesian beds; and all in company of damourite ore bearing slates.†

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kind.—To my mind it is only another proof that the limestone was not a chemical precipitate, but a regular mechanical sediment; and that the rivers which brought the sediment to the sea carried large quantities of floating flakes of mica from some mica schist region; sometimes spread the mica flakes when most abundant in thin layers; at other times when less abundant the mica flakes would slowly settle singly to the bottom and stand or lie as they happened to touch bottom. A typical locality for this exhibition is the limestone exposure in the bottom of the Ironton R. R. Co.'s iron mine.

*It has been already said that some, if not many, of the smaller limonite banks of Northampton and Lehigh county, located in the middle region of the limestone belt, may have been produced by damourite slate partings in the middle of the formation. But many more of them are connected with synclinal folds in which the slates of III have once lain, but are now swept away; these mines must be referred then to the damourite slates at the top of II. But see a subsequent chapter for reasons to modify this statement so as to make it refer to the top of the magnesian limestones and not to the top of the Trenton.

† Instances are:—A sandstone bed 19 inches thick, cut by the L. & S. RR. just west of the round house at Bethlehem; quite conformable; lower 9″ a pure quartzite; upper 10″ more of a conglomerate of quartzite with some limestone; evidently a breccia of two adjoining beds produced by pressure. (D3, p. 172.)—A thin bed of saccharoidal sandstone at the Breinig mine between Trexlertown and Breinigsville; analysis showed quartz, with small quantities of damourite; evidently a sandy layer in the ore bearing potash

Oolitic limestone beds are frequently encountered, but not confined to any fixed horizon in the series; no use can be made of them by the field geologist in establishing the order of the beds; for they are very local and irregular, the oolitic character often disappearing from a bed only a few feet from where it is strongly pronounced. The round grains are generally a little larger than sturgeon's roe; sometimes loosely scattered through a crystalline limestone; at other times so abundant that there is hardly room between them for the cementing paste.*

Breccia beds. It frequently happens that one limestone bed lying between two others is a sort of conglomerate, but differing from pudding stone conglomerates in two features: —(1) The fragments are all and always angular, sharply angular, and not rounded or rolled in water;—(2) These angular fragments are not composed of various kinds of rocks, but are all limestone, and all of the same sort of limestone, whether more or less magnesian;—(3) These beds moreover are to be met with in all parts of the limestone belt, from the bottom magnesian beds, to the top non-magnesian beds.—It is evident then that such beds are not of the nature of *gravel conglomerates* formed on ancient shores by the action of waves; but that they are *breccias*, that is, broken-up or smashed layers of limestone, crushed by the pressure force of an earth movement from the south, the fragments of the bed remaining in their places, and being afterward cemented together by percolating lime waters depositing calcite.†

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slates. (D, p. 34.)—A similar layer, *only one inch thick*, occurs in the ore slate of the Schwartz and Fogel mine. (D, p. 36.)—A bed of sandstone 5″ thick is interstratified in the quarry next but one to the Brewery on the Delaware; and another 5″ to 8″ thick in the quarry next the Brewery, in company with thin beds of damourite and an oolite limestone. (D3, 171.)

* The fish-roe grains of oolitic limestone have been usually explained as grains of sand around which the carbonate of lime has concreted itself. Recently it has been proven by the microscope that some limestones, if not all of them, are made oolitic by rounded fragments of fossil bryozoa. They are apparently the lime mud of destroyed coral reefs in which lie enclosed small bits of coral rounded by the waves but not reduced to mud.

† Prof. Prime notes, as typical localities, Mary Kohler's quarry ¾ m. W. of Whitehall station (L. V. RR.), and an exposure on the Jordan just N. of Helfrich's spring. (D2, p. 13.) He gives an analysis of the M. Kohler breccia on page 15.

Cement beds occur somewhere in the Trenton limestone (*II c*), along the edge of the slate belt, which crosses the Lehigh river at Coplay. Here are the quarries of the Coplay Cement Works, and of the Lehigh Cement Works on the west bank; and the quarries of the Old Lehigh Cement works and of the Allen Cement Company on the east bank. They are traceable westward to the Ironton * mine in Lehigh county; and eastward all along the road from Siegfried's Bridge to Nazareth in Northampton county; and again in the neighborhood of Martin's Creek village at the Delaware.† A subsequent chapter will be given to these cement beds, their quality and use.

The folded stratification of No. II.

The limestone quarries along the Lehigh show the folded and compressed condition of No. II; and yet much of it is seen to be less complicated than was formerly supposed; merely lifted and thrown into waves; as for example in the Lehigh Valley Iron Co.'s long quarry at Coplay, the north end of which shows two short sharp little upfolds disturbing an otherwise almost horizontal outspread.‡

The prevalence of cleavage planes, generally sloping southeast, obscures the stratification, and sometimes almost obliterates it. Sometimes it is impossible to read the dip, the beds being broken up into a mass of blocks of irregular shape.§

While the majority of the dips are towards the south,

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* D2, p. 57, 58. Dr. Genth's analysis of a sample from here reads: Carb. lime, 82.05; insoluble silicates of alumina, etc., 15.07; ferrous and mang. carbonates, 0.09; carb. magnesia, 0.17; water, 2.42; carbon and undetermined matter, 0.20.

† D3, p. 164.

‡ See the beautiful photo-lithograph picture in D2, plate 2, p. 54. The south end of this quarry, on the contrary, shows the limestone beds thrust up suddenly into a vertical attitude, and then turned sharply over in a larger anticlinal with a squeezed top. (See plate 1 in the same report D2.) What is exceedingly interesting, one of the upfolds in plate 2 is crossed on top by horizontal beds, proving the great amount of *slip and slide* of bed on bed which took place during the movement.

§ As in H. Stein's quarry 2 m. S. W. of Fogelsville, a picture of which is given in report D, p. 9; also the Hokendauqua quarry close to the L. V. R. R.; the Coplay quarry; and those just outside of Catasauqua (D2, p. 54).

there are many exposures of north dips, but not enough to account for all the south dips; consequently many of the south dips must be *overturns;* and this is proven by overturned compressed anticlinal folds exposed in the quarries along the Lehigh river.*

The *magnesian limestone* lowest beds are said by Prof. Prime (D2, p. 55) to be always conformably superimposed upon the Chiques ("Potsdam") quartzite, even when the latter show steeper dips than those of the neighboring limestone beds.

The *Trenton limestone* uppermost beds also, as a rule, conformably underlie the slate beds of No III; although in some places both are seen *inverted* so as to place the slates underneath the limestones.†

Fossils in Lehigh county are very rare in the limestones; too few to serve the palæontologist who wishes to use them for subdividing the whole into formations of separate ages. A *Maclurea*, and some cross sections of *Euomphalus* (species unknown) were first found in a quarry 2 m. E. of Ballietsville, indicating the *Chazy age* of the beds. Then three casts of *Monocraterion* (worm burrows) were found in the bed of the Jordan, just W. of Helfrich's spring.‡ A dozen specimens of *Lingula* (species unknown) were found in Schadt's quarry, ½ m. N. W. of Helfrich's spring. A

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*One such at Catasauqua passes through a hill and is quarried on the east and west sides of the hill. The two sections of the arch thus made were photographed and lithographed for plate 3 (Rau's quarry) and plate 4 (Weaver's quarry) in Prof. Prime's report D2. The *slip and slide* of the beds on one another in the pinch of the arch is finely shown in Rau's quarry.

†The anticlinals and synclinals of Lehigh county are located and described by Prof. Prime in D2, pp. 55 to 57.

‡ Here is a cave and a water sink. Prof. Torell indentified these casts as belonging to his Swedish Cambrian genus; the name *M. lesleyi*, will probably be abandoned for *Scolithus*, as the funnel-shaped end of the cast is often seen in the Cambrian Scolithus. (For figures and description see Appendix to Report D2, p. 80.) But the presence of this fossil cast is no evidence of the Cambrian age of the magnesian limestone beds. As Prof. Prime says in his summary of evidence of their *Chazy* and *Calciferous* age there is no sign of a stratigraphical break in the series from the top of the acknowledged *Trenton* beds to the bottom of the *Magnesian* series. "There s not a particle of evidence that any of these limestones belong to *Huronian* (as suggested by Dr. T. S. Hunt) or older epochs; all the facts point the other way." (D3, p. 163.)

poor fragment of an *Orthoceras* was found in a loose rock 1000′ N. of the tavern at Scherersville.

Fossils in Northampton county have been got from the middle and upper limestones; thus—*Maclurea* (or *Euomphalus*) in Dech's quarry, 1¼ m. S. W. of Bath; probably of *Chazy age.*—*Encrinal stems*, not far N. E. of last; *Trenton age*; also abundant in the upper beds of Krock's quarry at Christian spring; also, from there eastward to ½ m. E. of Nazareth, wherever the limestones are weathered; also, in Russ' quarry, just S. W. of Nazareth (here in company with a few *Orthis testudinaria*); also, on Knecht's farm close to Bushkill creek, ¼ m. S. W. of Stockertown (here in company with *Chætetes lycoperdon* and *O. testudinaria*); also, at quarry opposite Churchville church, in upper weathered rocks (the lower beds affording *Leptæna sericea*, *O. testudinaria*, and *O. pectinella*); also ¼ m. E. of Keller's tavern (two or three encrinal outcrops). All these exhibitions prove that *encrinal stems* mark the *Trenton outcrop.*—In the quarries on the Delaware just S. of Howell's cotton mill are found *Leptæna sericea*, *Orthis pectinella*, *O. testudinaria*, *Strophomena alternata*, *Chætetes lycoperdon*, and one or two other undetermined forms, lying in colonies of from 20 to 200 individuals, and not scattered through the rocks, which are evidently of *Trenton age.*

CHAPTER XXVI.

Limestone quarries of the Great Valley between the Schuylkill and the Susquehanna rivers.

Looking from the car window of a train moving westward from Reading towards Harrisburg a geologist is struck with the remarkable fact that the limestone beds cut by the line, or exposed in quarries within his view, seem to be all dipping southward, and usually at low angles.*

But after passing Myerstown station, a broad flat plain of limestone or shale begins to spread out south of the railroad, showing few exposures of any kind. At Lebanon, across this plain runs the branch railroad to the Cornwall iron mines, and along this railroad quarries and natural exposures show the limestone formation, lying comparatively flat; that is, rolling with gentle north and south dips; the last south dips sinking beneath the Cornwall trap dyke. South of the dyke the lime shales at the top of the formation dip S. and are cut off by the great Cornwall fault, their edges abutting against the downthrown edges of the trias.

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* Thus approaching Wernersville station the dip is 10° S. Great quarries opposite the station show the same. Passing the station the same dip appears at the creek. Approaching Robesonia station the dip is 20° S. Beyond that station is a fine quarry with dips of 20° S. Here a branch RR. runs south up a little valley between highlands to Robesonia furnace. The hill W. of the furnace is perhaps 500′ high; a long gentle slope of limestone descending to the railroad; the slope from the foot of the hill to the railroad at Womelsdorf station is half a mile wide; dip at the station 5° N. (?); beyond the station, 30° S. Most of the line between here and Richland station is through slaty, thin-bedded limestone beds all dipping gently S. but at one exposure 30°.

Black slates make a great show in the cut east of Richland station. Curiously enough the fields to the south expose ribs of limestone *striking N. and S.;* and in a second *black slate* cut, west of Richland station, there is an *anticlinal roll striking also N. and S.* but much crushed and contorted. Further west *dark limestone and slate* dip 10°, W. of S. Still further on, approaching Myerstown station, are more fine cuts in *dark* slate dipping 10° south.

In spite of the general flatness of the limestone of the Lebanon plain, there are plenty of contortions, rolls, steep dips and probable overturns in the quarries around the city of Lebanon, and up to the south edge of the slate belt, which is itself greatly compressed and crumpled with overthrown south dips.

From Lebanon to Harrisburg S. dips prevail both in the limestones and in the slates ; and of course more than half of them must be overturns ; for the two great formations *as a whole* are descending northward to profound depths beneath the Anthracite coal basins of Schuylkill county. And the same state of things obtains west of the Susquehanna river all the way to Maryland and Virginia.

In the following description of the quarries it will be noticed that the southward dips vary between S. E. and S. West. This shows that the pressure has operated in all directions, subjecting the stratification to all kinds of irregularities ; often so excessive as to swing the dips round to east and west, that is directly across the strike lines of the valley. For instance, on the east side of the Schuylkill at Reading, the dips are due east, or towards the mountain back of the city. On the west side of the river they are S. E.; further west they are S.; still further west S., S. W. and sometimes even west.*

That the south dips are sometimes *normal* and sometimes *overturned* is not a matter of theory. In Brinkley and Zinn's quarry at Wernersville can be plainly seen a *fold thrown over to the north, the beds on both sides of it dipping 45° S. 20° W. the fold being tightly compressed.* Another fold, not quite tightly compressed, but *overthrown to the N. 40° E.* is visible in Goul's quarry, 2 m. W. of Wernersville. Another is seen in Donges' quarry at Myerstown, Lebanon county, in the laminated lime slate beds dipping to the eastward, the fold being pushed over to the west.

Other evidences of the generally folded, compressed and overthrown condition of the whole formation would appear

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*Supposing a N. and S. fault at Reading, which is not probable, the fault line 4 projected southward would strike the trap mountain W. of Birdsboro'.

in the quarry faces were it not that the excavations usually follow the outcrop lines of such beds as are of superior quality, and seldom cut across a series of folded strata.

In the following *condensed description* of the limestone quarries of the Great Valley in Berks, Lebanon, Dauphin, Cumberland and Franklin counties, between Reading on the Schuylkill river and Mont Alto near the Marvland state line, I make use of the elaborate notes of Mr. E. V. d'Invilliers, published in the Annual Report of the Progress of the Survey in 1886, part IV, pages 1517 to 1562.

Berks county quarries.

Frill's quarry, at the west end of the Lebanon Valley RR. bridge over the Schuylkill river at Reading; large, excellent for building, curbing, or paving; quarry beds good and regular for 60′; dip regular 40°, S. 30° E.—*Another*, 1000′ S. of bridge, rich, dark blue, good building stone; 2200 perches per year, at 40 to 60 cents a perch; dip 40°, S. 25° E.

Drexel's quarry, near the last; occasionally wrought; beds, 1′ to 4′ thick; easily quarried and handled; dip, 40°, S. 20° E.

Gudlin's quarry, 1½ m. W. of Schuylkill, small; abandoned; dip *steep*, S. E.

Private quarry of thin lean beds, 3½ m. W. of river; abandoned.

Deckert's quarry, Sinking Springs, poor, abandoned; dip irregular 35° to 50°, say S. 25° E.

Pfeifer's quarry, near last, abandoned like the others because the lean stone is neither fit for furnace fluxing nor lime burning. Dip obscure, probably S.

Huyett's quarry, on the turnpike, 1 m. W. of Sinking Springs; large, abandoned; lean, hard, dark blue-gray, beds alternately thick and thin (slaty), all dipping 30°, southward, and much cut up with cleavage planes.

Evans' quarry, on RR. ½ m. west of Columbia Branch junction (1 m. W. of Sinking Springs); large, old, abandoned, beds not pure, dip 40°, S.

Ruth's quarries (two), on Columbia branch RR. No. 2 furnished flux for Birdsboro' furnaces; dip 35°, S.—No. 1

sent flux to Reading furnace; light blue, lean, quite thin-bedded, dip 40°–45°, S. 15° E.

Ludwig's quarry, S. W. of last; 3 kilns; 500 bushels per week; home market at 7 cents a bushel; opposite the Hat Factory, first station on Columbia branch RR. 1¾ m. S. W. of Sinking Springs. Slaty, curly, crushed beds next the road, expensive and irregular to quarry. Elsewhere in the vicinity beds dip regularly S.

Seltzer's quarry, ½ m. W. of last, old; beds fairly good, weathered, broken, irregularly dipping 35°, S.

Old quarry, long abandoned, 8 m. W. of Reading (near Wernersville), beds very hard, with occasional slate parting, irregular, dip? 55°, S. 20° E.

Miller's quarry, E. end of Wernersville, 300 yds. W. of last, small exposure of thin beds, dipping 25°, S. 20° W. (not E.).

Brinkley and Zinn's quarry, opposite Wernersville station, once used by Reading and Pottstown furnaces, now for farm lime; 125′x100′, face 25′ high; beds in west wall *a compressed anticlinal roll leaning over to the north, both legs dipping 45°, S. 20° W.* (not E.) and only 10′ of beds, as thus doubled, visible.*

Whitmoyer Bro.'s quarry (*Knorr's*), near Wernersville station; large, 20′ high; 2 car loads a day to Reading and Pottstown furnaces; dip 20° to 40°, S. 35° W.

Deppen's, J. W. (No. 1); an immense quarry N. W. of Wernersville; very old; 3 kilns; much flux also sent to furnaces; stone not quite good enough for flux; 550′x300′; 25′ face of beds dipping 20°, S. 20° W.; bedding not especially prominent, and much of the stone quite silicious, pale blue to grey.—(No. 2) on a line with the last further east and in the same beds, 9 kilns sometimes in use.

Hull's quarries (two) west of last, small; *beds quite conglomeritic* (not plainly stratified, dip (?) 20°, S.) *containing a number of different silicious limestone and sandstone*

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*This is a notable instance of the complicated structure of the whole limestone belt, and of great value to the geologist; but it must be used with due precaution; for it may mislead the student into the error of doubting the *normal south dips* when they present themselves, as in the exposures south of Lebanon.

*pebbles, only slightly rounded, and all firmly cemented together.**—A quarry, ½ m. E. of last, in bluff 400′ N. of pike; lean, cavernous, pale blue, abandoned.

Goul's quarries (three) in a N. W.—S. E. line crossing the RR. 3 m. W. of Wernersville (1½ m. E. of Robisonia); —(1) just S. of pike; 2 kilns; good, heavy bedded, dipping 55°, S. 40° W. in N. wall, *arched over to a less steep S. 40° W. dip.*†—(2) S. of RR. (11 m. W. of Reading); disused; *mouth of cave;* dip 30°, S. 40° W.‡—(3) S. E. of last, small, 1 kiln.

Two small farm quarries, ½ m. N. W. and in line with the three Goul quarries show dips of 40°, nearly due S. and 40°, S. 15° W.§

Wenrich's (*W.*) quarry on the hill slope S. of RR. 1 m. S. E. of Robisonia station; small; dip 40°, S. 15° W.—*Wenrich's* (*A.*), ½ m. N. of the station; 35°, S. 20° W.

Deppen's (*Sam.*) S. of RR. ½ m. W. of Robisonia station; 2 kilns, 35,000 bushels per annum; some building stone sold, but beds thin and broken; dip 20°, S. 20° W.

A quarry, on the RR. 1½ m. west of Robisonia station; small; important as showing a dip of 85°, S. W.—Another ¼ m. W. of it, just N. E. of Womelsdorf station, worked for RR. ballast, dips 60°, S.‖

Moore's quarry, on RR. 1 m. W. of last, and S. W. of Womelsdorf; small; much earth to strip; beds ½′ to 1½′

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*These conglomerates are among the strangest phenomona of the formation No. II, and very hard to explain. Were it not for the sandstone pebbles, they might all be taken for *breccias*, or crushed limestone beds cemented.

†Here then is another evident *compressed, overthrown anticlinal*, not quite transverse to the strike of the belt, but *very oblique to it.*

‡The stone here is reported quite *manganesian.* This shows that we are in the lower division of the formation (*IIa*); and the sum total of dips southward must be interpreted and calculated with this fact in view.

§This only emphasizes the general rule of the whole limestone belt, that *the strike lines are all local*, and cannot be followed for even half a mile. In other words the irregularity of limestone *strikes* is as great and universal as that of *dips.* The compression of the formation was equal in all directions vertical and horizontal. The structure could not exhibit these features had the movement not been effected under the enormous weight of the higher Palæozoic formations.

‖These are instances of very high dips which help to give credence to the overturned anticlinal exposures.

thick ; very dark blue, medium quality for flux ; good for ordinary building ; dip, 35°, S. 10° W.

Lebanon county quarries.

Gehret's quarry, on RR. near county line, W. side of steep hill, E. of Sheridan furnace, small, fair building stone. —*Eckert's*, small quarry N. of RR. W. of Sheridan station.—*Kauffman & Co.'s*, ¾ m S. of Sheridan station, once worked for flux, lean and slaty and abandoned for the Annville stone now in use.

Kauffman & Co.'s large abandoned quarry, just S. W. of Richland, slaty beds, dipping 25°, S. 15° W. round to due W.*—*Shaffer & Yingst's* small pits, in hard, silicious, irregularly disturbed beds.—*Landis'* quarry, on RR. at Richland ; old ; all stone (when quarried) sent to Tamaqua, Schuylkill conuty, lime kilns ; quality fair ; beds of variable thickness, broken, dipping 15° to 20°, S. 25° W.—*Loose's* two small quarries, ½ m. W. of last, 75′ long, 20′ high ; dip 15°, S. W.

Hartlieb's quarry, on RR. 2 m. W. of Richland, 1½ m. E. of Myerstown ; stone admirable for *curbing, paving and light building ;* light covering ; dip 10° to 15°, S. 10° to 20° W.—*Royer's*, near last ; 300′ long along RR., 20′ high, beds ½′ to 3′ thick, uniformly good for building and curbing ; dip 10°, S.

Myerstown, three quarries on the canal, by which their stone is shipped to Reading for *plastering* walls :—*Miller, J.*, in *thinly laminated slaty* beds *dipping S. E.* (not S. W.) —*Miller, I.*, dip, 20°, S. 10° E.—*Donges'*, 250′ long, 22′ high in N. face, which shows a small *anticlinal* arch, dipping 20° to 35, *east* (not south, or S. E.) beds thinly laminated, with some slaty impure layers ; 2 kilns of 300 bushels capacity each.†

Bassler quarry, 1 m. W. of Myerstown, ½ m. N. of RR.; 35 years old ; 2 kilns of 350 and 400 bushels capacity ;

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*Here is a specimen of the universal warped structure of the whole belt, full as it is of innumerable small short dying anticlinals around the ends of which the strike lines swing sharply, and throw the dips off fanwise.

†Here we have both anticlinal and transverse dips.

45,000 bush. have been burned here in one year all for farm use at 8 cents per bushel ; in 1886 only 4,500 ; 250′ long N. and S. by 150′ E. and W. by 20′ high ; dip in W. wall 32°, S. 22° E. in N. wall 45°; in E. wall still steeper.

Urich's (*Val.*) quarry, ½ m. W. of last, ½ m. N. of RR., semicular, 70′ long, 18′ face ; 2 kilns ; 3,000 bush. per season for farm use ; beds good, hard ; ¼′ to 2½′ thick, easily quarried ; produces some of the best building stone in the whole Lebanon Valley ; much of it used for building ; 2 horse load sold for 75 cents, (1 perch measured in the wall) if the purchaser loads and hauls his own stone. Dip, 55°, S. 15° E.

Urich's (*S.*) 1 m. W. of last, on canal, very long rambling quarry, 200′ wide near E. end ; one pit at the lock, 100′x-50′x15′ deep ; dip here 60°, S. 20° E.; in N. face 57°, S. 25° E.; in next pit 55°, S. 15° E.; stripping uniform and rather heavy ; stone good flux shipped east.

Beckley's, 1 m. S. W. of last, ⅓ m. S. E. of Prescott station, small, 1 kiln of 250 bush. drawing 80 bush. per day ; quarrying costs 5 c. per 100 bushels : lime sold to farms at 8 c. per bush.; ballast delivered on RR. track for $1 per one-horse load. N. B. this is the last quarry until the Lebanon quarries are reached, four miles further west.

Lebanon city group.

At Lebanon, on the east side of the city is a line of quarries extending N. and S. viz.: Horst's & Fritz's N. of the RR., Shenk & Herr's, Wagner's, Houck's, ——, March's and Coleman heirs', S. of the RR. On the west side of the city are: Brock Bro.'s, N. of the RR. and Meily & Brother's, Groninger's, Coleman heirs' and Horst's.

Horst quarry, very old, 150′x250′x40′ deep ; 2 kilns, drawing each 125 bushels daily; yearly output 35,000 bushels, worth 12 to 15 c. picked lime delivered, 4 c. slaked, used chiefly for mortar and plaster ; beds 1′ to 2½′; dip 35°, westward, in some parts swinging round to the south.—In a brick yard quarry, 1000′ E. of last, the limestone beds dip 35°, S. 25° W.—*Fritz's* quarry, abandoned ; 2 kilns (supplied from Wagner's quarry); bluegrey beds, withou regular dip: cleavage planes 70°, towards W.; 275′ long, 20′ deep, stripping heavy.

Shenk and Herr's; old; 2 kilns; 120′x75′x20′ deep, dip on W. side 15°, westward; on E. side 55°, southward.*

Wagner's; ½ m. S. of last; 160′x100′x20′; beds massive, used largely for Lebanon city buildings; dip 35°, S. 30° E.

Houck's, S. end of city; 100′x20′; good bluegray beds, dipping 35°, S. 30° E.—Another, near it, exclusively for building stone, 250′, E. and W. 20′ high; dip 20°–30°, S. E. (This stone is finely *laminated.*)—*March's*, near the last, and on the Cornwall and Lebanon RR. 175′ N. and S. 35′ deep; flux and building stone; dip 20°, S. 50° E.†

Coleman heirs', two, immense quarries, old, abandoned, together 1000′ long, along the RR., formerly fluxing Cornwall and Donaghmore furnaces, but too hard and lean; N. quarry beds all dip 35°, S.; S. quarry 32′ wide, 35′ deep, dip 35° to 50°, S.

Brock Brothers' quarry exclusively worked for the N. Lebanon furnaces, on the old canal; 400′x500′x40′ deep; steam drills, etc., in use; 35′ of beds (1′ to 4′ thick) dip 20°, S. 20° W.; in places wavy; but in S. and E. sides strata even beds and regular dip; the stone is light gray to pronounced blue and of superior quality, but not quite so non-siliceous as the Annville stone.

Meily & Brother, just S. of their Lebanon furnaces, S. of RR.; started 1868; in 1886 400′x100′x30′ deep; very handsome face, especially along the north side of main cut, and dipping gently 15°, toward S. W.; stripping heavy; massive stone can be quarried through the larger part of the uncovered area; stone blue-gray, somewhat lighter than Annville stone; beds thin and massive (1′ to 3′) *quite free from silicious matter;* quarry contracts, 30 c. a ton; 1200 tons of flux per month.

Gloninger estate, small, 1 m. W. of Lebanon center, on Quittapahilla creek, 2 kilns, each draws 200 b. per day; 12½ c. picked, 6 c. per bushel run of the kiln; local market; dip, 25° to 45°, S.

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* Another case of rapidly changing dip; or warp.

† Here we have one of the very highly diagonal strike lines.

Coleman heirs', near Donaghmore furnace; hillside quarry; dips S.

Coleman's quarry, on RR. just W. of Colebrooke furnaces, 2 m. W. of Lebanon city; enormous excavations; output of flux for the Colebrooke furnaces very great; steam drills, etc.; all the strata good, lie very flat, but generally dip gently southward.*

The Annville group.

Annville is 4½ miles W. of Lebanon city.—*Kreider's* quarry is 3 miles W. of Lebanon, on the RR. 1¾ m. E. of Annville; started 1885; 100′x90′x20′; exclusively for flux, 15 small car loads per day; strata vary; 30′ of good blue stone; stripping heavy; dip of S. face 12°, S. 10° W., of W. face 15°–20°, S. 60° W.—*Yake's*, 1¼ m. E. of Annville, small, 2 kilns.—*Kreider's*, ½ m. E. of Annville; good stone, dips steep S.

Light and Houser's quarry' just W. of Annville; stone deep blue, excellent; stripping heavy; long cut in hillside to reach best stone in S. end, where 75′ wall, 20′ high; cleavage prominent (with slips 75°, N. 80° E.) dip 25°, W. and 25°, S. 10° W.

Beaver's quarry, just W. of last, on same S. side of creek; old, large, 600′x800′, back from creek to pike; dip everywhere *gently S. E. and S. W.; small roll*, one-half of saddle exposed, with 35° dip, diminishing rapidly to 10° at the pike. Farm lime and *chemical lime*, and much furnace flux (80 tons a day to Sheridan and Topton). In 1886, 1,000 bush. lime a month went to C. Warner & Co.'s paper works at Wilmington, Del. Five draw kilns, 6′x26′, 150 bu. per kiln, four always in action. Cost of quarrying, breaking and delivering at kiln, 85 c. per 100 bushels, powder and tools furnished to contractor. Flux stone sold on cars at quarry for 41 c. per ton. *Analysis 96 to 98 per*

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*Here is a typical case of *undistured localities in the great belt, which have escaped the otherwise ubiquitous pressure-crumpling.* The belt is here nearly at its widest, and the quarry is not far from the edge of the slate belt to the north of it. Consequently the purer beds of the upper or Trenton division (*IIc*) of the great formation are here quarried.

cent. carb. lime.—Light and Houser's, small, new in 1886. —*Messner's*, old, abandoned.

Kauffman & Co.'s two quarries; one on RR. 250′ from creek; beds 1′ to 1½′, very regular and uniform, 25° to 30°, S. 10° W.—The other S. of it, 150′ wide, 20′ deep; stone finely *laminated*, dips 20°, S. 40° E. (sometimes swinging to S. W.); beds not massive, nor thick, and more gray than the other Annville stone; output of both quarries 3000 to 4000 tons per month to Sheridan and Reading furnaces.

Brightbill & Son's two very large quarries on RR. 1⅔ m. W. of Annville; one 500′ long; 50′ of rock exposed; excellent, fine-grained, soft, brittle, blue-gray, thin beds, wavy on W. side, regular (on E. side) dip 60°–70°, S. 40° E. Crush in S. face.

Kreider's quarry just west of last; 5 kilns, output 5500 bush. per month shipped to Powers & Weightman's chemical works in Philadelphia, and to Pa. Salt Co. Always in high repute for chemical and other special uses, and flux; 100 bush. lime from 6½ tons stone and 1700 lbs. coal (best record); output of flux stone 1000 tons per month, at 31 c. per ton on car. Quarry 250′x175′; 10′ to 30′ deep; dip, 12° to 45°, S. E.

Batdorff & Beaver's, next west in the line; 300′ long, irregular shape, 40′ to 50′ face in places; inexhaustible quantity of first-class limestone; output 2300 tons per month; best stone from center of quarry; blue, soft, *250′ thickness of beds suitable for the market;* dipping uniformly, 40° to 70°, both to S. E. and S. W.*

Shenk Bro.'s old quarries, ⅓ m. W. of last, small, abandoned, 10′ face, dip 65° (?) S.

Gruber & Bowman pits and kilns at Palmyra, near the Dauphin county line, furnish good building stone, and farm lime. Their beds have no geological connection with the Annville beds (3 miles E. of them) and are out of line with

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*There are *slaty layers* in this quarry which do not appear in Kreider's quarry probably because they run past the Kreider quarry to the south of it. It is a task for a future survey to clear up the geology of this important line of beds; to determine whether these dips are overthrown or not; to fix their place in the column of II *a*, *b*, *c;* and to reveal their connection with the slate belt III *a*, *b*, to the north of them.

them far to the south, but in line with the first quarries in Dauphin county next to be described.

Dauphin county quarries.

Shenk (*Ab.*) quarry, 1000′ S. of RR. 1 m. W. of Palmyra station, in *horizontal strata*,* peculiarly adapted for buildings, in layers from 9″ to 2′, sold at the quarry for 60–65 c. on cars at RR. station for 90–95 c. per perch.—*Barber's* (*R. RR.*) ½ m. W. of last, on S. side of RR.; old; dip 10°, S.

Landis quarry, ½ m. N. of RR., ½ m. W. of Lebanon county line and ½ m. N. W. of Shenk quarry; superior quality of beds† (Trenton?); 6 kilns, for farm use from 1856 to 1881, since then for building and plastering also; 200′ long N. and S. 50′ wide, 30′ face, dip 35° to 40° S. 20° E.—*Gingrich's* quarry near and south of last; face 25′; dip 25° to 35°, S. 30° E.—*Hoke's*, near last, abandoned, dip 60°, S. 25° E.

Moyer's abandoned quarry just S. of Derry station, on steep bluff facing Spring creek; beds ½′ to 3½′ thick, dip 50°, S. 60° E.—*Hershey* quarry, near and E. of last; building stone for new Derry church; 50′x25′, 18′ face, dip 12° to 20°, S. E.

Swatara quarries.

Kauffman & Co., abandoned, 300′ long, face 20′, dip S. E.—*Landis* quarry, facing last on W. and *Zimmerman* quarry its continuation north.‡ Landis kilns (3) put out 2800 bush. lime per week.§ Dip of S. end of Landis quarry 45°, S. E.—Zimmerman quarry makes a fine display of

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*Perhaps with the slightest possible slope S. E.

†Rock grey-blue; output 6000, 7000 bush. per month, all sold in Philadelphia and New York for paper, glassware, sugar refining, medicine, as well as building, large wagons holding 85 to 90 bush. (80 lb. to bush.) take it to Palmyra station; hauling $1.75 per 100 bushels; kilns, 6x18x20, consume 1¼ tons pea coal to 100 bush. lime; drawn twice a day.

‡There are only 25′ of interval strata between the top Zimmerman bed and the bottom Landis bed; but the strata are crushed and folded, hard to read, and expensive to work. The deep blue massive Landis N. beds can be faintly identified with the S. Zimmerman beds.

§See statistics of hands, powder, etc., etc., in An. Rt. 1886, part IV, p. 1535, by d'Invilliers.

good stone for lime; 60′ of beds exposed dipping 20° to 25°, S. E.* Output 13,000 bush. of farm lime per year.

Union Deposit Furnace Co.s' large quarry just N. W. of Swatara station, E. side of branch RR. to furnace; 200′ (N. & S.) long, 35′ working face, *displaying 200′ of successive beds all dipping* 60°, S. 35° E.; lower beds (N. end) somewhat slaty; center beds handsome blue stone (like the Annville stone only rather more massy 1′ to 3′ thick); best center beds measure 25′; upper (S.) beds broken by cleavage, not so pure, harder to quarry.

Erb's quarry, ⅓ m. N. of Swatara station, N. side of Spring creek; 125′ (N. & S.) 22′ high; tightly folded beds, dipping E. (?), 3 kilns for local market.

Ginrich's three quarries ¾ m. N. W. of Swatara station, S. of Swatara creek, *close to the edge of the slate belt* (*Hudson River Slate, No. III.*)—(a) 180′ long, 20′ face, dip at E. end 45,° S. 25° E.; at W. end the same but more massive; —(b) 125′ long, 28′ face, beds wavy, dip irregular;—(c) 175′ long, 20′ face. Average stripping (on all) 5′; beds 1′ to 4′ thick, each layer very uniform.†

Hummelstown group.

Garman's, 1 m. E. of Hummelstown; long disused 100′ long, 20′ face; beds hard and slaty, dipping 30°, S. 60° E. (⅓ m. E. on RR. there is a dip of 45°, E. S. E.)

Hershey's three small quarries, ½ m. E. of Hummelstown, on branch RR. to Walton's Brownstone (Trias) quarries;—(a) 75′ long, 15′ high against steep W. hillside, in beds slaty and finely laminated, dipping 25°, S. 40° E; (b) on level, older, 40′ diameter;—(c) at limekilns, small. Analysis (claimed) 97 to 98 p. c. carb. lime. Building stone sent to

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*Thickest beds 3′; much good building stone could be obtained here, the stratification is so regular; breaking in rectangular blocks.

† The fifteen quarries just described (Palmyra, Derry, Swatara groups) work a belt of upper (Trenton?) limestones next to the slate belt, under which they should descend. And yet all the dips are S. S. E. away from the slate belt. This parallelism with the slate belt edge precludes the notion of nonconformability; therefore there must either be an upthrow fault; or all the limestone beds must be overthrown and therefore reversed, the lower beds lying upon the upper.

Harrisburg builders, and Reading bridge work.* Dip in all three S. & S. E.

Holler's, at Hummelstown, between RR and Swatara river; 250'x125'x25' face; beds 4" to 3', dipping uniformly 23°, S. 10° E.; stripping averages 3'; sold for building; 4 kilns, output 40,000 bush. per year.—*Rutherford's*, ¼ m. W. of last, on N. bank of river; 200', narrow, 20' face, building stone like last; dip 20° to 30°, S. 40° E.—*Engle's*, on turnpike at bridge, ¾ m. W. of Hummelstown; small, for local farm lime; dip obscure, gently S.

Beaver station group.

Allwein's quarry, 300 yds. E. of Beaver station (175 yds. N. of RR.) *on the edge of the slate belt;* 200' long (on N. side of steep bluff), 25' face; dips observed 30°, S. and 60°, S. 23° W. showing much warping.†

Webner's quarry, abandoned near RR. E. of Beaver station; beds thin, S. dip.—*Rutherford's* quarry just W. of station; 150'x150'; 30' N. wall; dip in N. wall *30° S. becoming quite flat southward along E. and W. walls.*‡ Some beds large and massive building stone; 2 kilns, 20,000 bush. farm lime per year.—*Cassel's* quarry, long abandoned, midway between Beaver and Rutherford stations.

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* None of the layers exceed 4', but there is little cleavage.

† A very interesting locality, being near the east point of a long narrow belt of limestone enclosed between the great slate belt on the north and an isolated branch of it running from it S. W. and W. to the Susquehanna below Harrisburg. The limestone belt must be anticlinal; and the slate branch belt synclinal. On the RR. near Beaver, limestone dips 20°, S. E. towards the southern slate; so also 20°, S. dips are to be found along the south edge of the limestone belt one and two miles from the river. On the RR. approaching the Susquehanna limestone N. dips are seen, as if going under the great slate belt edge to the N. But generally—almost universally—the limestones dip S. at various angles, as will be shown in the description of the quarries between Beaver and Harrisburg. Of course the 30° and 60° S. dips in the text above *must be overturned N. dips.* What makes this more striking are *slate dips* of 35° and 32° S. within a mile E. N. E. of Beaver. These and also, 58°, 40°, 60°, 70° S. dips in the slate belt a mile and more north of Beaver, must be all or most of them overturns.

‡ This would make an *overturn* of the 30° dip an impossibility; and an anticlinal between the quarry and the slate edge on the north a necessity, unless an upthrow fault be made to run the 7 miles from Beaver to Harrisburg.

Paxtang group.

Metz's quarries E. of Paxtang station.—(a) 150 yds. N. of RR. 250′ E. & W. 20′ to 25′ face; hard, thick, building stone beds, dip in S. face 55°, S. 20° W.; in E. face 35, due S.; 4 kilns.—(b) 50 yds. N. of last, 100′x100′x25′; dip wavy, 25° to 35° S. W.—(c) N. of RR. ¼ m. E. of station; regular beds, 1′ to 2½′ thick, dipping 25°, S. 5° W.—(d) S. of RR. near last; beds of pale blue, or bluish grey inclined to be cavernous, 6″ to 2′ thick; output 60,000 bush. in a single year (3 kilns).*— *Wilhelm's* quarry a little north of (c), beds 1′ to 3′, dip 20°, S. 15° E.

Rutherford's (J. A.) ¼ m. S. E. of station, (3 m. E. of Harrisburg) worked in 1884 for fluxing McCormick & Co's Paxton furnaces; large N. E.—S. W. opening each side of Spring creek; beds very fine grained; so much cleft as to obscure the dip, which is S. S. E. in 40′ of beds, S. end.

Rutherford estate quarry ¼ m. S. of station S. side of Spring creek; 2 kilns, best lime hauled to Harrisburg where it brings 16c. per bushel; local farm lime, 7c.; 2240 lbs. coal to 100 bush. lime; 30′ face of good grey-blue strata, dipping 40°, S. 15° E. (cleavage 55°, N. 15° W.).

Rutherford No. 2, N. of RR. close to station; 200′, E. and W.; long abandoned; beds hard, siliceous, like or perhaps the same as the beds in the RR. cuts towards Harrisburg.†

McCormick's quarry, on RR. ⅜ m. W. of Paxtang station and 2 m. E. of Harrisburg; 400′ long (S. W.); best stone now got at S. end; good, pure, smooth-grained, gray limestone, very low in silica, and easily quarried; beds 2′ to 4′ thick; 40′ face; dip generally S. E. but a *small synclinal and anticlinal roll* near center of quarry close to a *clay seam* (*fault?*)‡ Output of flux for Paxton furnaces at Harrisburg 165 cars of 16 tons each per month; quarry

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* See statistics of work, cost, etc., in An. Rt. 1886, IV, p. 1527.

† No dip is given by D'Invilliers; but on Sander's dip map of Dauphin a *N. dip* is here marked; which, if true, is important.

‡ It seems as if the change from the northern 4 to 12 p. c. siliceous beds to the southern non-siliceous beds took place at the clay seam; the color certainly changes there, the siliceous beds being a medium blue.

started April, 1886; steam-drill (2″ diam.) drills 80′ per day.—An old quarry, 300′ E. of last, shows a *synclinal* with gentle dips on S. side and 70°, S. 30° E. on N. side.*

Wister Bro.'s quarry, on RR. 1¾ m. E. of Harrisburg; stripping 8′ over 30′ beds (6″ to 3½″), of good quality, mostly massive, full of cleavage planes; dips at both ends 42°–52°, S. 10° E.

Great quarries are seen in the hills facing the Susquehanna south of Harrisburg, furnishing flux to the iron works.

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* Precisely the reverse of what we should expect; even an upthrow fault north of it would not furnish a probable explanation, for such a fault would have a N. dipping brush on its southern side. We must take this, like so many other structural features of the limestone belt, as an exhibition of the infinitely irregular effects of the general movement-pressure. The common diagonalism of these dips to the straight course of these anticlinal limestone belts is very remarkable and hard to explain.

CHAPTER XXVII.

Limestone quarries of the Great Valley west of the Susquehanna, and in Mountain Creek valley.

Cumberland county quarries.

Opposite Harrisburg there is a continuous exposure of upturned limestone beds in the Susquehanna right bank, and in the railroad cuts, from Bridgeport down (south) to New Cumberland, a distance of two miles; this being the width of the Beaver-Rutherford-Paxtang limestone belt (of the quarries last described) where it crosses the river at and below Harrisburg. The belt is enclosed between the great slate belt on the north, and an outlying synclinal slate belt on the south; as shown on the colored geological map of Cumberland county.*

All the exposures of limestone for the whole width of the belt show south dips; and yet the belt ought to be anticlinal, with south dips at New Cumberland and north dips at Bridgeport. Consequently the south dips at Bridgeport must be *overturned north dips;* but the overturn is so extreme that the beds dip only 30°, with great regularity and perfect conformability along the whole face of the great quarries of McCormick & Co., beginning at the limekiln south of the west end of the Harrisburg bridge. The *lowest beds* at the limekiln must therefore be *geologically* the *top beds* of so much of the series as is exposed in the quarries; and the slates at the bridge instead of overlying them must descend southward beneath them.†

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* Published in Atlas to D5, with Franklin and Adams county maps, etc.

† It is impossible to construct the curve of such a gigantic collapsed overturned anticlinal without imagining a slip fault on the north side of it, either in the limestone or in the slate, or between the two. There is no sharp distinction between the limestone and slate formations; the limestone grows shaly upward and gradually merges into the shales; and this is well shown by Mr. B. S. Lyman's field sections of the *passage rocks* between II

McCormick & Co's (old *Walton*) quarry, about ½ m. S. of the RR. bridge, exposes along the N. C. RR. about 400′ of strata dipping 25° to 30°, S.; varying in thickness from 2 inches to 12 feet solid; and in quality from a nearly pure limestone, with but 1 or 2 per cent of magnesia, to a nearly typical dolemite with 35 or 40 per cent of magnesia.*

Williams' quarry, on Yellow Breeches creek, 10 m. S. W. of Harrisburg, at the junction of the Dillsburg Branch and H. & P. RRs.; purer blue limestone 20′, overlaid by less pure greyish white 20′, dipping 12° to 15°, S. E. good strong lime for local market.

Boiling Springs quarry, 5 m. higher up the creek, west; 60′ face of blue limestone with smooth grain, in plates 6″ to 18″ thick, dipping 20° to 30°, due E. Furnishes flux to Katharine furnace.

Woods', and other smaller quarries between Carlisle and Mt. Holly, on the Gettysburg & Harrisburg RR. furnish farm lime for local market.

Pine Grove quarry on Mountain creek, 7 m. above Mt. Holly Springs, in the heart of the South Mountains, near

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and III in the horse-shoe bends of the Conedogwinet creek north of Hogestown, Kingston and Middlesex a few miles further west. Therefore there is no mode of exactly locating such a fault; nor of determining its exact shape, or vertical extent.

That the faulting was accompanied by much crumpling is plainly enough visible to one standing on the bridge and looking down upon the river bed (at low water) marked with beautiful zigzags of the slate edges; proving that the crumpling was not merely in vertical, but equally in horizontal and in fact all directions.

The overturn is proved also by a 70° S. dip in the slates at the bridge; by the almost universal S. dip exposures throughout the slate belt; by the great width of the slate belt (4 miles from Harrisburg bridge up to Marysville RR. bridge in the gap) which can only be accounted for by many collapsed and overturned folds in the slate belt itself; also, by the S. dips in the outlying slate belt (½ mile wide) at New Cumberland; and by the S. dips of the limestone further south, where it emerges from the S. edge of the same;—all concurring in one generalization, viz., that the Great Valley rocks, of all kinds, along the Susquehanna river, have been thrown into a series of folds large and small, by a northward thrust of the region, which, making the folds, also tightly compressed them, and tilted them over to the north—of course giving a S. dip to them all.

* An elaborate if not exhaustive study of this admirable exposure was published in report MM, 1879, pp. 311 to 362. The main facts and my deductions from them will be given in a subsequent chapter xxviii.

the Adams county line; opened more or less for a mile along the outcrop; but main output from one large quarry of flux for Pine Grove furnace, say 2500 tons a year; thickness of beds, 100′; dip 25° to 30° S. E.; stone blue, massive, low in silica; pit 250′x75′x50′ deep.*

Franklin county quarries.

Williamson's quarry (*Hawbecker's*) on S. Penn. Br. Cumb. Val. RR. 2 m. W. from main line above Marion; near the top of formation II*c* (Trenton), the slates of III outcropping to the W. and N. E. of the quarry; large and fine faces; 75′ to 100′ of beds dipping 45°, S. E. *away from the slate belt*, and therefore *overturned.*

Mt. Alto quarry, ¾ m. from furnace; 60′ face of beds dipping S. E.; good but rather magnesian flux stone; mixed with Harshman quarry flux at Quincy, which shows carb. lime, 95.482; carb. mag., 2.262; ox. iron and al., 0.440; silica, 2.340.†

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* Mr. King reports that these beds contain only 4 per cent carb. mag. and 5 of silica; while the dolomitic limestone in the neighboring ore bank contains 40 of carb. mag. and only 1 of silica. He says the "fat" valley stone shows 12 of silica; and only 0.005 of sulphur, as against 0.125 sulp. in Pine Grove stone. The car wheel iron of Pine Grove requires a minimum of sulphur, and the chemical composition of the flux is therefore carefully studied.

† All the limestone quarries described in the preceding pages, from Reading to Mt. Alto, are more fully detailed in d'Invilliers' Report in An. Rt. 1886, part iv, pp. 1517 to 1562, in an order from S. W. to N. E. But little or no account is taken of scores of farm quarries of very small size, mere pits for obtaining a few loads of stone to build houses, or other farm use.

Chapter XXVIII.

Magnesian beds in No. II.

The most striking phenomenon of this great formation is the subdivision of its vertical column into hundreds of beds of limestone and of dolomite or magnesian limestone, arranged alternately, regardless of their thicknesses, which vary from less than an inch to several feet or even yards.

This phenomenon seems universal to the formation, making its appearance in every natural rock exposure and in all quarries; compelling a systematic selection of certain beds only for the service of iron smelters and lime burners, and the rejection of the others in mining.

It was long ago well known that some of the beds of the formation were highly magnesian, and that other beds were comparatively pure limestones; but no clear idea had been obtained of (1) the relative number of the two kinds in any given thousand feet of the series; nor (2) of the relative proportion of the total thickness of one kind to that of the other; nor (3) of the range of variation of magnesia in any one bed, from top to bottom, or along the strike, or down the dip; nor (4) whether such variations in the charge of magnesia bore any fixed relation to the variable sum of other impurities in the limestone.

The geological and chemical literature of dolomites and magnesian limestone rocks was very extensive; but these special features of their sedimentation had not been sufficiently studied either in Europe or in America. The attention of geologists was fixed chiefly on a search for some probable theory of the origin of dolomite beds as such; and the discussion of that special subject by European geologists was intensified by the Austrian survey of the Tyrolean Dolomite Alps, about twenty years ago.*

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* Richthofen in 1874 discussed the Coral reef origin of the Schlern Dolo-

The iron masters of Pennsylvania have always been par-

mites in the Tyrol. (Zeitschrift Deutsch. Geol. Gesell. Berlin, XXVI, ii. 225–256.)

Mojsisovics defended Richthofen's separated coral-reef theory; referred the conglemerated portions and oblique lamination to surf action, and the thin beds to lagoon distribution. (Sitz. K. Ak. W. Wien, Math. N. H. Classe, Abt. 1, Vol. 71, p. 719.)

Hœrnes in 1875 published a preliminary notice of his views on the genesis of the Tyrolean dolomite beds, in the Verhand. K. K. G. R. p. 290, and at p. 266, notices their change eastward.—In 1876 he published another paper on the formation of dolomite beds in the same, pp. 76 to 80.—Afterwards a full description of this chemical theory of Hœrnes and Dœlter appeared in the Jahrbuch K. K. G. R. XXV, iii, 293 to 332, giving the literature of the subject up to date; a description of the Tyrolese beds and other Alpine exposures; analyses; and their conclusion that the *poor* beds were of organic origin, and that the *rich* beds were possibly organic limestones enriched soon after deposit by the reaction of magnesium chloride; the proportion of lime being afterwards lowered by the solvent action of carbonated waters.

Hoppe-Seyler, in 1875, showed experimentally that dolomite cannot be artificially produced at ordinary temperatures; maintaining that the magnesia of dolomite beds could not have come from eruptive rocks, but must have come from sea water heated by submarine volcanos sufficiently to admit of magnesian precipitations. (Zeitschrift D. G. S. Berlin, p. 495–930.)

Green (W. L.) in 1875 suggested the formation of extensive magnesian limestone oceanic deposits out of the *fine detritus of olivine volcanic sand and dust*, mixed with the extensively distributed fine detritus from coral-reefs. Such a mixture must cover an immense area of sea bottom around the Hawaian islands and in other parts of the Pacific. (Jour. R. Geol. S. Ireland [2] IV, iii, 140–143.)

Murray (John) describes the universal distribution of volcanic debris over the ocean floor, in the shape of deep sea mud, containing also peroxide of manganese, *native iron* and *cosmic dust*, with local mixtures of wind dust from desert regions; and supposes the mixture of such deposits with limestone precipitations to account for the red earth of Bermuda, Bahamas, Jamaica, etc., but thinks that no analogous sediments can be found in the strata of past geological ages. (Proc. R. S. Edinburgh, IX, pp. 247–261.)

E. T. Hardman discussed in 1877 his views of the history of Carboniferous Irish dolomites, favoring their chemical precipitation. (Proc. R. Irish Acad. [2] II, 7, pp. 705–730.)

Analyses of rock dolomite beds in the Carboniferous Limestone and Calcaire Grossier beds of Flanders, and in the magnesian limestone beds of Durham (4 in number) by Corenwinder, will be found in the Ann. Soc. Geol. du Nord (Lille) 1870–4, p. 17, 18, 19.—Analyses of Silurian *dolomitic sandstones*, by Stolba, are noticed in Jour. Chem. S. London, [2] XII, 967, 1874.—Analysis by Roth, using dilute acetic acid on *dolomite limestone*, may be found in Min. Mittheil. heft i, p. 69, 1876.—Analyses of *dolomitic conglomerate*, with description of beds (Trias) are given by W. W. Stoddart, in Proc. Bristol Nat. S. II, i, 39–47, 1876.—Analyses of *insoluble residues* of dolomitic limestones (Cretaceous, Jurassic, Triassic, Carboniferous and Devonian), are given by Pfaff, in the Zeitschrift Ges. Nat. [3] III, p. 273–294, 1878.

ticular in the choice of the beds they quarried for flux stone, being guided for a long time by experience alone, but in later years by the analyses of their own chemists. A vast number of such analyses are on record in the office books of iron works; but while they show the range of dolomite variability in the formation as a whole, they do not show the variability of its beds in series of regular superposition; at least, not in a series of beds sufficiently large to furnish a broad generalization. Serial researches into the chemical character of the quarry beds on the Lehigh were not carried far enough, as may be seen by reference to Prof. Prime's Report D3, 1883, p. 187, where analyses are published of 18 sub-divisions of 5 beds in Troxall's quarry, and of 14 beds in Eberhard's quarry, the latter series being lower in the formation than the former, and nothing coming of the investigation except the two facts: (1) that there is very little variation within each series; and (2) that the upper series is almost exclusively limestone, and the lower almost wholly magnesian.*

In like manner a series of analyses by Dr. Genth of 12 samples of the magnesian limestones (No. II) taken from the banks of the Schuylkill between Conshohocken and Potts Landing, and from beds low in the formation, but not consecutive, merely showed great variations in percentage of magnesia, and especially of silica; three of them, in fact justifying the term "Calciferous sandstone"; and three others being extraordinarily pure limestones.†

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*Thus: Sub-divisions of Troxall's quarry bed A, carb. limo, 77, 80, 82, 82, 80; B. 76, 86, 84, 72, 77, 74; C. 66, 54; D. 76, 61, 84, 50; E. 87.—Carb. Mag. A. 1, 1, 2, 7, 4; B. 1, 0.4, 4, 3, 2, 3; C. 15, 14; D. 4, 2, 2, 1; E. 0.5. (There are probably errors of transcription in the second and fourth layers of bed D.) —The Eberhard beds read: Carb. lime, 55, 54, 68, 61, 64; 60, 55, 64, 60, 57; 60, 59, 50, 57. Carb. mag. 35, 36, 21, 27, 23; 21, 27, 23, 33, 26; 31, 25, 22, 9. Silica, 2, 3, 3, 4, 4; 4, 12, 6, 7; 3, 6, 4, 16; Ferric Ox. and alumina, 7, 7, 7, 8, 9; 14, 6, 7, 2, 9; 6, 9, 14, 17. Phosphorus, .007, .019, .026, .017, .015; .007, .013, .005, .011, .003; .002, .012, trace, .017. A residue of carbonaceous matter varying from 0.12 to 0.84 was left when any of the limestones were dissolved in acids, and represented the organic life of that age. All the Harrisburg analyses showed such *carbon* in percentages from 0.166 up to 0.560. Life must have been very abundant.

† See report C6, 1881, page 126.—Carb. lime, 60, 55, 42, 40, 48; 63, 92, 53, 58, 61; 93, 85.—Insoluble residue, ?, 3, 26, 46, 38; 3, 8, 10, 6, 7; 6, 5.—A complete

A large number of analyses of limestone specimens from various other areas of No. II in the State, made by the Chemist of the Survey, Mr. McCreath, and published in his reports M, M2, M3, and in the reports of the various counties where they were collected, do nothing more than repeat and enlarge the testimony to the infinitely various proportions of lime, magnesia, silica, alumina, etc. in the beds of the formation, leaving the true mode of the variation from limestone to dolomite, to say nothing of its origin and cause, quite unexplained. Up to 1877, no idea of how the magnesian and non-magnesian layers are arranged had been got; no law of regular or irregular interstratification had made itself apparent; it was not possible to say whether the several magnesian beds resembled each other, whether the several purer limestone beds were alike or not, nor in what degree, if at all, the two series represented two kinds of physical action intermittent in the ancient seas. Yet until this was learned we could not make the first step towards a stable rational theory of our larger limestone formations.

I therefore directed to be made in 1877 a careful sampling of 115 beds (with a total thickness of 370 feet) exposed at the old Walton (McCormick) quarry opposite Harrisburg by the Northern Central railway cutting for a length of 800 feet: a consecutive series of beds, all conformable, and dipping regularly southward at an angle of 30°*

This afforded a good opportunity for collecting two sets of samples, two samples from each bed, one at the soil above, the other at the level of the railroad, therefore from 15 to 80 feet apart according to the varying depth of the cut; and

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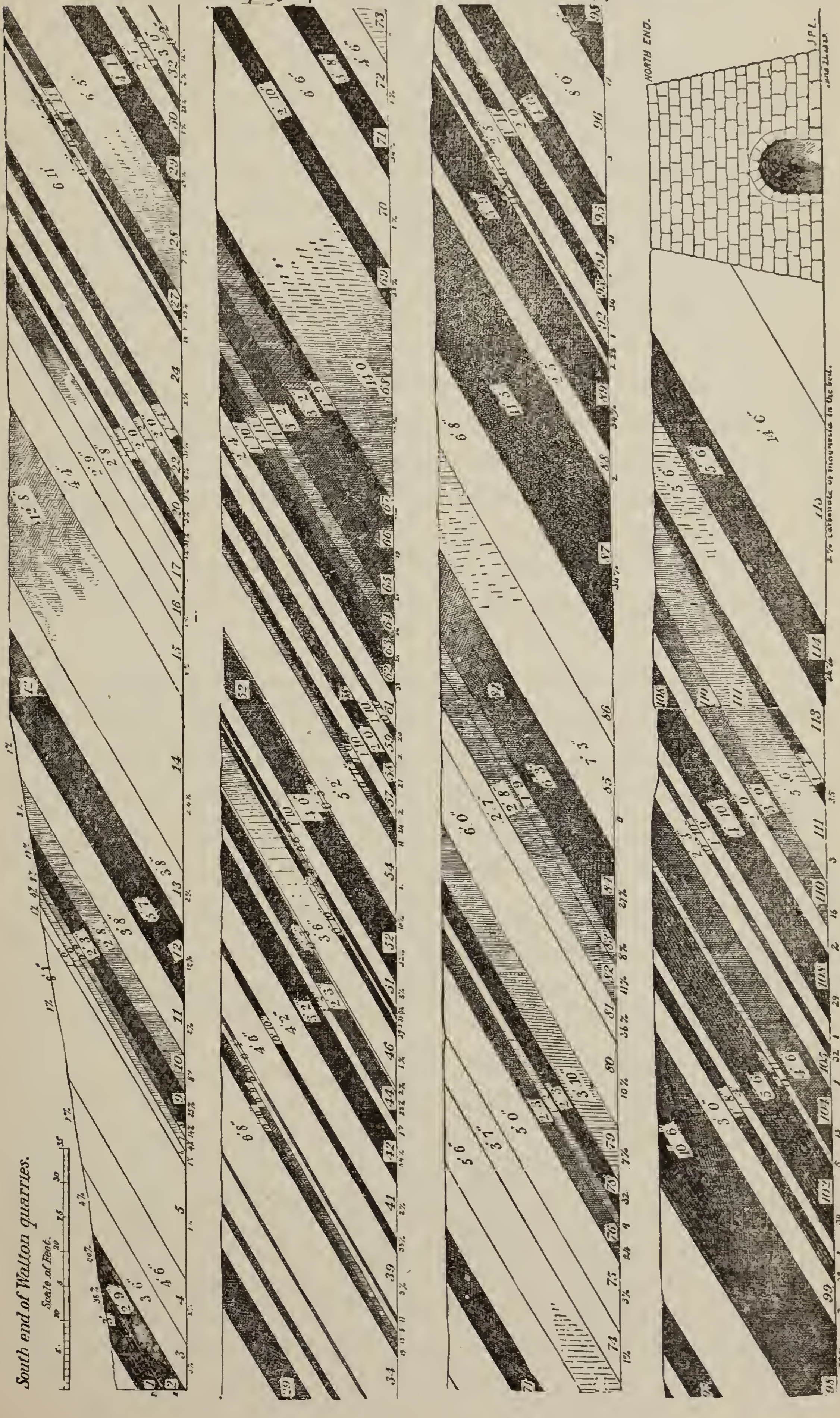
analysis of the *fifth bed* gave: carb. lime, 40.27; carb. mag. 31.24; insoluble residue 28.49 (of which 24.23 was silicic acid or quartz). The specimens analysed, No. 7106, etc. are labeled and preserved in the Museum of the survey.

*The cut was surveyed and the beds marked by Mr. Sanders, who numbered them from 1 to 98 (see Table X, M2, p. 353). Mr. Hartshorne saw reasons for subdividing some of the beds and renumbered them from 1 to 115 (see Table XI, on p. 354). Mr. Sanders' sum total footed up 372′ 9″. Mr. Hartshorne's remeasurement footed up 370′ 10″.

Magnesian limestone beds at Harrisburg, Pa. Final Rept. Chap. 23
reduced from page-plates in Rept. MM, 1879, pp. 355-358. pl. 7.



sometimes a third or intermediate sample. Many of the analyses of individual samples were duplicated.*

A cross section of the exposure was published in M2, p. 344, and repeated (cut up into eight lengths) in four page plates, pp. 355 to 235; all the beds numbered from 1 to 115 along the bottom line; thickness in feet and inches of each bed given on its face edge; *percentage of carb. magnesia* given below and above; the lime beds left white; *the magnesian beds shaded*, the darker or lighter shading showing the *proportionately more or less magnesian* character of the bed.

This cross section reduced one-half linear as exhibited on plate 7, page 331, will give the reader a general idea of the scope of the investigation and the facts it brought to light. For a better study of it the chemist or geologist is expected to resort to my original memoir in Mr. McCreath's Report M2, the results of which I shall here state as succinctly as may be.†

Table I (M2, pp. 345, 346, 347) shows in vertical columns the carb. lime, carb. mag. and insol. matter percentages of each bed, at grade and at top of cut.‡

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* The investigation was put under the direction of the Chemist of the Survey, Mr. A. S. McCreath. The analyses were made in the Laboratory of the Survey at Harrisburg by Mr. Joseph Hartshorne in 1877-8; and concluded by Mr. S. S. Hartranft in the summer of 1878. The analyses were published in full in Mr. McCreath's Report M2, 1879, pp. 312 to 341;—with three very interesting analyses of *calcite* contained in beds 9 and 23 (showing about 88 p. c. of carb. lime; 10 of insoluble matter; 1 to 2 of carb. mag.; about 0.2 of carb. iron; about .03 of sulphur, and about .3 of phosphorus.); —also two analyses of the *flint* in bed 5 (showing 90 p. c. silica; 6 to 9, carb. lime; 0.5 carb. mag.; 0.6 carb. iron; .02 to .06 alumina; 0.05 sulphur; and traces of phosphorus. See M2, p. 342).

† A preliminary account of them will be found in a paper read before the Amer. Philos. Soc., Phila., Dec. 20, 1877, and published in the society's proceedings of that date.

‡ Abnormal analyses are brought out by *bracketing* unexpected and perhaps erroneous percentages, thus:—

	Lime Carb.		*Magnes. Carb.*		*Insol. Matter.*	
	Grade.	*Top.*	*Grade.*	*Top,*	*Grade.*	*Top.*
Bed 17, ...	96.60	[60.20]	1.10	[33.40]	1.10	[5.90]
26, ...	90.00	[70.85]	6.80	6.30	3.40	[22.95]
43, ...	97.80	[91.00]	1.30	[1.30]	1.30	[7.90]
62, ...	[49.80]	61.90	31.90	28.40	[16.90]	8.20
68, ...	85.10	96.00	[10.40]	2.30	3.20	1.90
77, ...	85.50	97.90	[9.80]	1.80	4.50	1.00
80, ...	79.80	95.90	[9.90]	2.00	9.40	2.60
81, ...	54.90	56.70	[35.70]	24.00	7.70	18.40
84, ...	66.80	[75.60]	[27.20]	16.30	4.40	5.60

N. B. All percentages given in these tables are only to one or at most two figures of decimal.

The first thing noticeable is that not a single one of the 115 beds is entirely destitute of the magnesia carbonate; and that in no bed does the magnesia carbonate rise high enough to make the rock a perfect dolomite.*

The second remarkable fact is that the alternation of magnesian and non-magnesian (*i. e.* of high and low magnesian limestone) beds is constant, rapid and sharp; for in only one case, that of the group of beds 6, 7, 8, 9, 10, 11, is there any appearance of a gradual increase and decrease of magnesia in a sedimentary sense.† Seldom a bed occurs with any intermediate percentage between the very high and very low.‡

The third fact is equally striking and important, viz., that so far as analyses at the two ends of the exposure of a bed can warrant the assertion, each bed is wonderfully homogeneous in its magnesian character, whether high or low. In only a few cases is there any practical difference in the percentage of magnesia at grade and at top. In those that do occur, however, the difference is as great as that which marks the alternate beds.§

A fourth important fact is, that the greater percentages of insoluble matter (silicates) are almost invariable found in the high magnesian beds, the beds which are free of magnesia being free of silica and alumina likewise.

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* Bed 85 has only 0.9 at grade (4.1 at top); and bed 2 has 38.50 at grade (39.75 at top).

† In these the mag. carb. p. c. runs thus: 1.40, 3.60, 14.50, 24.80, 8.05, 1.80 at grade (and 1.30, 3.70, 7.50, 27.00, 8.15, 1.30 at top). This is also a fair example of the remarkable uniformity of the two percentages at grade and at top in each bed; proving (1) the general chemical accuracy of the laboratory work, and (2) the general homogeniety of each bed from end to end of its exposure.

‡ Such however are beds 14, 33, 36, 38, 55, 64, 84, 97, 104.—Of the 32 beds from 84 to 115, half of them are low (12 under 2.00, 3 under 3.00, the remaining one 4.6); and of the other half all but two are high (9 range between 36.00 and 30.00, five between 30.00 and 25.00; one is 17.00, the other 14.00). On page 348, M2, these are so arranged in a table that the rapid alternate up and down oscillations are patent to the eye. It is specially remarkable how few beds occupy an intermediate chemical position between the extremes.

§ In how many of these instances the difference may be due to some accident in misplacing the samples, I cannot tell; but they are so few that they offer no great obstacle to a conviction that each bed is really a homogeneous deposit.

Other facts are, that the planes of separation between bed and bed are ordinary bed planes as in sandstone and shale strata;—that no current, cross, or false-bedding is visible;—that some of the beds (of both species, magnesian and non-magnesian) are only a few inches thick, while others are 6′, 8′, 10′, 12′, even 14′ (bed 68) thick; that there is no rule by which to connect the thin beds with one species, nor the thick beds with the other;—that a limestone layer only 5 or 6 inches thick crosses the whole exposure between two equally thin layers of dolomite, with no show of grading into each other (the same analysis being got at both ends;—that two thick limestone strata will enclose a thin magnesian layer; and vice versa two massive dolomite beds will enclose a thin limestone layer;—and finally, that beds of the highest and lowest magnesian character lie directly and repeatedly in contact with each other.

Negative deductions from the facts.

The only generalization I can make from the above data is a negative one, namely: that no theory of percolation can account for the facts; that no theory of more rapid dissolution of carbonate of lime, leaving a growing charge of carbonate of magnesia behind, will apply to rocks which are neither honeycomb, nor visibly porous, nor unusually cleft, nor otherwise disturbed; and that any theory to account for the presence of the magnesia must treat the layers of both species as equally mechanical sediments; especially, seeing that the larger part of the insoluble matter resides in those which contain most magnesia; while magnesia is present in all of both kinds.

Amount of Magnesia present.

There only remains to be considered the question: whether there be any feasable mode of calculating the *actual quantity of carbonate of magnesia in the formation*, or in this exposed subdivision of it, *in proportion to the actual quantity of carbonate of lime and insoluble matter* which together make up the bulk of the deposits. In other words: what are the average proportions of the three principle elements of strata 370 feet thick, by which we can judge of their distribution through the whole formation several thousand feet thick.

In attempting this problem the beds were at first grouped in fives and averages taken (Table II, p. 349, M2); then in tens (Table III, p. 350); lastly in three groups of 50, 50 and 15 (Table IV), which yields a final average for the whole 115 beds as follows :—C. L. 80.662 ; C. M. 14.215 ; I. M. 4.715.*

Excluding the third element (insoluble matter) and calling the carbonates of lime and magnesia 100, their average proportion to each other in the whole 115 beds, taken together as a solid series, stands 85.02 : 14.98.

The next step in the calculation was to separate the beds into two series : the limestones (L.) and the magnesian limestones (M.), and treat each series separately to get a grand average for the whole. For this purpose I selected the 29 beds at the north end of the section (next the limekiln), 15 of them high in magnesia and 14 low, alternating with remarkable regularity.†

Combining the top and bottom analyses of these 29 beds, we get the following *general average analysis* of the high magnesian beds (M) and the low magnesian beds (L):—

Table VII, { (M), . C. L. 63.41 ; C. M. 28.22 ; Insol. 7.24
{ (L), . C. L. 95.77 ; C. M. 2.06 ; Insol. 1.42 ‡

which is probably as good a formula for the chemical distribution of the lime and magnesia constituents of our Cambro-Silurian (or Ordovician) limestones as we are likely to get by any such method.§

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* The reasons for the failure of worthy results from the smaller groupings are given in M2, p. 350.

† Of the 164 percentages five were abnormal. These were included in Tables V, VI but excluded from Table VII, p. 351, the general result being however but slightly affected.

‡ The direct proportion of C. L. to C. M. however is in (M) 69.2 : 30.8, and in (L) 97.9 : 2.1 (Table VIII).

§ To try the method in another form I selected 57 high and 58 low magnesian beds (using only the figures of the fourth column of Table I) to be treated in two separate series, sub-divided into four groups of beds (1) beds 1 to 30 ; (2) 31 to 60 ; (3) 61 to 90 ; (4) 91 to 115. The result was as follows :—

Table IX. { (M) . . . . C. M. (1) 27.96 (2) 23.56 (3) 26.05 (4) 27.04
{ (L) . . . . C. M. (1) 3.01 (2) 2.62 (3) 2.25 (4) 2.00

giving a general average of *carbonate of magnesia* in the 57 high magnesian

The *different thicknesses of the beds* must now be taken into consideration; for no possible combination of two analyses from each bed of a series could possibly give the true proportion of lime and magnesia in the whole series *unless the beds of the series were all of equal thickness.**

Treating the beds according to their thicknesses by the formula given in the foot note, but using only the percentages of C. L. and C. M. in columns 1 and 3 of Table I (that is the samples at grade line) I got the results of Table XII, (M2, p. 359):—

132.6′ (beds 1 to 50)	C. L. 92.00	C. M. 12.20
179.9′ (" 51 to 100)	" 79.25	" 14.00
59.5′ (" 101 to 115)	" 83.75	" 11.86
371.0′ (" 1 to 115)	" 84.47	" 13.02

Considering the probable animal origin of the flints from sponges, and the proven animal origin of the oolite beds from broken up bryozoa, together with the known abundance of molluscs, articulates, etc. in the waters of that age, it is reasonable to ascribe part of the surplus of lime over magnesia to that cause; the small amounts of sulphur to plant life; and the small amounts of phosphorus to animals like *Lingula* which preferred phosphate of lime to carbonate of lime for making their shells; or perhaps to large armored fish which a recent discovery informs us lived in great numbers at the beginning (or before the beginning) of the Trenton age; though why no traces of such fish have been reported from any Lower Silurian outcrop in the world except only at one spot on the Colorado river is wonderful enough.

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beds, 25.89; and in the 58 low magnesian beds, 2.53. It will be noticed that this result differs somewhat from that in Table VII in the text above, where the figures read 28.22 and 2.06; but not more than we might expect from using 115 beds in one case and only 29 beds in the other.

*Suppose for the sake of illustration we have a series of 100 beds, half of them averaging C. M. 2.00, the other half averaging C. M. 30.00; if they were all of equal thickness the *general average* would be, of course, C. M. 16.00.—But suppose the first fifty had an average thickness of only 1′, and the other fifty an average of 6½′ (making a total of 375′), the calculation must run thus: $50\times1'\times2.00+50\times6.5'\times30.00=9850$ per cent.; which divided by 375′ gives a *general average* of C. M. 26.70.—If the 1′ beds were 30.00 p. c. and the 6½′ beds were 2.00 p. c. the *general average* would be only C. M. 5.73.—Of course all this is only true on the presumption that each bed is in itself homogeneous and would give the same percentage wherever sampled; which is evidently not quite the case.

CHAPTER XXIX.

Hydraulic Cement Quarries of No. IIc (Trenton) on the Lehigh—Gypsum.

These were referred to shortly in Chapter XXV, but their importance demands a more detailed description. Four companies have quarried and burned the stone, two on the west and two on the east bank of the Lehigh at Coplay, where the Trenton limestone with its cement beds, crosses the river. These works are described in Prof. Prime's Report, D2, 1878, pages 59 to 67.

The Lehigh Hydraulic Cement Company commenced operations in 1872, on the west bank, 1 m. above Coplay station, Lehigh Valley RR. In 1874 the mill was burned down. It had 3 run of stone, and could grind 300 bbls. a day; four kilns of No. 12 pattern as decribed in Gen. Gilmore's book on cement; quarry near mill; color of cement light yellow; very like in color and quality the old Lehigh and the Allen cements.

The Coplay Cement Company, organized in 1867, have 11 kilns a short distance above Coplay station, 6 miles above Allentown; the quarry adjacent; a steam engine hoisting the quarry stone to the kilns for burning Anchor cement, and at the same time running the crushers for Portland cement; 7 set-kilns burn Saylor's Portland cement (Hubett's London pattern) built of cement, concrete, firebrick and iron; total capacity 2,500 bbls. of Portland cement clinker per month. The other 4 are draw-kilns, of Rosendale, N. Y. pattern (Gilmore's No. 12), burning Anchor cement, 300 bbls. per day. Store room capacity 15,000 bbls.

Some beds of the quarry are fit for Portland, others for Anchor cement; but good technical knowledge is needful to decide what stone to use and what to reject, that the product may successfully stand the engineer's tests. Of the samples of Portland cement made from 8 beds (of which analyses are given below) some were very good, while others fell far below the required strength.*

The requirements of the Department of Docks, New York, in purchasing are as follows: Weight, per barrel, 400 lbs.; weight, per bushel, 110 lbs.; fineness, 80 per cent.; tensile strength, at seven days, 250 lbs. per square inch.†

Tests of Saylor's Portland cement as packed and offered for sale in market, 4 in number, are tabled D2, p. 61:—Weight per cubic foot, 112 lbs.; fineness through a 2500 mesh sieve, 85 to 100 p. c.; date of grinding Jan. 12; dates when blocks were made, April 26 to 30; weight of block, 24 and 25 oz.; weight of water in each block, 5¼ to 6 oz.; temperature of cement and water, 60° Fahr.; time to set in mould, 16 to 20 minutes; time left in mould, 90 minutes; immersed immediately; left in water 6 to 7 days; broken immediately on being taken out of water; age when broken 6 to 10 days; average tensile strain on square inch, 411, 392, 426, 566 lbs.; 3 blocks made of each; tensile strain per

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**Analyses of quarry rock for Portland cement by Mr. John Eckert, under Prof. W. B. Chandler.*

Analyses of quarry rock for Portland cement by Mr. John Eckert, under Prof. W. B. Chandler.

Silica,	12.88	12.81	13.72	14.68	15.03	15.40	14.79	14.32
Alumina,	4.25	4.86	4.09	5.32	3.97	4.26	4.50	4.20
Ferric oxide,	1.09	.97	1.04	1.12	1.93	1.38	1.34	1.65
Carbonate of lime,	72.87	72.64	71.54	69.26	74.12	74.66	72.95	73.12
Sulphate of lime,	1.60	1.68	1.79	2.29	1.19	.86	1.75	2.02
Carbonate of magnesia	4.69	4.62	4.37	3.67	2.41	2.66	3.84	4.09
Phosphoric acid.	.10	.11	.10	.09	.13	.09	.06	.17
Organic matter,	1.57	1.72	1.78	1.68	1.47	1.88	1.46	1.31
Total,	99.05	99.41	98.43	98.11	100.25	101.19	100.69	100.88

Analyses of Portland cement made from the above beds.

Silica,	22.71	22.04	23.26	23.40	23.33	24.25	23.21	23.07
Alumina,	9.85	10.11	7.88	8.06	8.73	7.88	8.35	7.32
Sesquioxide of iron,	2.52	1.61	2.70	2.38	1.83	2.14	2.74	2.49
Sulphate of lime.	2.31	1.78	1,98	2.44	1.92	1.63	2.36	2.17
Lime,	58.98	61.93	60.50	59.94	60.52	60.28	58.50	59.04
Magnesia,	2.31	2.13	3.53	3.21	2.61	2.67	3.05	3.27
Total,	98.68	99.60	99.85	99.43	98.94	99.88	98.21	97.36

†A copy of official report on 1,000 bbls of Saylor's Portland cement, tested Nov. 13 to Dec. 20, 1877, is printed in D2, p. 62. Average gross weight per barrel, 400 lbs.; average weight of U. S. bushel, 131 lbs.; number of barrels sampled, 105; average fineness, 82 p. c.; average tensile strain per sq. in., 347 lbs.; number of minutes in mould, 53 minutes.

section of each block, (1) 875, 976, 925; (2) 825, 825, 1000; (3) 950, 1025, 925; (4) 1325, 1350, 1150 lbs.*

Saylor's Cement is fully equal to the English and French Portland cement and is manufactured by the same patent Aspdin process (1825), except that the quarry rocks at Coplay yield all the needful elements, and therefore, does not require the addition of clay, etc.†

Anchor Cement is a patented light burnt cement of a peculiar chemical composition; sets rapidly; has great cohesion; becomes uncommonly hard both under water and in air; has a beautiful greenish gray color; makes smooth and uniform drain pipes, turned out rapidly from the mould; is desirable for beton or concrete for bridge piers and abutments.‡

The Old Lehigh Cement Works near Siegfried's bridge, E. bank of Lehigh river, erected by the Lehigh Naviga-

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*Prof. Prime writes (D2, p. 62) Portland cement in England is made by burning mixture of chalk and Thames river clay to a partial vitification. All attempts to find (or to properly mix) the proper rocks failed to produce a cement equal to the best English and French brands, which is a triple silicate of alumina and lime and iron, *without any free lime*, as a sharp crystalline powder, varying from dark to light gray, with a bluish or greenish tint. The Coplay Cement Company after long and costly experiments in selecting and mixing several beds in their quarry got an analysis thus:—(1) Soluble in hydrochloric acid: Carb. lime, 70.34; carb. mag., 4.47; carb. iron, 2.98; (2) Insoluble silica 14.73; alumina, 4.54; ferric oxide, 0.93; magnesia, 0.89; water, 0.98=total 99.86. This mixture, when its carbonic acid was driven off in the kiln, analyzed: Silica, 22.77; alumina, 7.03; lime, 60.91; magnesia, 4.67; ferric oxide, 4.63=100. Prof. W. T. Roepper of Bethlehem. But as the same quarry bed varies in quality, samples of stone are frequently analyzed and burned in a testing kiln. The stone is crushed and ground, thoroughly mixed dry and tempered with water in a pug mill, spread out on drying floors, cut into bricks, placed in a kiln with alternate layers of coke and burnt; the clinker is then selected, the pulverulent scarified, and the underburnt taken out; the burnt bricks then ground and stored in bins for a few weeks to sweat and cool before shipment to Communipaw to be barreled and stored.

†The N. Y. Dock Department used 5000 bbls. of it in 1877. The U. S fortifications have made much use of it; Gen. Gilmore fully endorsing it. The East River Bridge Co. used it, Engineer Martin endorsing it; and it received a medal at the Centennial Exhibition.

‡It was selected before all other American cements for the Girard bridge at Philadelphia. See reports of tests in Journal Frank. Inst. Phila. March 1874, p. 181 (copied verbatim into Report D2, p. 65, 66). The mixture finally fixed on was: Anchor cement 1 part, sharp river sand 1 part; furnace slag, 4 parts.

tion Co. In 1872 leased by Gen. J. Selfridge and enlarged to 200 bbls. a day ; new quarry opened on Hokendaqua creek, 1 m. E. of old quarry and on the same rock beds of argillaceous limestone. Idle after 1875.

The Allen Cement Company, organized (1872), works at their quarry on Hokendaqua creek, 1 m. E. of Siegfried's bridge, Northampton county; 2 small draw-kilns and 2 run of stone ; steam power ; 75 bbls. per day of "Allen" or "Keystone" light yellow cement. Idle after 1875.*

In Mifflin county.

A new dydraulic cement plant is about being established at Milroy in Kishecoquillis Valley, on an outcrop of Trenton limestone (1891).

In Centre county.

Hick's Cement Quarry is on Logan's branch, south of Bellefonte, in Spring township, close to the Benner township line. It is a small quarry of magnesian limestone (dipping 15°, S. 38° E.) near the junction of IIb (Chazy) and IIc (Trenton) and therefore at the same geological horizon as the cement quarries on the Lehigh near Coplay. Excellent limestone beds, 150′ thick in all, show below the cement works, dipping 40°–50°, S. E. The plant consists of two double kilns, each holding about 200 bushels, capacity 1600 bush. per annum. It is near the site of the old Valentine furnace. (Report T4, 1884, pp. 314, 341.)

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*Prof. Prime in his report D3, 1883, p. 164, reported that both these works had been idle up to that date, and added : "It must not be supposed that because these operations have been apparently unsuccessful, that there is no future in the business of manufacturing hydraulic cement in this part of the State, on the contrary the success of the Coplay Cement Co. shows what perseverance under difficulties can and does accomplish. Of course, the composition of some of these cement-stone beds is far more favorable to the manufacture of cement than that of others, but all may be more or less profitably utilized by careful intermixture. There is no reason why the manufacture of hydraulic and Portland cement should not be slowly and surely extended, not only by rendering this portion of the State free from foreign competitors, but actually rivalling these in many of the Western markets on account of the excellence of the product and the cheapness of freights."

CHAPTER XXX.

Limonite mines near the top of II.—Ironton in Lehigh; Moselem in Berks; Cornwall in Lebanon; Mt. Pleasant in Franklin; Henrietta in Blair.

Along the northern edge of the limestone belt of the Great Valley in Lehigh county, that is, not far from the foot of the low hills which mark the southern limit of the slate belt, and therefore along the outcrops of the *top beds* of the magnesian limestone formation, lie a range of limonite mines of considerable age and size, one of which is the famous old *Balliet mine*, now known as the *Ironton mine.*

It is difficult to make a clear statement of the geological situation of the *damourite slate*s which have furnished the material for these pots of white and black clays, brown hematite iron ore, and oxide of manganese; but they seem to be transition beds between the magnesian limestones of II and the purely argillaceous slates of III; and it may be said without much fear of error that they are the representatives of the *Trenton formation*, or of the lower part of it, because Trenton fossils mark the range of argillaceous non-magnesian limestone beds which is traceable from the cement quarries at Coplay on the Lehigh to and *behind* the Ironton mine, that is between the ore pit and the slate hills.

How the *Utica black slate formation* (*IIIa*) is connected geologically with the black clays of the mines it is not easy to say; for this formation has no conspicuous outcrops along the Great Valley, but only manifests its presence here and there at long intervals between the Delaware and Potomac, and seems to be merely a part of those passage beds from the magnesian limestones of II up to the clay slates and roofing slates of III which are so admirably and repeatedly exposed, standing vertical, in the bluffs of the oxbow bends of the Conodogwinnet in Cumberland county.

Some of these mines are close up to the edge of the slate (III); others are at a distance from it of several thousand feet, and ought to be at considerable depths below the slate in the geological column.

Beginning with the first mines west of the Lehigh, on the line of the Ironton railroad, we have, near Egypt, and 2 m. W. of Coplay:—

P. Steckle's three abandoned excavations, 1600′ long. The west end of the west one is ½ m. from the edge of the slate belt; and yet on its south side is a large bank of the Hudson river slate (III*b*.) with a small quantity of Utica black slate (III*a*.) on the dump. In the middle pit a little black and red clay on N. side, and slate in several places. It looks as if it were a deposit of surface ore in gravel overlying slates of III*a* and possibly III*b*. Blue and black clay (III*a* decomposed?) was struck halfway down shafts sunk in middle pit, and little or no ore found (D2, 46.)*

D. Steckle's two abandoned pits in a parallel line with the last, 1000′ distant to south; gravel ore.

J. Ritter's mine, west of the last, and only 800′ from the edge of the slate belt (as drawn on the large map of Report D2), is 800′ long by 500′ wide; abundance of black clay at its south end in both E. and W. walls, and just below the sod; *just under the black* (and also east of it) an abundance of white and pinkish clay; line of color sharply defined; composition the same,† dip different (black N. W. white S. W.) but this may be due to folding and settling when the sup-

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*It must be kept always in mind that the slate belt once extended over the limestone belt. These gravel banks are on two sides of a shallow vale descending eastward, and they are the remnants of a much more extensive drift deposit, the main body of which has been swept away in the erosion of the vale.

†Analysis of "white clay" (1), and "yellow clay" (2) by I. R. Shimer of Lafayette College, and of "yellow clay" (3) by A. S. McCreath are given in Report D, 1874, pp. 13 to 33. The yellow clay is used as ochre for paint. In the range of limonite mines along the base of the South Mountain between Easton and Bethlehem the miners call the White clay "hill clay" and ceased to look for ore when they struck it, and are careful not to go through it for fear of being drowned out. It is a working hypothesis that as the damourite slates were turned into clay they were able to play the part of an impervious water-bearing stratum, upon which iron solutions remained tanked and threw down their limonite. (Prime, in D. p. 14.)

porting floor of limestone was dissolved away.—N. B. Here there is a layer of limonite 8″ to 13″ thick which *cut through both black and white clay.*[*]

The Ironton mine, 2000′ long by 800′ broad and 90′ deep (in 1878) is owned, at the east end by the *Balliet heirs*, in the middle by the *Balliet brothers*, and at the west end by the *Ironton company;* worked since 1837, when the ore showed itself above the surface of the soil; limestone beds at various points deepening from east end to west end; walls mostly plastic (damourite) clays, mostly iron-yellowed, much white, some manganese, pink or red, also masses of (Utica) black at N. W. end, in center, and at east end.

The black clay masses, once continuous and now separated by mining the ore, contains itself a curious ball ore (*siderite, carbonate of iron*) like that so common in the coal measures, but too little of it and too scattered to be worth mining. *Native copper also occurs in the black clay*, in small filiform pieces, having been reduced to nature by carbon in the clay. The black clay deposit varies from 1′ to 10′, and sometimes swells to 20′. It contains *graphite*, which makes its genesis from the Utica slate still more probable.[†]

Ore occurs in various parts of the mine, mostly under the black clay, especially at the west end, in the central deep pit, and along the northern side.[‡]

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[*] This remarkable fact is of great importance, but only increases the obscurity under which the origin of our limonite deposits lie. If the original undecomposed black and white slates were of the same age and conformable, the ore must be of that age; if the clays are of different ages the segregation of the ore layer must have occurred later. The ore of this curious layer yielded to McCreath: Iron, 39.3; mang., 0.006; sulp., 0.008; phos., 1.27; insol., 28.20. The ore from the pit floor: Iron, 47.7; mang., 2.97; sulp., 0.05; phos., 0.33; insol., 12.60. Crane Iron Co.'s analyses are given on p. 46, D5.

[†] Analysis of black clay (called "blue ochre") by Dr. Genth:—Loss by ignition in closed crucible (water), 4.84; ditto in open crucible (*graphite*), 4.26; quartz, 44.50; combined silica, 26.25; alumina, with traces of ferric oxide, 17.95; magnesia, 0.94; alkalies etc. (not determined), 1.26 = 100. (D, p. 32.)

[‡] The quantity of manganese in the ore is surprising. An average sample of ore taken from the Ironton RR. Co.'s wharf, analyzed by McCreath, gave: Iron, 26.40; manganese, 17.65; sulphur, 0.01; phos., 0.09; insol., 21.86. (D2 43.)

Local beds of *black oxide of manganese* has occurred twice; one in 1872 over a part of the limonite yielded a good many tons; another in 1875, in the deepest part of the mine, just over the limestone floor, yielded several hundred tons; just over it a red clay separated it from the overlying limonite.*

P. Brown's mines, 70′ deep, is only 100′ from the east end of the great Ironton mine, and lies exactly in the center of the trough; ore-breast 30′ to 40′ high at W. end, consisting almost entirely of pure ore, with intermingled damourite slate and clay and more or less allophane.†

White damourite clay, in the east wall, under the incline-plane contains *lignite* (carbonized wood) and *fossil leaves;* a *beech nut* has been found in it; of course of *post-tertiary age.* The clay lies on the ore and is a deposit of human age; whatever the age of the ore may be; but probably both are of the latest geological age, and in fact deposits in a cavern, which has lost its roof. *Black clay* (*Utica?*) overlies the ore thickly in the N. wall, but has been swept away from the south wall.‡

The limestone floor beds dip S. E. and N. W., in such a way as to make a synclinal basin or trough, which runs east, south of Ritter's mine; and this trough holding the ore mass and sinking westward towards the head of the cove, makes the ore mass greater and deaper westward. There are signs of exhaustion, unless ore be found W. of the road to Balliettsville; and eventually in any case in that direction the edge of the slate belt will cut the ore

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* Mostly shipped to Johnstown for spiegeleisen. Analysis of average specimen by McCreath, Mang. binox., 77.96; mang. ox., 4.32; ferric oxide, 3.66; silica, 4.84; alumina, 0.71; baryta, 0.15; lime 0.77; magnesia, 0.24; soda, 0.37; potassa, 3.04; cobalt ox., 0.39; nickel ox., trace; copper ox., trace; phos. acid, 0.15; water, 3.98. A picked specimen gave mang. binox., 84.88+ox. 3.77; cobalt ox., 1.68; lime, 1.90; mang. 0.79; soda, 0.19; pot., 3.50; water, 4.38 (D2, p. 42.)—Manganese appeared at the surface near the Big Spring, W. of Trexlertown. (H. D. Rogers, 1858.)

† A very fine white and sky blue stalactitic hydrous silicate of alumina, vitreous or resinous, waxy or pearly, found in masses at the Cornwall mine; at Jones' mine near Morgantown, Berks county.; at the Friedensburg zinc mines; and here.

‡ For mining prospects and analysis see D2, p. 44.

mass off, for "at no point hitherto has the ore been followed in under the slate."

Ironton is at the W. end of the mine, and the cove of limestone is made by the projection E. of a sharply pointed prong of slate (III) more than a mile long; the real synclinal of the district; the trough in the cove being a mere local roll, although a large one.*

The Ironton RR. Co.'s Kennel mine, and the *H. Mickley* abandoned and exhausted, lie to the south of the slate prong and 1000′ from it. Damourite white clay and Utica? black clay in the latter. The former mostly yellow plaster clay, but some white, and a little black clay *overlying the white;* a little ore visible in contact with and *under the black clay.*†

The great Siegersville limestone cove, further south, contains many mines, none of them less than half a mile from the edge of the slate belt, and most of them a mile or two from it. They are all described in D2, pp. 34 to 39; many abandoned; some mere wash ore; most of them showing white clay.

S. Sieger's mine at Siegersville, worked at E. end, has a 6 inch ore layer under the sod; then 12′ barren; under which ore bed 2′ to 4′; ore in shaft in floor *reported* 40′ thick;

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*But, as an illustration of the difficult geology of the limestone belt, observe on the map the long (N. E. and S. W.) line of observed limestone dips *obliquely crossing the point of the slate prong*, and reading only 32°, 23°, 28°, 32°, 12° (at the point), 11°, 22°, 25°, 32°, 24°, *S. E.* Even the violent theory of a collapsed overthrown and flattened down synclinal will not explain so puzzling an exhibition. It almost justifies the theory of the nonconformability of III upon II. To increase the embarassment there are dips of *N. E.* 17° and 28° *in the slate prong* along the high road. (See the fine colored map of the Ironton mines in D2, pocket.)

† A remarkably beautiful colored geological sheet map of the Ironton group of mines and slate prong which separates them may be found in a pocket to Report D2, 1878. The limestone in the mine floors, the ore masses, the red, white, yellow, and red clays, and the undecomposed slates are all distinguished by separate colors. The depths are shown by contour lines, which are also extended over the whole sheet. It is a rarely perfect exhibition, on a scale of 300′ : 1″ of an unusually complete piece of difficult field work. It is dated 1875, and is the work of Mr. Ellis Clark, Jr., aid to Prof. Fred. Prime, Assistant Geologist in charge of the Survey of the Lehigh region.

much lump ore and blood red clay; in one place *limestone over the clay*, the limestone "thoroughly permeated by damourite.*

Jas. Kline's mine, at Orefield, ½ m. S. of Siegersville, is within ½ m. of the N. edge of the long *synclinal slate prong* which runs out eastward four miles, eastward N. of Wennersville. Most of the ore is extracted. At N. E. corner soil 20′ deep; then red ore bearing clay 10′, then yellow and white clays streaked with ore; very little lump ore found. Damourite slate sticks so closely to much of the ore that it cannot be separated by washing. White clay both above and beneath the ore. At W. end, soil 14′ feet; then all white clay down to standing water, with a good deal of only partially decomposed damourite slate in the clay. Yield of mine has been great.

B. Weaver's mine, 1 m. E. of Orefield and Guthsville, and *just on the north edge of the slate prong;* 40′ deep; near top damourite slate with white ore clay underneath; at N. end *damourite slate holding thin strings of ore*, but the ore mass is beneath it; slate resembles No. III.

The *Thomas I. Co. and Crane I. Co. and D. A. Guth's* and the two *Wanner mines* range eastward along the north side of the slate prong. They have furnished large quantities of ore, but are exhausted. At Guth's mine limestone is seen dipping S. E. towards and under the slate prong; but the *Utica slate* (*?*) *seems to dip N. W.*

Toward the end of the slate prong are six mines: *Kratzer's*, *Jobst's* (2), and Scherer's, on the north edge of the slate prong; Marck's at the extreme point; and Barber and Alney's on the south edge near the point. In these are seen pinkish damourite slate, and sometimes a black slaty rock which may stand for the *Utica*. The whole range are abandoned.

In the next limestone cove 3 m. N. W. of Trexlerville, there are about 15 mines, mostly abandoned, all but one within

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*This either shows a cavern deposit of clay, or proves the decomposition of damourite layers far down the stratification beneath an insoluble roof of limestone beds.

½ m. of the edge of the slate:—Lichtenwallner's, Loros' (two), Stein's (two), Moyer's, Steininger's (two), Scholl & Co.'s, Miller's (two), and Haines' and Smith's (Schlong's), the last two in front of the east point of the slate prong which shuts in the cove.*

In the centre of the Cove a mile from the slate edge Kræmlich & Lichtenwallner's mine (D. p. 42), 50′ deep, not worked since 1873, *has its ore mass lying on horizontal blue limestone*, probably the flat crown of the anticlinal of the cove. There is evidently a large amount of damourite slate and white clay *underlying the ore* and in some places *inside of it.* If we could tell the shape of the arch, this would settle the question whether or not some of the Lehigh limonites were made from damourite sub-formations in the body of No. II. But if the arch is flat, or subdivided by a synclinal, the damourite clays in this mine may also belong to the slates at the top of II.

At the head of the next shallow limestone cove and close against the edge of the slate belt, 1½ m. N. W. of Breinigsville, is *Fr. Breinig's* large exhausted mine, 50′ deep; but a small pit on the east of it was still worked in 1874; ore streaks in damourite slate and white and yellow clays; ore and clays pitching 18° to 25°, S. 80° E. *away from the slate belt!* And yet a glance on the large sheet map of D2 is sufficient to show a bridge of slate (III) thrown across

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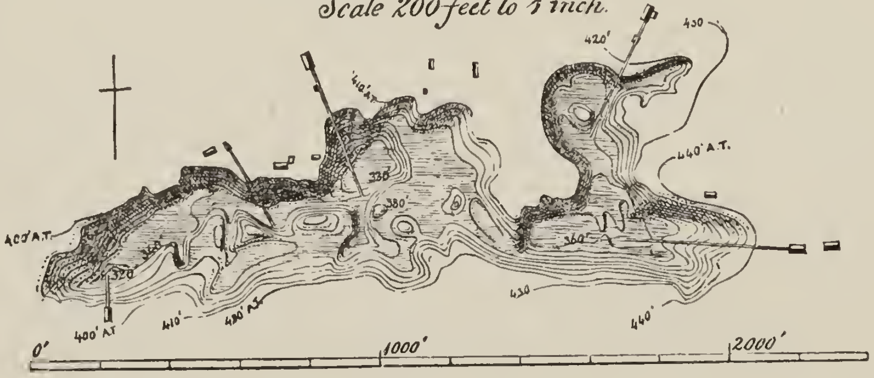
*In *Lichtenwallner's* pits (one 40′ deep) the ore lies both on and under white clay over damourite slate; blue limestone reported at the bottom of a well 130' deep.—At Loros's mine a gravel of clay, quartz and slate (all in small pieces) 15′ deep covered the west end.—*Stein's* oldest mine must have had a great output. The other leased to the Thomas I. Co. shows no slate; the ore lies in and over white and pink damourite clays 47′ deep; limestone at 40′ in one place dips 42°, S. 41° E. (top layers drab slaty 4′, laying on common blue limestone water worn); ore clays over the limestone dip 42°, S. 40° E. *A hole 10″ square in the floor drains the mine into some unknown cavern.*—*Moyer's*, a new stripping (1875). *Steininger's* old mine; very productive; 600′x20′ deep; exhausted. The other leased by Lanigan, 25′ deep; ore *in damourite slate overlying white* clay, dipping 22°, S. 40° E. In one place *under 12′ of solid white clay* is ore 6′, then clay 12′.—*Scholl & Co.'s* ore in *rolling clay;* general average dip 10°, S. 5° E.; local dips. to S. W. (one of them 55°, S. 25°. W); output 25 tons per day (1883)—*Miller's*, abandoned, described by Rogers (1858) as ore interstratified irregularly with clay.—*Haine's*, abandoned—*Smith's*, 40′ deep, described by Rogers as Schlong's, in damourite slate.

Final Report: 1891

Plate VIII.

fig. 1.

A map of the Moselem brown hematite mine in Berks county.
Contour lines 10 feet vertical apart.
Scale 200 feet to 1 inch.



J.P.L.

D.3. Vol 2.

fig. 2

fig. 3.

Index Map showing the location and
geological relationship of the
Cornwall Iron Ore Mines, Lebanon Co., Pa.

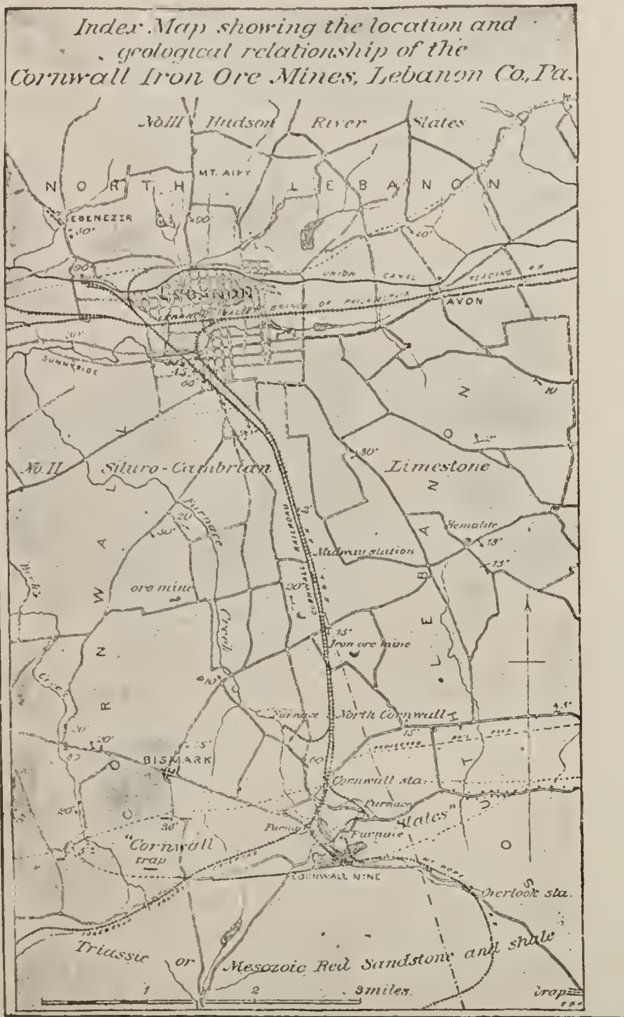
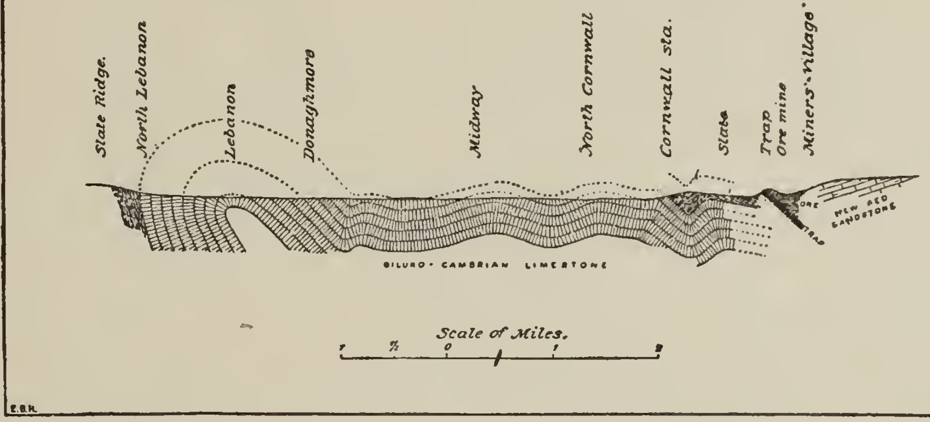


Plate IX.

Final Report. 1891.

fig. 1.

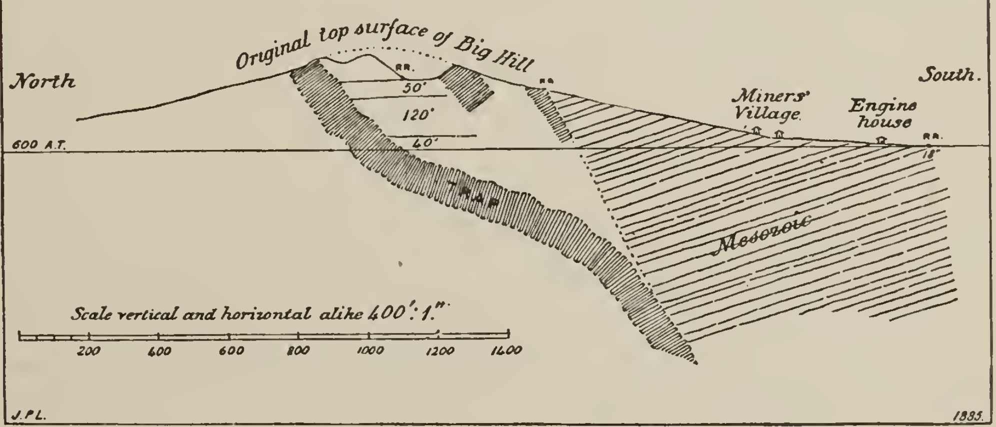
Section along Cornwall Railroad
From Lebanon to Miners' Village.



f. 2.

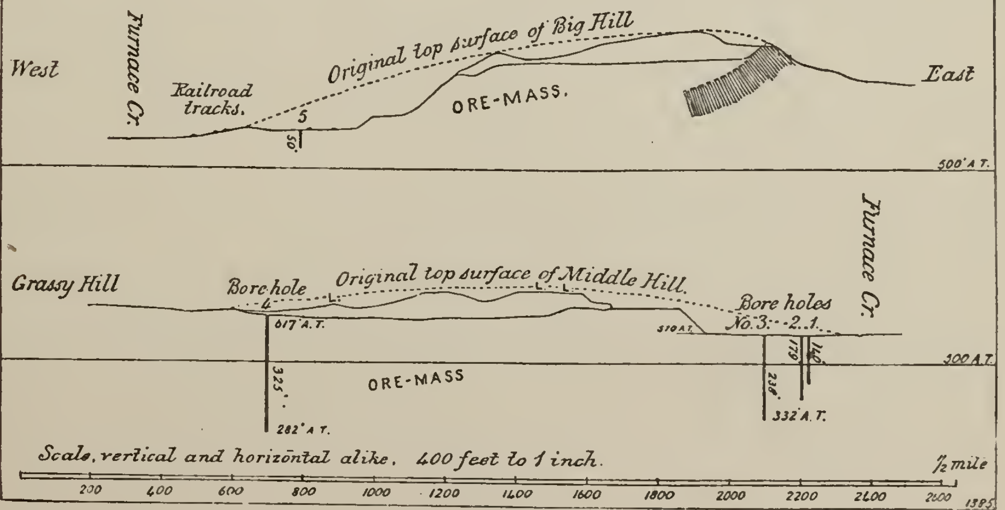
Section across Big Hill combined with Section along Furnace creek.

The foreshortening of the southern trap distorts its relationship to Creek section.



f. 3.

Section lengthways through the Cornwall Big and Middle ore hills.



the limestone of the cove (II) and isolating the head of the cove as an enclosed limestone circus in the body of the slate belt. This abnormal dip must therefore be a sag of the decomposed ore-mass into some cavern in the limestone.

The Trexlertown Copperas mine deserves mention here for the bore hole records preserved in Rogers' Geol. Pa., 1858, p. 265; 1 m. W. of Trexlerville (½ m. N. E. of Breinigsville); worked in 1836–1840? by N. Whitely.

Boring No. 1 recorded: Clay and gravel, 30′; iron ore, 4½′; clay, 7½′; *black clay*, 2′; *sulphuret of iron* (*pyrites*), 12′; iron ore, 5′.

Boring No. 2: clay and gravel, 15′; iron ore, 1′; clay, 15′; *slate*, 5′; clay, 6′; pipe ore in clay, 9′; clay, 4½′.

Boring No. 3: clay, 14′; iron ore in clay, 8′; iron ore, 9′; clay, 3′; *copperas earth*, 2′; *copperas in black clay*, 2′; *copperas* in white clay, 2′; brown clay and iron ore, 8′; solid iron ore (pipe?), 2′; clay, 8′.

Manganese oxide appeared in the west wall. The *slate* mentioned in No. 2, was made somewhat gypseous by the reaction of the sulphate of iron on its lime element. "The origin of this large deposit of sulphuret of iron," says Mr. Rogers, "is to be traced probably to a small shallow bed of Matinal [Utica] black slate which appears to have rested on the limestone and to have undergone disintegration." But if this opinion is correct we may extend the explanation to most of the other limonite mines in the central area of the limestone belt.

The Moselem mine in Berks Co.

This famous old mine, 5 m. W. of Kutztown, is within 1000′ of the edge of the slate belt, and corresponds exactly to the great Ironton mine. The ore was reached at first by shafts through surface stuff 20′ to 40′ deep. Immense quantities of good ore were mined from nests and irregular layers varying from 1′ to 8′ thick; some of it bluish and slightly manganesian. Limestone beds in the ridge south of the mine dip *northward, as they should, under the ore, and* (*if continued*) *under the slate belt.* Large quantities of dark chert, some of them hundreds of pounds in weight, lay scattered over the soil. (Rogers' Geol. Pa., 1858, p. 226.) In 1878 the mine was surveyed by A. P. Berlin, in common with the whole valley between the Schuylkill and the Lehigh county line. It was then 2000′ long and 100′ deep, with five inclined planes. (See Fig. 1, on plate VIII.)*

It is certainly a surprising circumstance that this great Moselem deposit should stand alone; that nothing like it appears for so many miles along the edge of the slate belt in Berks and the counties to the west of it. One is tempted to suspect great local variations in the thickness or richness of the upper damourite slate formation. Or perhaps a *mechanically produced non-conformability* has shoved the damourite slates beneath the slate belt edge. But more probably the only and sufficient explanation is, that only here and at Ironton and a few other places caverns have been eroded to receive the iron drainage. Vague as this suggestion may seem it is borne out by such exhibitions as the Pond banks of Franklin county; and by the cavern deposit of Penns valley in Centre county, to be described in another chapter.

The Cornwall mine.

This summary description of the Lower Silurian Formation No. II would be incomplete without a special mention of one of the most important mines in Pennsylvania, the great magnetic iron ore mine of Cornwall, in Lebanon county, unique in its character, standing alone in the geology of

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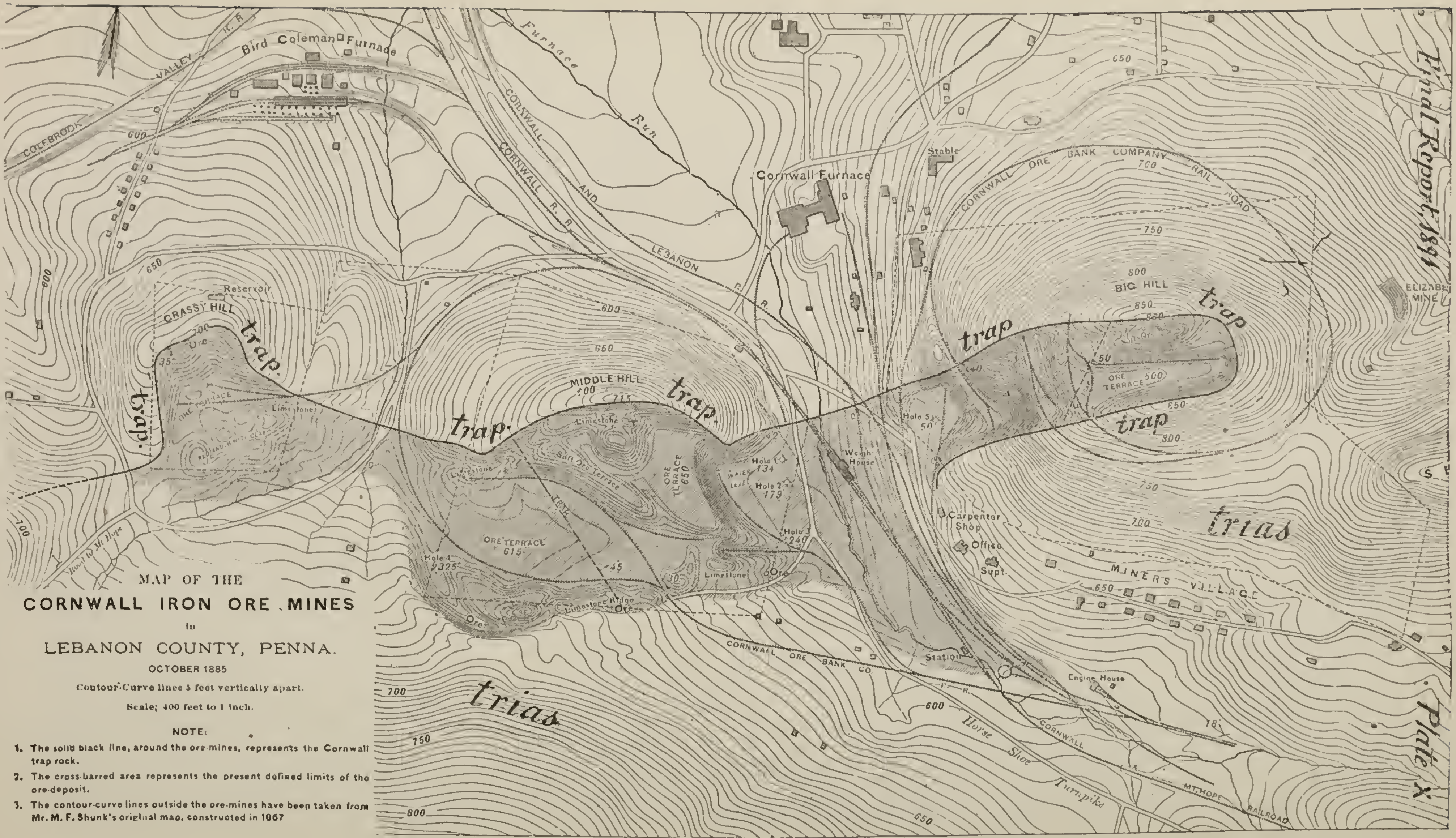
*Fig 2 on the same plate is a reduction from Sheet XIV, of the great topographical map of the South Mountains (Reading and Durham highlands) published in the Atlas to Report D3, Vol. 2, 1883. The survey of the limestone belt was made by Mr. A. P. Berlin in 1878. The small portion of it given in Fig. 2 illustrates the flatness of the limestone belt; the steep hillside edge of the slate belt, through small gorges in which its back drainage issues upon the limestone belt; and the close proximity of the great limonite deposit to this outcrop wall. At the the east edge of the figure the reader will notice the normal 36° northwest dip of the limestone descending beneath the slate belt in the ravine; also northwest and southeast (anticlinal roll) dips in the quarry east of the ravine; also an 18° northwest dip in the little quarry west of the ravine; and other northwest dips around Leibensperger's; so that the geological place of the ore slates is unmistakably at the top of II under the slates of III, with no evidence of non-conformability between the two formations.



MAP OF THE

CORNWALL IRON ORE MINES

in

LEBANON COUNTY, PENNA.

OCTOBER 1885

Contour-Curve lines 5 feet vertically apart.

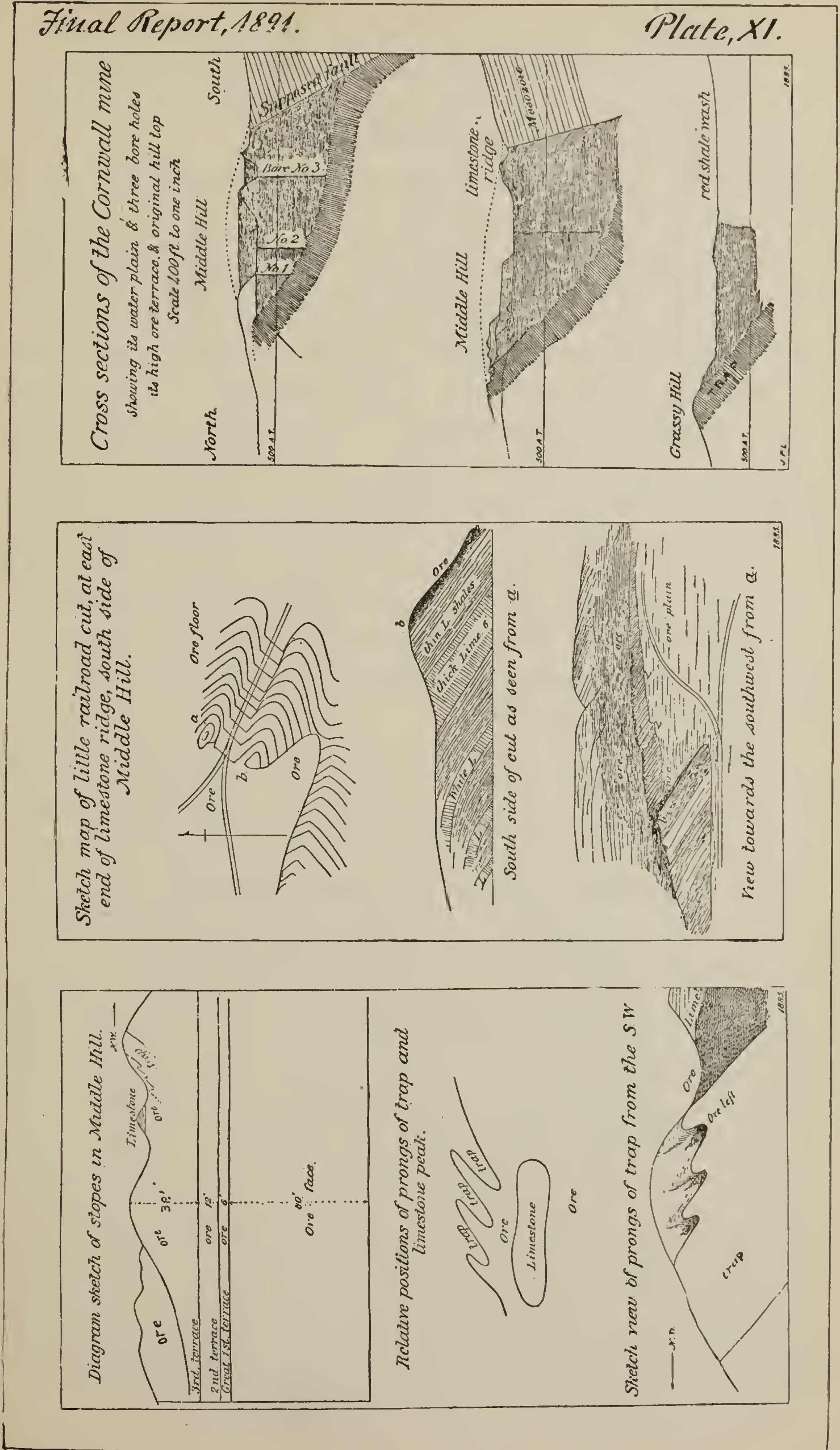
Scale; 400 feet to 1 inch.

NOTE:

1. The solid black line, around the ore-mines, represents the Cornwall trap rock.
2. The cross-barred area represents the present defined limits of the ore-deposit.
3. The contour-curve lines outside the ore-mines have been taken from Mr. M. F. Shunk's original map, constructed in 1867

Final Report, 1891.

Plate, XI.



Cross sections of the Cornwall mine
Showing its water plain & three bore holes
its high ore terrace, & original hill top
Scale 400 ft. to one inch

Sketch map of little railroad cut, at east end of limestone ridge, south side of Middle Hill.

South side of cut as seen from a.

View towards the southwest from a.

Diagram sketch of stopes in Middle Hill.

Relative positions of prongs of trap and limestone peak.

Sketch view of prongs of trap from the S.W.

the State, and pouring year after year its flood of wealth into the business world. Worked for more than fifty years, it shows no sign of exhaustion; on the contrary, its annual output continually swells in volume.

Three hills of ore three hundred feet high, are ranged in a line a mile long and a third of a mile wide. Walls of solid ore 80 feet in vertical height are stoped down by dynamite; and the fragments, broken up to portable sizes, are loaded in cars and distributed to the iron furnaces of the region. A floor of the solid iron ore at water level conceals an underlying ore-mass, into which test holes have been bored varying in depth from 50 to 300 feet. A great volcanic trap-dyke, like the half of a cup, supports the ore-mass at its northern edge, and has been proved by some of the bore-holes to be its floor. Along the southern edge runs one of the few great faults of the State, limiting the ore-mass on that side. Against this fault descends (northward) at a gentle slope the Mesozoic beds of northern Lancaster, their sheared-off edges making the southern side of the cup which holds the ore-mass.

It is this unusual occurrence of Mesozoic red sandstone faulted against the limestone formation of the Great Valley, with an outburst of ancient lava rising through the crack thus produced and making its way sidewise between the limestone strata, lifting them and holding them isolated, as in a vat in a chemical laboratory—it is this unusual combination of circumstances which has given its unique character to the Cornwall iron mine. The mine has been a puzzle to geologists; and a satisfactory explanation of it has been only recently obtained by a laborious research upon the ground.

It is now made evident that the whole ore-mass was originally a set of lime-shale strata belonging to the very top of Formation No. II, which we may call the passage beds between No. II and No. III. These beds, held between the two walls of Trap and Trias, have been attacked by hot acid waters flowing into them, dissolving away the carbonates of lime and magnesia, and leaving behind in a concentrated mass the insoluble silicates and hydrated peroxide of iron, converted much of it into the magnetic oxide.

The whole mass of ore is distinctly stratified, and shows the process of concentration. The original insoluble matters in the lime-shale still remain in the ore. The stratification of the ore-mass is perfectly regular; but almost unchanged *white crystalline limestone beds* lie interstratified in the midst of it, showing that some of the original strata had a mineral composition not susceptable to a change into ore. These limestones lie in their original places among the other strata which have been changed into ore. But they have been subjected to merely enough change to convert them into an inferior kind of crystalline marble. The rest of the ore strata were no doubt first charged with hydrated peroxide of iron (brown hematite); but the change went on one step further; the water was driven off, and the oxide of iron was crystallized into magnetic iron ore; still retaining all the impurities of the original lime-shale beds.

The remarkable features of this ore mass are: First, the quantity of sulphur which it contains; and, Secondly, the universal distribution of a small percentage of copper through the whole mass of ore; and its concentration into strings and plates of native copper *only in the upper part of the mass* where attempts were made at one time to obtain it in sufficient quantities to make it marketable; but the richest pockets of it at the top of the hill were soon exhausted, and none others have been met with lower down.*

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*The origin of the copper, and of the sulphur also, has been connected with the outburst of trap, and also with the neighborhood of the Triassic sandstones, but the subject is still entirely obscure. Nor is it of practical importance, for all attempts to mine copper in Pennsylvania have signally failed. But to geologists the question of the origin of the copper in the Cornwall ore is one of high interest. At present the only facts which we can bring to bear upon it are those connected with the old copper operations at the edge of the Mesozoic sandstone in Chester county west of Norristown; and these are not sufficiently understood to throw much light upon the subject. It is remarkable that the mines near Dillsburg in York county furnish the same kind of copper-bearing magnetic iron ore as that at Cornwall; that they are surrounded by Mesozoic red sandstone near its present northern edge; and that outbursts of trap similar to the trap enclosure at Cornwall are also in contact with the Dillsburg ore. Similar ores are also mined on Fritz's island in the Schuylkill near Reading, and at Boyertown and at Seitzholtzville further east in Berks county, where copper and trap again accompany the ores. All this suggests, although it does not prove, that the copper has come in some form, perhaps as vapour, with the fluid lava from the interior

I do not propose to repeat in this summary of the geology of the State the very full description of the Cornwall mine published as a separate memoir in the Annual Report of the Survey for 1885, pages 491 to 565, with maps and sections and page plate diagrams, showing stope-faces, the structure and the construction of the ore-mass. In lieu of verbal descriptions I give the more important of these illustrations, greatly reduced, but legible enough to make the whole thing comprehensible.*

The geological situation of the Cornwall mine and its railway connections with Lebanon are shown by Fig. 3 on Plate IX.

The reason for placing it geologically at the top of II instead of at the bottom, although it is on the southern instead of the northern edge of the limestone belt, is made clear by Fig. 1 on Plate IX, which represents a cross-section of the belt (looking east) from the edge of the slate belt to the edge of the Trias country. The vertical rise of the top beds of II at Lebanon, their flattened rolls across the belt, and their descent at Cornwall, require no commentary.†

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of the earth; and it is possible that the sulphur accompanied it. On the other hand we have copper shales in the Devonian formation of the northern counties of the State a hundred miles from any trap, and several miles above the plutonic floor. But one of the most conclusive proofs that the Cornwall and Dillsburg copper has no necessary connection with either the Trap or the Trias is found in the facts mentioned on a previous page, namely, that similar leaves and strings of native copper are found in stripping the black clay from the limonite ore mass at Ironton, which is not at all magnetic, has no trap near it, and is in fact a simple leaching from the upper damourite slates at the edge of the slate belt. It looks as if the sea-water of that age was heavily charged with soluble salts of copper, as the water of the Mediteranean Sea is now. As for the abundance of sulphur, it is only necessary to allude to the many *red-short ores* of our back valleys, far from any source of heat; but especially to the account given on a previous page of the *Copperas mine* between Breinigsville and Trexlersville in Lehigh county.

*The reader may find a condensed statement of all the facts, and a number of their illustrations, in Mr. E. V. d'Invilliers' paper read before the Institute of Mining Engineers at its Pittsburgh meeting, Feb., 1886, and published in its Transactions. I assisted Mr. d'Invilliers by a personal examination of the mine, and am responsible for the theoretical conclusions to which he did not yield an unqalified assent, and at which other competent geologists may demur. Cornwall must continue to be for many years a theme for discussion.

†I have in a previous chapter described similar descents of the slates of III along the south edge of the limestone belt in Cumberland and Dauphin

Cross-sections of the ore mass and trap are given in Fig. 2, Plate IX, and Fig. 1, Plate XI; and a section lengthwise through the three ore hills is given in Fig. 3, Plate IX.

A reduction of D'Invilliers' topographical map of the whole mine (in part) is given in Plate X. The most striking feature of this map is the *trap hook* at its eastern end. I can imagine no other explanation for this most interesting structure than that suggested in the memoir in the Annual Report, viz: that the ore-mass really represents a body of limeshales thrown into a sharp and deep synclinal, and that the out and up-flowing trap followed the synclinal bedding. This south side of the synclinal trough was sheared off by the fault, and, therefore, the *trap hook* stops at the fault. But this leaves unexplained why the trap did not follow up the fault to the present surface, and preferred rather to rise sidewise (N.) between the beds.

The curious tongued structure of the trap on the north edge of the Big Hill shown in Fig. 3, Plate XI suggests that we are there not far from the extreme limit of the trap ejection upwards.

The outcropping unchanged limestone beds in the body of the ore mass are shown in Fig. 2, Plate XI.

Path Valley mines in Franklin County.

Path valley is an anticlinal limestone cove in the northwestern side of Franklin county, extending for about ten miles in a N. E. and S. W. direction along the eastern base of that portion of the North mountain locally known here under the name of the *Tuscarora mountain.* It ends on the S. W. in a cove between this mountain and an outlying spur known as *Bear Knob*, while to the N. E. the anticlinal

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counties. Another occurs in Lebanon county east of Cornwall. But the most extraordinary instance is to be seen at Reading, where a north and south belt of III is colored on d'Invilliers' map as intervening between the Schuylkill and the mountains back of Reading. How the structure here is to be explained I can only conjecture by supposing a westward slip of the valley rocks from over the mountain gneiss. At the beginning of Chapter XXVI, I have described the east dips of the limestone in the quarries at Reading, but I omitted to notice this belt of overlying slate, which Mr. d'Invilliers has no doubt of being No. III, and not primal slates.

lies about midway between the *Round Top* and *Dividing Mountain* spurs. The limestone of No. II is exposed in this valley between Doylesburg on the N. E. and the Richmond furnace on the S. W. and is nowhere over two miles wide, tapering toward each end. The north dips toward the mountain flank are usually somewhat steeper than those on the south side of the axis, especially for a distance of six or eight miles in Metal township, owing largely to the presence of a fault along the base of the mountain, which swallows up a large portion of the No. III slate formation, and opposite Fannettville brings the limestones of the valley within close proximity to the mountain sand rock No. IV. Along this line the dips are often vertical, if not overturned to the S. E. and it is mainly in this portion of the limestone area, *near the junction of Nos. II and III*, that the iron ores of this region are exposed and developed *for a distance of about eight miles* between Richmond furnace and Fannettville. The South Pennsylvania branch of the Cumberland Valley railroad was originally constructed to reach these deposits, which were then thought to be of great extent and purity, but which after a considerable development, have proved a source of expensive disappointment to the projectors of the road and those interested in the resources of that region.*

Richmond bog ore bank at the S. W. end of the range, 3000′ N. of Bear Knob; long abandoned, 20′x20′x15′ deep; uniformly good rich non-phosphatic ore, but not much of it.

Mount Pleasant bank, the oldest and largest of this range; two open cuts separated by barren clay partition at S. W. end and uniting in one large open cut at N. E. end towards Cowan's Gap. Southern cut still 250′ x 100′ x 60′ deep, although a good deal filled up since its working was abandoned. A 60′ high steep barren red-sand-wash wall on the S. E. in which a few decomposed layers of sandstone, with steep (overturned ?) S. E. dip, appear above the conformably dipping limonite. On the N. W. side, the dividing partition is largely of white, blue and yellow clays.

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*D'Invilliers in Annual Report 1886, part IV, page 1490. The following description of the banks is greatly condensed from pages 1401 to 1501.

Behind the partition dense close-grained limonite under sooty-black clay; left in wall a N. W, dipping lens-shaped bed 10′ to 20′ thick, interrupted by barren clays. Total length 450′. On the mountain side 8′ to 20′ of stripping stopped work in that direction. Total output said to be 100.000 tons. Analyses: Iron, 47.5; manganese, 2.3; sulp., 0.05; phos., 0.34; silicious matter, 11.7.

Beaver bank, 2500′ N. E. of last; 200′ x 150′ x 20′ to 40′ deep; bed of limonite 20′ thick said to be left along E. wall. *A rib of barren iron stained sandstone* extends through the middle of the oval open cut; and another shows in the N. W. (mountain) wall, through which a drift reached some good ore. No black clay; all the barren stuff is red. Whole output 10,000 tons; ore very irregularly scattered; well 80′ deep in floor, said to have gone through good wash ore.

McGowan pit, 1000′ N. E. of last; small, irregular; all wash ore; no black clay; less red than white and yellow clay. Worked long ago. Other small pits, abandoned; one 20′ deep said to have been all good lump ore.*

Well up the mountain side, N. W. of the banks at the foot of the slope just described, is another range of banks:

Old Johnson bank; furnished say 500 tons of ore mixed through a sand and clay wash.

Lessig pits; the one furthest (N. E.) yielded say 200 tons of slaty cold-short ore. From the other pits, 10′ to 18′ deep, clean good limonite, say 50 tons in all. The outcrop runs straight across both tracts and would yield some ore here and there if opened.

Carrick furnace has a run of 1½ miles on the outcrop further N. E. First pit 50′x′30′x10′, yielding considerable good ore; shaft 10′ deep in floor stopped in ore. Porous wash ore making tough iron shows in the bank wall under 7′ stripping. Two other pits (600′ N. E. of last), 50′x25′x 15′, gave say 500 tons of ore condemned at the furnace.†

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*The banks described above are on S. Pa. M. & R. R. Co.'s tract of 6000 acres. The company holds leases on several thousand acres more; but the field is practically abandoned.

†This is a curiously interesting illustration of the *variation in quality in limonite along one and the same outcrop line.*

After many smaller pits comes a large one, 100′x50′x30′; a 25′ shaft in the floor produced excellent lump ore. No water here; water scarce in all the pits; pits therefore often abandoned even when good ore could be got. Another cut (a little lower down the slope) 300′ N. E. of last; 150′x50′x 20′; slope (very old) put down 20′ on N. W. side in good lump ore.

Old Carrick bank, ½ m. further on N. E. and just in front of the Wind Gap by which the road passes over into Huntingdon county. *Here only the top of No. III crops out*, all the rest of the slate formation being *swallowed up in the fault*;* and the ore mine 300′x40′x25′ runs along the fault and close to the limestone. A shaft 125′ deep sunk in the mine floor is said to have passed through a steeply dipping 30′ to 35′ ore bed. Another shaft (at W. end) is said to have gone 75 feet through this ore and stopped in solid lump-ore. Yet the whole place is abandoned and dilapidated. Most of the output came from gallery workings N. E. and S. W. of the ravine. All the wall towards the mountain shows soft sooty black clay, like that which caps so many of the mines along the foot of the South mountain. Four sets of lessees have worked the mine; output estimates vary so as to be worthless. Analyses of samples of ore used by Carrick furnace in 1880: (1) *lump ore*:—Iron, 45.3; mang., 1.1; sulp., 0.05; sil. mat., 16.3; phos., 0.36—(2) *wash ore*:—36.4; 1.7; 0.06; 26.0; 0.27.

Railroad bank (Carrick Fur. Co.) 1200′ further N. E. than last; 400′x40′x16′; not much ore visible in 1886; stripping very heavy; shaft under S. E. wall 40′ (reported) entirely in ore, and in drifts to N. and W. Bank must have had a very large output. Analysis of a sample picked up:—Iron, 43.6; mang., 0.24; sulp., 0.005; sil. m., 18.5; phos., 1.482 (unusally large).

A few more pits are seen further on N. E. beyond the Fannettville road; outcrop distinct for more than a mile; G. Umbril's abandoned pit being the last.

A short distance E. of Mercersburg are three small banks,

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*Henderson's fault, as we used to call it, because discovered and described by A. A. Henderson of the First Geol. Survey of the State 1839–40.

Leib's, *Stauffer's*, *McFarland's*, now abandoned, which yielded some good bog ore.

Stinger's old pits at the mouth of Bear valley, 1 m. E. of Loudon, and on or near the II–III line; long abandoned; analysis: Iron, 39.5; mang., 4.8; sulp., 0.04; sil. m., 18.8; phos., 0.61.

Garlic Bank—E. of last (2½ m. S. W. of St Thomas); 200'x100'x20'; walls of red clay carrying fine ore and a little lump; not worked for 15 years (1886); too far from RR.; good ore; analysis: Iron, 52.9; mang., 0.08; sulp., 0.15; sil. m., 6.89; phos., 0.06.

In the other direction 2 m. W. from Mercersburg, the *Webster bank* is on a II–III contact line; abandoned.

The Henrietta mines of Blair Co.

These limonite deposits are the only others to be described in this chapter as appearing to have a geological horizon at the top of II, in contact with the slates of III, and along lines of fault like the Path Valley mines in Franklin county last described.*

Leathercracker Cove is made by an anticlinal of No. II limestone, faulted on both sides, so that the arch is thrown up 2000' and rests against the slates (III) and the sandstones (IV) of Tussey mountain to the east, and of a small slate ridge (III) to the west. The big fault (the eastern one at the foot of Tussey) is about a mile long, and approximately parallel with the strike of the country. The anticlinal runs on N. 20° E. to and through Canoe Valley in Huntingdon county. See Fig. A in Report T, p. 91.

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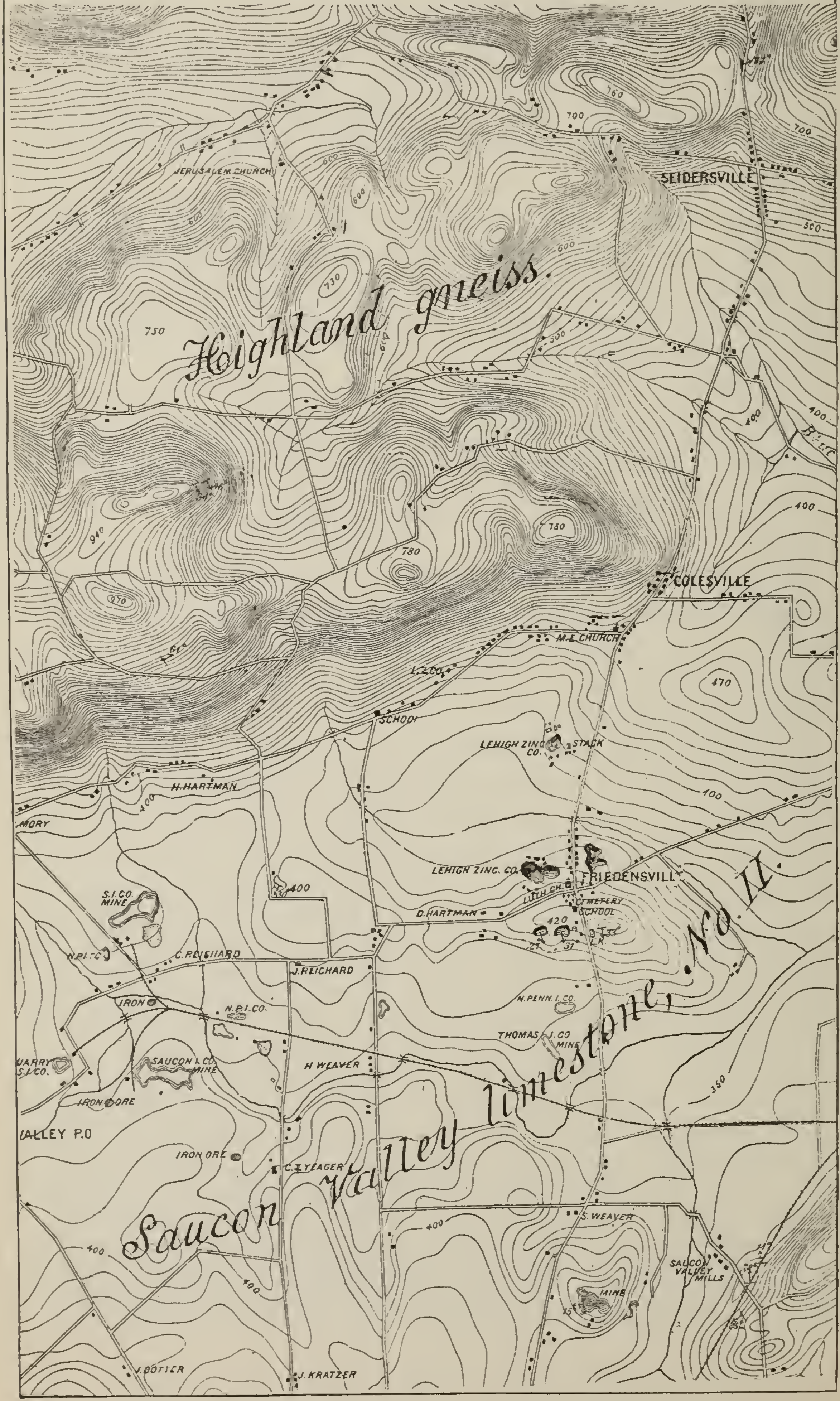
* I am loth to mix these up with the great mines of the Great Valley, and to separate them from the regional mines of Nittany Valley and Morrison's cove; but they are the only notable mines in middle Pennsylvania behind the Great Valley referable to the top of II, when I made my last survey of that iron region; all the other limonite deposits of II being referable to various horizons in the body of the formation. But it will appear in a subsequent chapter (XXXIV) that I now place a different interpretation on that fact, and believe that the Henrietta ore horizon is only accidentally connected with the slates of III by reason of a great upthrow fault.

Map of the Saucon Zinc mines and vicinity. Pl. XII.



The line of contact limonite ore deposits runs from the Henrietta bank due south. At the south end of the line of ore the Oneida terrace (IV*a*) and the Hudson river slates (III*b*) are swallowed by the fault.* It seems a logical conclusion that this line of limonite ore has been produced in some way by the fault. The contact of II and III is sharply defined along Tussey mountain its whole length across four counties, and along Dunnings, Lock, Loop, Canoe, Bald Eagle and Nittany mountains, for about a hundred miles of outcrop. Almost every ravine cutting through the terrace of slate into the limestone valley affords as good an opportunity as could be desired for finding any ore deposits existing at the contact of the two formations, or produced by the decomposition of lime-shale beds of passage from limestone to slate. In most cases the cultivated fields at the base of the mountain would betray the presence of such ore deposits. In spite of all this however not a single such discovery of any importance has been reported, except in Leathercracker cove. The conclusion is obviously good that the Henrietta ore mines occupy this geological horizon exceptionally, by accident, and solely in virtue of the Leathercracker faults.

But this conclusion has a wider range and applies forcably to the Great Valley, where we see the Path Valley deposits of Franklin county lying along just such another fault ; and then we must go 140 miles along the middle contact line II and III before we reach the Moselem mine in Berks county, where we have seen there is some reason for suspecting a faulted structure. In the Ironton region of Lehigh county there is scarcely a single mine which can be assigned *with certainty* to the contact of II and III ; and from Ironton eastward no deposits of limonite can be proved to overlie the Trenton. Even at Cornwall there is solid limestone (Trenton ?) at the very top of the ore shale mass. Remembering that no limonite appears with the passage beds in the bends of the Conedogwinit in Cumberland county, and keeping always in mind that we have as

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*All the arguments for the fault are given successively in detail in T, p. 90, to which the reader is referred.

yet no assistance from fossil forms in determining the true position of any limestone or lime shale beds faulted against the slates of III at Henrietta mine or elsewhere, it must be regarded as quite possible that all our Great Valley limonites are cavern deposits of very recent date derived from the decomposition of a series of damourite lime shales belonging to various horizons in the Magnesian limestone formation, that is, the Chazy and Calciferous.

In the next chapter such horizons will be exhibited.

CHAPTER XXXI.

Nittany Valley limestones, No. II. Centre County anticlinals. Nittany Valley cross-sections.

The ore horizons of the Great Valley have been seen to be obscured by the folded and crumpled condition of lime stone and slate belts. In Nittany, Brush, Penns, Canoe and Kishicoquillis valleys, and in Morrison's, Friend's and McConnellsburgh coves, *a simple anticlinal structure*, disturbed by only a few faults and hardly at all crumpled, makes the order of the limestone beds an easier study, sufficient to establish the different horizons by approximately parallel ranges of ore banks.*

The great rock waves of Middle Pennsylvania are splendidly exhibited in the McConnellsburgh Cove in Fulton county, with its 8000′ fault on the western side; in Kishicoquillis valley in Mifflin county, with its surrounding terrace and eastern keel-shaped mountain prongs; and most of all in Nittany valley and Morrison's Cove (united by Canoe valley) where the grandest anticlinal of the State brings to the surface the whole of the magnesian limestone (capped by 400′ of Trenton limestone) with immense deposits of iron ore. A description of the Nittany anticlinal, and of the subordinate waves which broaden and spread out its southern slope, is a necessary preliminary to the description of that oldest and richest iron ore region of middle Pennsylvania.

Centre county anticlinals.

The great *Nittany valley anticlinal*, which brings to the surface the top layers of No. II in Mosquito valley in

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*Mr. D'Invilliers in Report T4, p. 137–8, says that the popular belief in continuous belts of ore-producing territory along fixed outcrop belts or horizons was not confirmed by his survey of Centre county; but this does not invalidate the statement that limestone horizons are demonstrable, and ore horizons approximately so.

Pl. XIII.

Cross Sections of No. II in Nittany Valley, Centre Co.

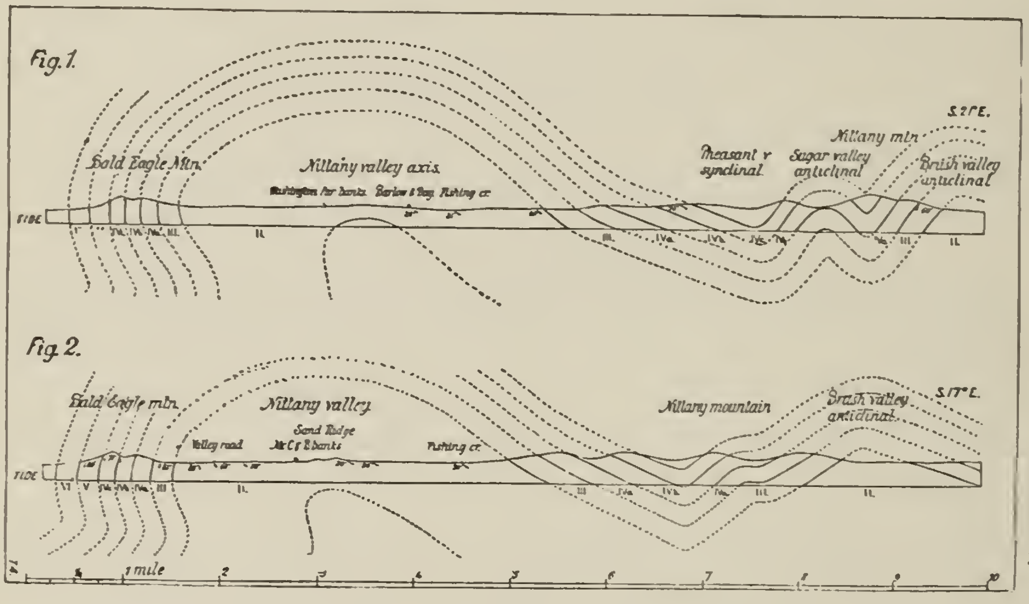

Fig. 1.

Fig. 2.

28 T'.

Plate III.

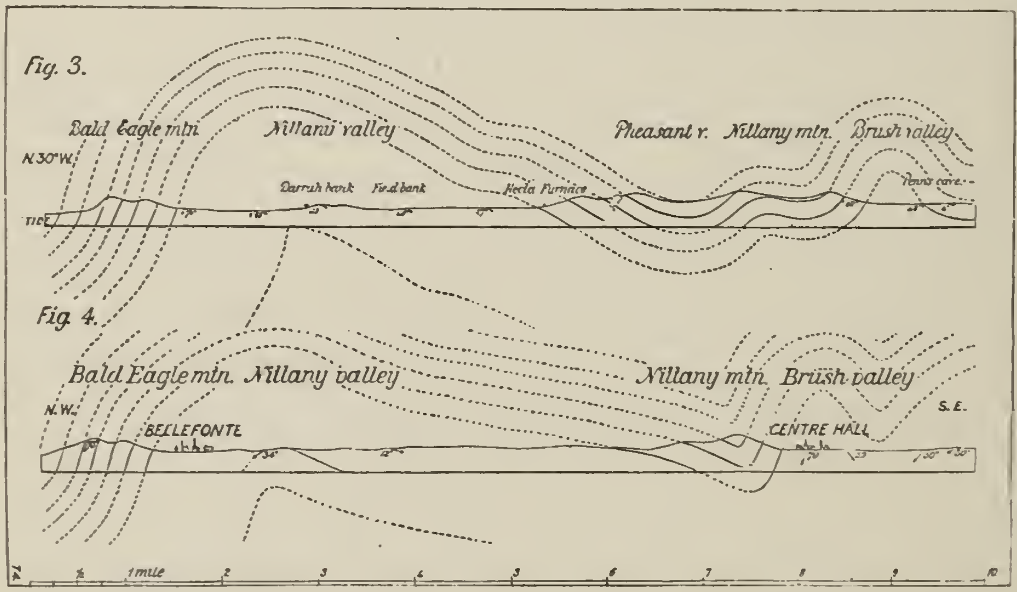

Fig. 3.

Fig. 4.

34 T

Plate IV.

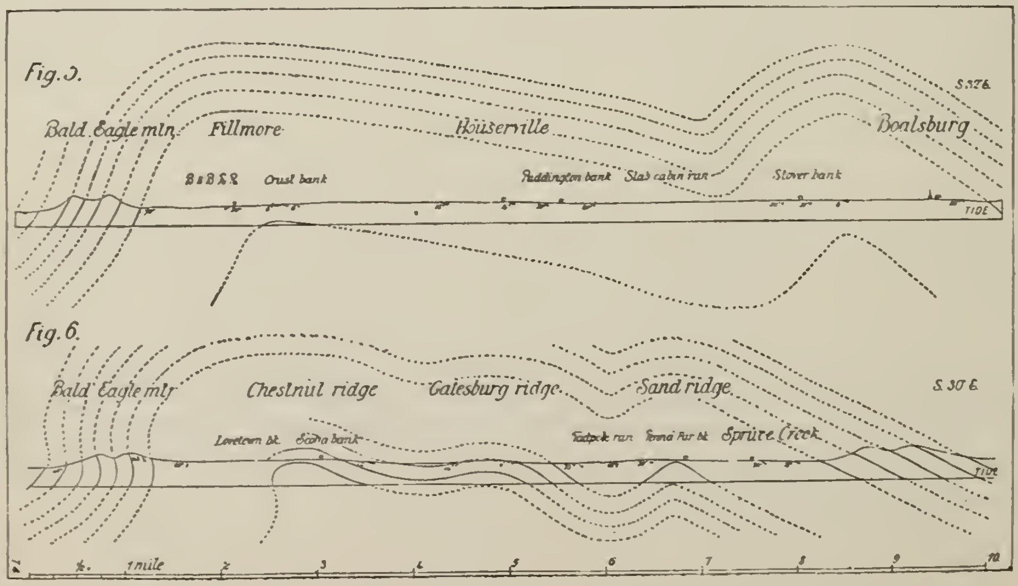

Fig. 5.

Fig. 6.

38 T'

Plate V.

Lycoming, and Nippenose valley in Clinton, rises in Centre county so as to expose on the Centre-Huntingdon line, west of Bellefonte, at least 6000′ of the formation, without however bringing the bottom beds to the surface.*

Continuing S. W. across Huntingdon into Blair at a still higher elevation it exposes more than 6000′ of No. II down to (or nearly to) the bottom beds at Birmingham on the Little Juniata. Then it sinks rapidly to the head of Sinking Creek valley, where the slates of III close over it, and the mountain rocks of IV, the Frankstown fossil ore red-shales of V, and the Hollidaysburg limestones, etc. cover it; and so it runs on south through the Devonians into the coal measures of Somerset county.

The *Gatesburg ridge anticlinal* in Centre county runs parallel and 1¼ miles to the S. E. of the Nittany (Chestnut ridge) anticlinal; and becomes the *Hickory ridge anticlinal* of Huntingdon county, crossing Half Moon creek 2 m. N. of its junction with Spruce creek.†

Dry Hollow synclinal lies between the Chestnut ridge and Hickory ridge anticlinals.

Sand ridge (*Tadpole ridge*) *anticlinal* in Centre county, runs parallel and 1½ m. S. E. of the Gatesburg ridge anticlinal, and its S. E. dips pass beneath Spruce creek down into the roots of Tussey mountain. It is the *Spruce creek anticlinal* of Huntingdon county. On the county line, opposite Pennsylvania furnace, it brings to the surface

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* D'Invilliers in T3, p. 443: East of Bellefonte the axis beds are the "Barren" sandrocks of Sand ridge; west of Bellefonte the axis runs along Chestnut ridge. Its S. E. dips are rather gentle here, but its N. W. dips (in the Stormstown valley, 1½ miles wide, between Chestnut ridge and Bald Eagle mountain) are steep, vertical, or even overturned so as to dip S. E.

† This arch is quite subordinate to the great Nittany arch, and is in fact a roll on the grand S. E. slope of the formation from the Nittany arch crest towards Tussey mountain. One result is that the Hickory ridge barrens are not the Sand ridge barrens of Centre county, but are much higher in the series; giving us two quite distinct horizons of Calciferous sandstone strata in No. II. This roll appears to die down rapidly N. E. and S. W. from Half Moon run, and probably flattens out before reaching Warrior run; at all events there is no trace of it in the long exposures of the Little Juniata. It seems to bring up the particular horizon of shales from which the Old Seat, Huntingdon furnace, and Dorsey ore deposits were generated. (D'Invilliers letter of May 18, 1885, in T3, p. 445.)

3500′ of No. II; *and it is in this upper half of the formation that most of the pipe ores of the region are mined.*[*]

The Brush valley anticlinal runs along at the S. E. foot of Nittany Mountain, between it and Brush mountain.[†] It passes north of Rebersburg and Madisonville, with N. W. dips of 65° to 70°, and S. E. dips of 15° to 20°. Just north of the Penns Valley cave, pure soft gray Trenton limestone beds dip 70° N. W. and 45° S. E. It reaches its greatest height near Centre Hall, where it brings to the surface beds 2500′ beneath No. III.[‡] Sinking and flattening S. W. it carries the *Watson*, *Ross*, *Slover* and other ore deposits. On Spring creek, 1½ m. S. of Lemont, its dips are 48° N. W. and 12° S. E., flattening to 8° at Boalsburg. Then it rapidly dies out before reaching the foot of Tussey mountain.

The Penns Valley anticlinal runs south of Brush mountain, between it and Stone mountain, in the slates of III in Pine Creek Hollow; lifts the top Trenton beds at Hosterman's saw mill, and runs into a cove of Tussey mountain.[§]

The Penns Narrows anticlinal barely lifts to the surface in the Narrows and in George's valley the top Trenton

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[*] This Sand ridge anticlinal axis runs from Pennsylvania furnace (N. E.) to Johnston's ore bank in College township, lapping past the dying *Brush Valley anticlinal;* and between the two begins the Nittany mountain synclinal which deepens (N. E.) and takes in the slates of III, the sandstone of IV, and the red shale of V, which make the canoe-shaped Nittany mountain. At Pennsylvania furnace the Sand Ridge dips vary from 25° to 60°, N. W. and 25° to 40° S. E. At Johnston's bank its S. E. dips vary from 15° to 30°. (T4, 35.)

[†] Eastward this axis makes Sand mountain in Union county and crosses the Susquehanna near New Columbia. Westward it curves from W. to S. W. just as the Nittany valley anticlinal does, entering Centre county in Miles township at the head of the narrow Hudson river slate cove with which Brush valley commences. It brings up the top Trenton beds near Rudy's mill.

[‡] This accounts for the ore-poverty of Brush valley; the uppermost ore horizons on steep dips affording no good opportunity for concentration and preservation; and the rest being buried.

[§] It crosses the Susquehanna north of Lewisburg. One mile east of Aaronsburg its limesand beds dip 68° N. 25° W. and 40° S. 35° E. It bends sharply southwards and crosses the pike ¼ m. S. of Millheim, where dips of 70°, 64°, 80° N. W., and 12°, 20°, 30° S. E. are seen. Then it bends and runs due west to the church, 1 m. N. E. of Penn Hall; here ½ m. N. of edge of III in Egg Hill. North of Spring Mills its dips are 60° N. W., 20° S. E, Gentle arch at Penns creek; greatest height 2 m. further west on the Bellefonte-Lewistown pike; then turns S. W. and dies into the Tussey mountain cove.

beds, with dips of 70° N. W. and 60° S. E. Its highest point is 2 m. W. of the Millheim pike with dips of 70° N. W. and 50° S. E. At Potter's mills are dips of 85° N. W. and 70° to 80° S. E. It sinks west in the slate "Loop" 4 m. west of Potter's mills, and issues S. W. from Tussey mountain at the Bear Meadows in Huntingdon county.*

It will be seen from the above sketch of the structure and from the figured cross-sections why almost all the limonite ore deposits are confined to the Nittany valley proper, the great arch of which brings up nearly the whole of formation No. II, exposing to erosion and concentration all its iron-bearing limeshale and limesand horizons.

Cross-sections in Centre Co.

Figs. 1, 2, 3, 4, 5, 6, on Plate XIII show the structure of the region by a series of *cross-sections* described in Mr. D'Invilliers' report on Centre county, T4, 1884, pp. 34 to 41. The rest appear as plates p. 668 &c. below.

The Madisonburg Gap cross-section, at the Clinton-Centre county line, shows the Nittany axis barely a mile distant from the Bald Eagle mountain in which the slates of III are vertical or overturned (S. E. 80° to 86°). Against these rest the thin-bedded shaly Trenton limestones (II*c*); against these rest the white, hard crystalline, magnesian, sandy Chazy limestones; and under these on the arch the limy sandstones of Sand ridge, making "The Barrens." At the *Washington Furnace* and *Beck ore banks* (2½ m. N. W. of the old Washington furnace) the measures are overturned, and the *ore horizon is about 3000′ beneath the Slates of III.* South of the arch the same ores lie at the *Snavely, Ballow and Day*, and *Huston banks*, dipping 30°, S. 35° E. (towards Nittany mountain) between beds of cherty limestone (Chazy, or Calciferous); the slates of III at the base of the mountain dipping 40°, and the Medina sandstone 50°, S. E.

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* *The Confer anticlinal* only exposes III in Decker valley, and in the small oval Lick valley (Lechenthal).

The Poe Valley anticlinal, passing from Union into Mifflin county, also only exposes III along the north foot of Paddy's mountain and south foot of Bald mountain.

The Howard and Jacksonville cross-section, 4 m. S. W. of the last, shows the sand-lime strata (containing some good pale blue beds) at Jacksonville *overturned* 68° to 80°, S. E. without any appearance of a break or fault in the arch. Fossiliferous blue limestone quarries are N. W. of the village; and black shiny *Utica slate*, polished by sliding pressure, within 300′ of the Bald Eagle mountain, has been prospected for coal! Near the *Butler ore bank interstratified magnesian limestone and common sandstone beds are overthrown* to 50° or 60°, S. E. Sand ridge has a double crest, the northern crest being made by very hard *blue flaggy sandstone* beds; the southern covered with loose sand. *The sandstone beds are regularly interstratified with the magnesian limestone beds.* The higher southern ridge shows 20° to 25° dips to S. E. The ore horizon in Madison Gap cross-section above here runs through the Hecla, Voneda, and Schwartz mine limestones dipping 30° to 40°, S. E. Then come the overlying dark blue Trenton beds (II*c*) making a reddish soil; then the *Utica black slates*, *extensively prospected for coal*, on the H. Brown tract, dipping 40°, S. E.

The Hecla Furnace cross-section, 3 m. W. of last. In Little Fishing Creek Gap IV dips 52°, 40°, 40°, S. E. Between Nittany mountain and Sand ridge a shallow valley. Blue very slightly calcareous sandstones, dipping 22°, S. E. were once quarried for *paving flagstones* (40°, S. 30° E.) near the McKinney ore bank. At the Darrah bank, N. W. of the Sand ridge, the same blue silicious magnesian limestones in bold ledges and cliffs *dip 20° to 25°, S. E. into the ridge.*[*] Along the north road, magnesian limestones are overturned to 85°, 83°, 70°, 83°, 80°, 88° to S. E., but others dip 85°, 88°, 60°, 65°, 76° normally N. W. The anticlinal begins to get its normal shape after passing S. W. into Spring township.

The Bellefonte cross-section is the best that can be got N. E. of the Little Juniata. The Barrens (sand ridge), sinking 4 m. E. of Bellefonte, do not show the sandstones

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[*] This is a mile from Bald Eagle mountain and must mean an excessive overturn.

on the section. The Medina sandstones, IV, in Bald Eagle mountain dip 80° to 70°, N. W. The slates of III on the mountain side, 50°, N. W. The Trenton blue fossiliferous limestones, III*c*, 600′ thick, both massive and thin bedded, fine grained and laminated, dip 50°, N. W., as in the Alexander and Morris quarries on Spring creek north of Bellefonte. Then at the Presbyterian church appear the uppermost magnesian (Chazy) beds, banded, broken by cleavage holding masses of chert, and decidedly *whiter* than those above them; all of them more or less *sandy* and cross-cracked; dipping on an average 50° (with local variations of 30° to 60°) N. W. to the anticlinal axis, a mile S. of Bellefonte, were they only dip 9° N. W. and S. E. Then the same beds descend in the same order, with S. E. dips of 30°, 20°, 12° and 10°, toward Nittany mountain.

The Fillmore–Boalsburg cross-section, 6 miles further S. W. crosses the whole valley (½ m. W. of the end of Nittany mountain) from the Bald Eagle mountain to Tussey mountain, 8 miles, across the Nittany valley anticlinal, the Nittany mountain synclinal, and the Brush Valley anticlinal. Here the bottom slates of III dip, 70°, N. W. The blue Trenton beds, at first 70°, lower their dips so rapidly that at Fillmore they dip only 20° to 15°, N. W. Half a mile further, on Crust farm, the arch of lime-sandstones is flattened to 6° dips both ways (10°, 12°, well exposed on Spring Creek, 1 m. S. of Roopsburg). South of the axis in Big Hollow, N. W. of Houserville, purer limestones descend at 10°, 15°, 18°, 16°, 30°, S. E. into *Paddington ore banks.* On Slab Cabin run, 15°, 20°, S. 60° E. (showing the shoaling of the Nittany mountain synclinal). Here the long synclinal prong of III is crossed. Then the Trenton limestones rise steeply (50°, 60°, N. 20° W.). Then the lime sandstones rise (48°, N. W.) on the Brush Valley anticlinal, and sink again (8° to 12°, S. E.)covered by the Trenton beds descending at 20° to 30° under the slates of III in Tussey mountain.

CHAPTER XXXII.

Centre county limonite mines. Pennsylvania Furnace ore banks.

Mr. E. V. d'Invilliers' elaborate report on Centre county, T4, was published in 1884, when the iron industry of the state was depressed, when only three of the four small char coal furnaces were in blast and the supply of water for washing the limonite ores of the county was very limited.

Since that date there has been an active movement in developing the iron ore resources of the district. Two large coke furnaces, with the latest improvements, have been erected at Bellefonte by the Robert Valentine Company,and the Philip Collins Company, and operated under various changes of name. Brown hematite banks have been opened up all along the ore belts, especially in the middle members of the limestone series. Branch railroads have been constructed to reach the mines near the State College and along the foot of Bald Eagle mountain. The use of jigs to separate the ore from the flint and sandstone of the ore masses is now common and will soon be universal. Water for washing away the clay and sand is procured either from the surface streams or, in the dry limestone districts, by sinking artesian wells to the drainage level; some of them being several hundred feet deep, and at least one of them west of the Huntingdon county line, a thousand feet. The market for the ores is found at the numerous furnaces along the main line of the Pennsylvania railroad and its branches. The fuel used is coke from the Clearfield and Connellsville coal districts.

*Two varieties of ore.**

The two chief varieties of ore occurring in the county are: 1st. The wash and lump hematite ore of the "barrens." 2d. The pipe ores.

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*This paragraph and those that succeed it as far as to the end of the list of mine groups are taken nearly verbatim from Mr. d'Invilliers' report on Centre county, T4, 1884, pp. 133 to 138. His detailed descriptions of the mines of these groups occupy 117 pages of that volume (pp. 139 to 256) of which no summary can be made with any success. I will confine myself to a description of the great *Pennsylvania Furnace mine* and refer the reader for the rest to his excellent work.

1. Of the first class it may be stated that the appearance and character of the ore in all the banks, as well as the accompanying waste material, show evidence of their being waste deposits, caught in vast caverns of irregular shape, showing mixed sand, tough clay and rolled ore, and though intimately associated with sandy measures *in* the limestone formation of II have really a still lower limestone bottom.

In the chief mines of the district—notably at Scotia and Tow hill—after a superficial covering of 15 to 30 feet of mixed clay, sand and fine ore has been removed, the under surface reveals solid rock-ore in large lumps, mixed with clay in a confused arrangement, of great richness and variety. An integral difference in the clays of these ores and the limestone pipe ores (one to be expected probably from their different horizons) is the much greater stiffness and toughness of the former. The clay of these lower ores frequently occurs in non-ferruginous bands or dykes, running through the length of the banks, barren, and hard to pass through the washers, but by no means cutting off the ore. This non-ferruginous clay has usually a white to pink color; while the yellow clay of the pipe ore deposits is intimately mixed with the ores and offers no material resistence to their thorough cleansing in the washing-machines.

Moreover, it may be noted that in every case the ore of the barren needs jigging in addition to washing to free it from the mixed sand and flint that accompany it.

All the analyses of these ores show an absence of bisulphide of iron, and the occurrence of all the iron as sesquioxide at once suggested a different chain of effects in the production of these as compared with the pipe ores, to be presently described, where this salt of iron is frequently present.

The sand rocks which originally held these ores occupy a position low down in the sandlime series of II. By having their lime leached out, these loosely aggregated sandstones have fallen into sand, and it is probable that this same leaching action has concentrated their iron salts, which would be deposited as insoluble peroxide. What changes may have followed this process of deposition to bring about the irregular and confused appearance of the banks to-day and the grading of the ore body from fine to coarse lumps is a matter of speculation still. The deposits do not look like formations *in sitû*, nor would such a theory explain the rounded character of ore and flint balls and occurrence of barren spots beside nests of great richness.

While no distinctively pipe ores have been reported from the ore banks in the "barrens," some persons detect in the compact needle ore (occasionally met with) a form of pipe, and illustrate their opinions of the common origin of pipe and hematite ores by this fact. Physically and chemically they appear to be quite different; but the general resemblance of all ores from different banks, divided only as to two classes, is not as remarkable as the local variations which give rise to the occurrence of bessemer, neutral and cold-short ores lying quite close to each other, and apparently along the same range.

2. The *pipe ores* have varying horizons in the limestone, and though generally *above* the essential "barrens" limonites, it is by no means certain that some of them do not occur also in the 1000± feet of limestone beneath these.

The frequent connection of *damourite slate* beds with the chief ore bodies in the southeastern district of the State is not observed in Centre county. It is true that most of the pipe ores are accompanied with a white and buff-colored clay, which may be the result of the decomposition of such slate bands; but it may also represent the disintegration of the magnesian limestones themselves.

While the chemical explanation of these facts is still a matter of speculation, repeated examinations of the ore banks in various parts of Nittany and Penns valleys leads me to believe that the pipe ores are deposits probably due either, first: To the decomposition of iron pyrites, originally contained in the limestone or slate bands, and after oxidation as sulphate, filled into interstices in the limestone, and changed into peroxide by contact with vegetable matter or other organic substances; or, second: To the prior production of ferrous carbonate, by reaction between the ferrous sulphate and the calcium carbonate of the limestone, afterwards converted into limonite by oxidation and hydration. The manner of occurrence between walls of regularly-bedded limestone, sometimes as thin shells of ore and again as large pipes in masses 8 to 10 feet thick, would confirm one or the other of these views, while the presence of iron pyrites in perfectly undecomposed pipes surrounded with thoroughly oxidized ore in the Sinking Creek mine in Penns valley, lends probability to the theory. The presence of pyrites in hematite is not new, and the many analyses showing bi-sulphide of iron in the succeeding pages will illustrate its frequency in this district. Crystallized brown hematite, a pseudomorph after pyrite, has been gathered in the Cumberland valley, as well as specimens of bomb-shell ore holding a clay inside filled with loose crystals of pyrites.

In other banks showing a low percentage of sulphur many of these ores may have occurred as carbonates in the slates, which upon the dissolution of their lime matter have deposited these iron salts as now found. In those banks where a considerable surface deposit has escaped from the general erosion, this oxidation has been so complete as to show but a low percentage of sulphur; whereas, in the case of the Sinking Creek mine before mentioned, the ore occurs in places between limestone beds, and has not yet had a chance to become thoroughly changed.

The outcropping of these pipe ores is spread out to a much greater extent than they occupy lower down between limestone layers. The width of these outcrops is affected by the topography of the country. This surface ore is greatly disintegrated, and occasionally is indeed so fine as to be hardly distinguished from so much reddish brown loam or earth; but a close inspection of it will reveal the presence of small stems or pipes, making usually a cubic yard of ore for each 4 or 5 cubic yards of material, and often better.

The work of the season did not confirm the popular belief in *continuous belts* of ore-producing territory along miles of surface outcrop. At best, while assigning approximate horizons to these pipe ore deposits, they have their

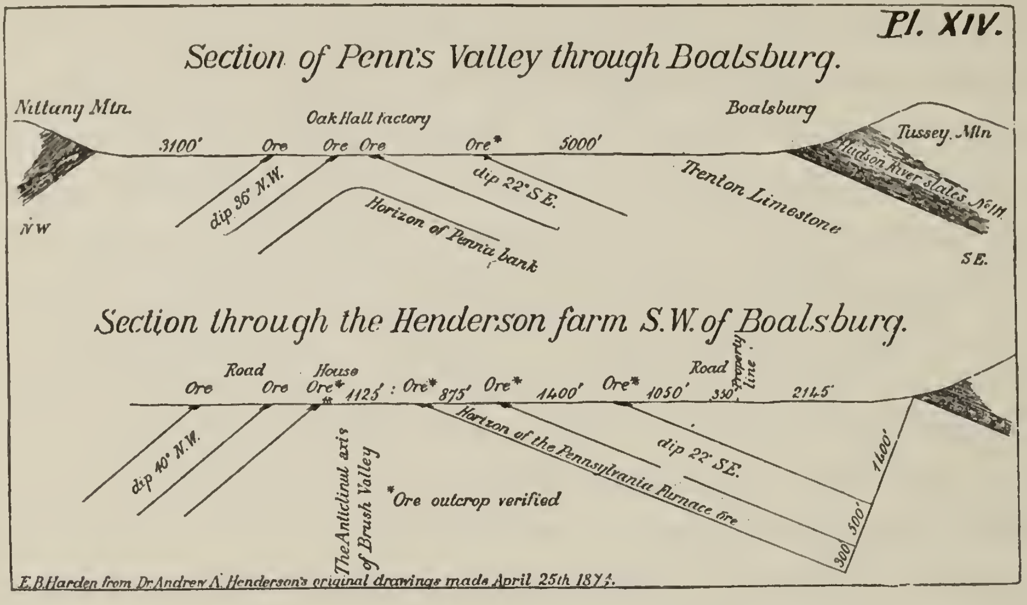


Plate 11.

Map of the Pennsylvania and other limonite mines in Centre Co.

T. 355

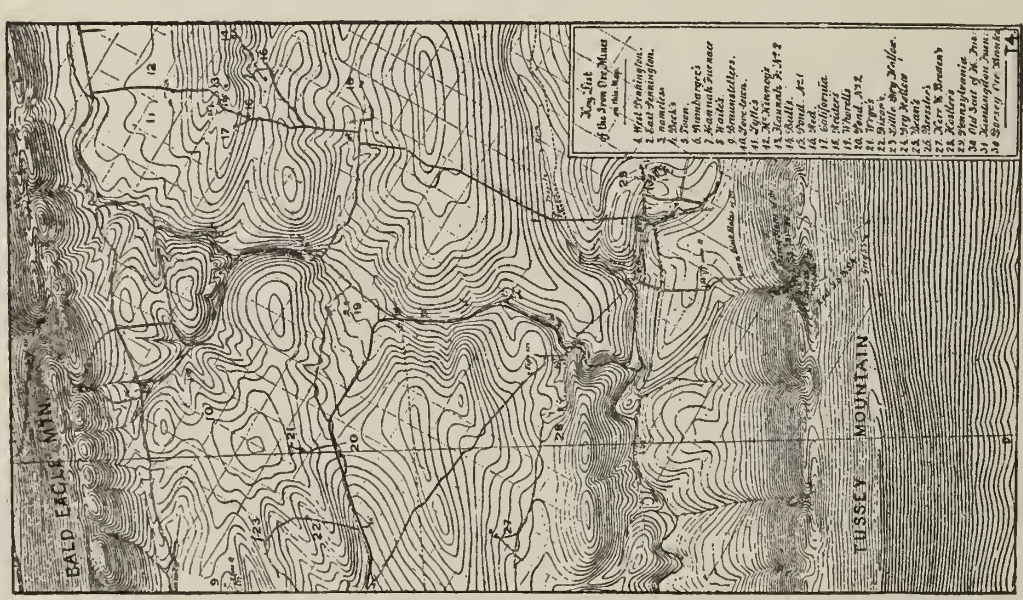


Plate XIV.

FIG. 37.

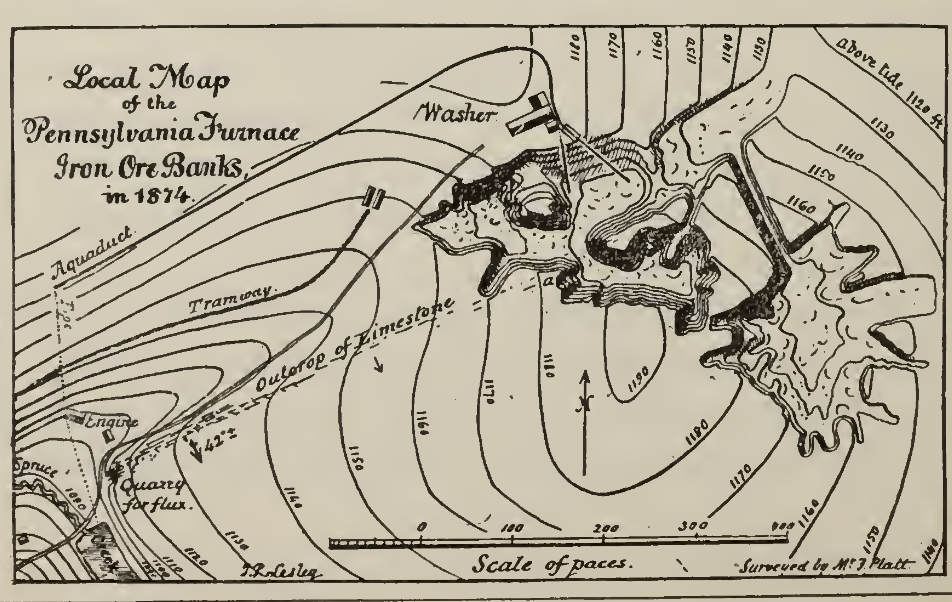
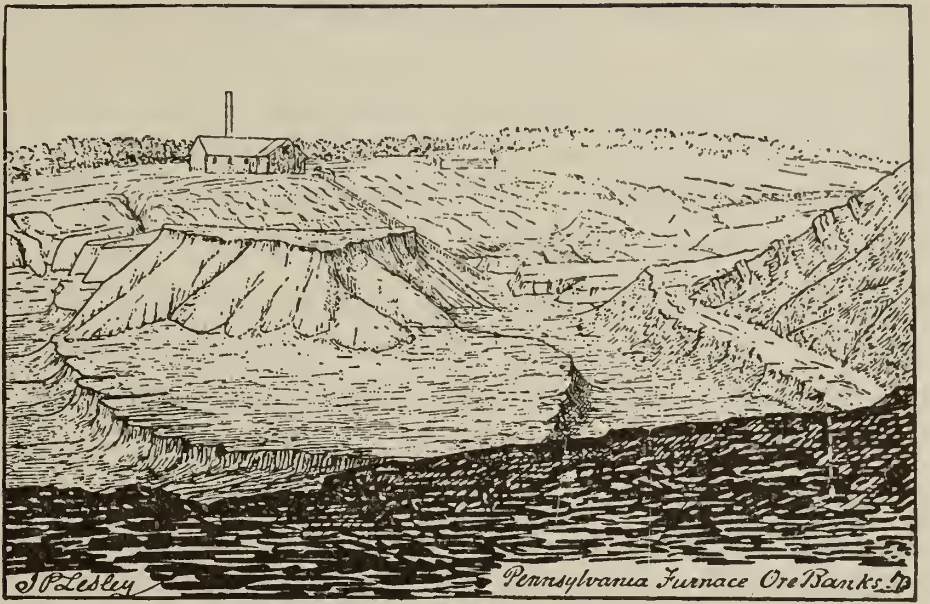
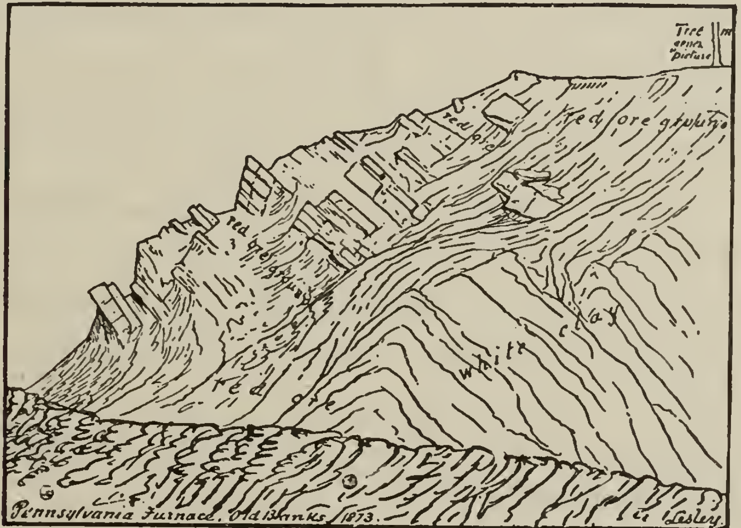


Plate XV.

Pennsylvania limonite mine in Centre Co. Pa.





rich and poor places—feather out entirely in the line of strike and widen again into masses several yards thick, while keeping a general parallelism of bedding with the parent rock and liable to show its change of dip. It is useless to speculate on the possibilities of these deposits, but the ore has been found at great depths, and much original outcrop soil is as yet untouched. For convenience sake it has been thought best to describe them in groups *geographical* rather than *geological*, as follows:

Bellefonte-Nittany Valley group, embracing the following banks: Curtin Bros., Fishing Creek bank, Jackson mine, Red bank, Hoy bank, etc., Gatesburg, Taylor, Nigh, and Logan banks.

Jacksonville Valley group, containing Zimmerman, Darrah, McCalmont, Butler, Beck and Washington Furnace bank, etc.

Hublersburg Valley group, with the Field, McKinney Quinn, Hecla, Howard, Voneda, Schwartz, Huston 1 and 2, Snavely and Barlow & Day mines.

Buffalo Run group, Hunter, Crust, Markle, Lambourn, Pond, Newell, Desert and Celtic banks.

Barrens group, Lovetown, Tow Hill, Scotia, Ackley, Lytle, Red bank, Bull bank, etc.

Pennsylvania Furnace and College group, holding Bryson bank, Johnson, Streuble, Stover, Puddington, and Big Hollow banks.

Penn's Valley group, Watson, Ross, Sinking Creek, J. P. Runkle, Emerick, etc.

The Pennsylvania Furnace mine.

This famous ore bank, on Spruce creek, in Centre county, close to the Huntingdon county line, has been mined since 1815. Its situation in respect to the other ore mines of Nittany Valley is shown on local map, Plate XIV, page 376, Fig. 2.* A special map of the mine as it was in 1873 is on

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*T4, 1884, Appendix A, p. 372. Extracts from J. P. Lesley's report to Lyon, Shorb & Co., in 1873. All figures given in the text above are copied (reduced to ½ linear) of the figures in T4. They will serve well enough as illustrations.

the same plate, Fig. 3. On Plate XV, page 377, Fig 1 is a view of the mine from the top of its S. W. wall; Fig. 2 is a near view of the ribs of undecomposed rock in the promontory seen at the edge of Fig. 1; and Fig. 3 shows the height of the wash ore in the walls.

The great excavation is about 1400′ long by 600′ wide and 60′ deep, but shafts sunk 35′ to a permanent water level proved that other and even better ore masses lie at least that much deeper, and these are covered by undecomposed lime rocks dipping 40°, S. E. as seen in the walls of the promontory above.

The geologist can here study the theory of the formation of the Lower Silurian brown hematite ores of Pennsylvania to great advantage. I know no better place, and few so good.

The ores are evidently not washings from a distance; neither from Tussey mountain, nor from the present surface of the anticlinal ridge; nor from any formerly existing surface in past geological ages, when the surface stood at a much higher elevation above sea level. They are evidently and visibly interstratified with the soft clay and solid limestone layers, and obey the strike and dip of the country; the strike being along the valley, and the dip about 40° towards the southeast.

Thousands of minor irregularities prevail; the streaks of ore and masses of clay are wrinkled and bunched, and thin out and thicken again in various directions. But all this irregularity is owing to the chemical changes of the strata, and to the changes in bulk of the different layers during the protracted process of solution and dissolution, during which the looser calciferous and ferriferous sandstone layers have lost their lime constituent, packed their sand and clay more solidly, and perhydrated their iron. In this long process cleavage planes have been widened into crevices; caverns have been excavated; pools or vats have been created; precipitates of massive (rock and pipe) ore have been thrown down; and a general creeping and wrinkling of the country been effected. But the original general arrangement or stratification has been preserved; and those portions of the whole formation which had but little lime have been left standing as sandstone strata; while others having but little sand remain as solid and massive limestone strata; those which had an excess of alumina are now in the condition of streaks, masses, or layers of white or mottled clays; and only such as were properly constituted clay-sand-lime-iron deposits (originally) have been so completely dissolved as to permit the lime to flow off, and the iron to consolidate into ore.

Every stage of this interesting operation, and every phase which it presents in other parts of the Appalachian belt of the United States from Canada to Alabama may be seen and studied in these old and extensive ore banks of Pennsylvania furnace.

At first sight of the bank the ore deposit looks as if it were a grand wash or swash of mingled clay and fine and coarse ore grains and balls, occupying hollows, caverns and crevices in the surface of the earth and between the solid limestone rocks; and some of it undoubtedly has been thus carried down into the enlarged cleavage partings of the limestones; and into sinkholes and caverns formed by water-courses; where it now lies (or lay when excavated) banked up against walls or faces of the undecomposed lime rock. But as a whole the ore streaks and "main vein" of ore must occupy nearly the places originally occupied by the more ferruginous strata after they had got their dip and strike.

The ore is taken out with the clay, and hauled up an incline by means of a stationary steam engine at its head, and dumped into a large washing machine, with revolving screens; whence, after the flints and sandstones have been picked out, it is carried on an ironed tramway to the bridge house of the furnace.

The ore forms from 10 to 50 per cent. of the mass excavated, and the small amount of handling makes the ore cheap.

The upper ores will furnish stock for yet many years. After that, or in case more furnaces are erected, or distant markets calls for the shipment of ore by railway, deep shafts or bore holes must be sunk to drain the underground, and the lower ones may then be lifted to an unknown extent. *The prism of ore in sight in 1873*, calculated roughly from the old banks and new cuts and shafts, old and new, in various places, contains several millions of tons of wash ore, lump ore, and pipe (rock) ore.* But the unproven ore ground ranges far into the surrounding lands. A large new area was stripped in 1873. Large quantities of ore are left between the limestone ribs in the walls of the pit, as shown in Figs. 33, 34. The limestone ribs dip 35° to 40°, S. 35° E. on the range of natural outcrops shown in the local map, Fig. 37. Slight crumplings of the limestone vary the dip from 18° to 65°; but these are due either to movements in the yielding ore mass or to a deception caused by mistaking cleavage planes for bed plates. No such variations are apparent at a distance from the banks, the whole limestone formation descending uniformly beneath the foot of Tussey mountain with a dip of something under 40°.

The height of the walls of the various excavations may be seen by reference to the ten-foot contour lines in Fig, 37. These also show that the ground now so deeply excavated once formed a high divide between a vale descending southwest to Spruce Creek, and a corresponding but shallower vale descending northeast to the settling-dam hollow. It looks as if the ore once filled both these vales, but has been swept away by the natural drainage into Spruce Creek, from the one which descends in that direction, and, perhaps, from the valley of Spruce Creek itself, down to and beyond the Furnace.

The entire walls of the cuts are of wash ore, and it is all torn down and taken to the washing machine. But the tops of pyramids of solid pipe ore are exposed in the floor, and some reached to, or nearly to, the sod above. At one of the deepest places in the floor, 60 feet below the sod a shaft was sunk 40 feet further through solid pipe

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* Proved area 550 x450 yards, which at 15 yards depth gives $3\frac{1}{2}$ millions of cubic yards, affording 600,000 tons of washed ore ready for use. Of this 100,000 have been smelted into 50,000 tons of neutral cold blast charcoal iron of the best quality.

ore, and then limestone, and was stopped by water. Water does not stand in the present floors on account of the free circulation at a still lower depth through crevices and caverns communicating with Spruce Creek, which itself issues from a cave.

The original name of the Pennsylvania ore bank was the *Bryson cut.* It was examined again by Mr. d'Invilliers in 1883, who found it little changed since my study of it in 1873. At that time (1883) it was in common with most of our mines idle, but a new lease promised a fresh development of it under better auspices.

The *Hosker bank* is on the steep N. W. dips of the Cale Hollow anticlinal ridge, so low down in II as to be 2500′ beneath III. The Pennsylvania ore rocks on the S. E. side of the ridge and dipping 40° S. E. are also sandy dolomites; but above them lies a series of white and blue limestones; and above all lie soft, blue and dove colored Trenton limestones dipping 18° or 15°, S. E. under the slates of III.

The Bryson cut ores are essentially pipe, finely disintegrated, and occurring in every conceivable form, whether in streaks of ore and clay, or in flattened scales, or bunched with sandy limestone, or in solid pipe masses; but everywhere showing a tendency to interstratification and pointing to their probable formation in place by the dissolution and leaching of the limestone rocks and the filling in of cavities with mixed sand, clay and iron-ore. Comparatively little lime has been left in this ore, showing how thorough dissolution has been; and the percentage of magnesia, though low, is probably due to its less solubility as compared with the corresponding lime salt.

Very little of the quartz and flint grains found with the ore are water-worn or rounded, and so create at once a marked difference between these ores and those of the barrens in the Scotia-Juniata range. But it must be remembered that these latter ores are much lower down in the measures. When visited in July, 1883, no work had been done here since the fall of 1882, when Carnegie Bros. & Co. returned their lease of the property.

The Messrs. Carnegie, while doing some little mining in the old workings south of the washer, turned most of their attention to the development of the *New bank* located east of the former and shown on map. About 10 acres in all have been disturbed here.

Various estimates have been made by different parties of the original amount of ore contained in this deposit (which roughly measured may be taken at 500 yards N. W. and S. E. and 350 yards N. E. and S. W.) which vary from 200,000 tons up to 600,000 tons, with a possible output of even 1,000,000 tons, allowing for increased depths over 50 feet, etc. All such estimates are greatly affected by the frequent occurrence of limestone ledges, clay banks and lean faces, and are in every case when carried beyond the depth of the wash deposit and into the solid pipes in the bottom, merely speculative.

The average wash of the materials is about 1 to 8 or 9, which will give 1 ton of ore to each 6 or 7 cubic yards of material, a cubic yard of ore being estimated to weigh only 1¼ tons. The washers occasionally showed a record of one to five, but this was when mining was being carried on in exceptional ground. The majority of the more recent pits (some outside the limits above given) show a depth of only about 10′ of wash ore, under which clay and limestone occur.

The old charcoal furnace was changed in 1881 to a coke furnace of 11′ at bosh, 43′ high and 8′ at tunnel head. It was not successful. The incline plane was abandoned and a narrow gauge railway running down around the edges of the pit was substituted. The new washers had a capacity of 140 tons daily for good rich ore. The difficulty was to separate the light pipe ore from the heavy flint; also to keep the flat or scaly ore from floating off the rig. Boys had to pick out the flints. A steam excavator was tried for stoping down the walls but failed on account of projecting noses or ribs of limestone.

The deepest part of the old bank has been nearly exhausted of cheap ore, and show several outcrops of silicious sandy dolomite, very much broken, but dipping southeast. This rock is frequently ore-bearing, showing occasionally streaks from one-sixteenth to several inches thick. While occurring in the center of the deposit, they do not seem to have affected the ore which occurs above and below them and frequently interstratified with them. Some 30 to 60 feet of stripping has been done here, but shafts sunk from the bottom of the open cut 30 to 40 feet deeper have proved the presence of good ore ground as yet untouched. In the days of early mining here fine exposures of pipes 40′ high are reported, though none such are to be seen to-day. The best ground, when last visited, seemed to be along the south side of the new workings, where really excellent wash ore still remained untouched in a face 30′ high. Good lump ore is reported all along the bottom of these workings, now covered with fine silt and mud, and in any future work this should be mined with the wash surface ore or that in the east end, thus making a cheap and rich average ore. All the work so far has been done above ground, the floor being usually limestone.

Dr. Genth's analyses of (1) two samples of amorphous, brown compact ore mixed with ochreous yellowish or reddish ore, some of its cavities lined with very fine coating of fibrous ore, and (2) of pipe ore, with cavities filled with fearuginous clay, were—Fer. ox., 81.55 (83.74) ; mang. ox., 0.10 (0.31) ; cobaltic ox., a trace (a trace) ; alumina, 1.49 (0.33) ; magnesia, 0.47 (0.34) ; lime, a trace (a trace) ; phos. acid, 0.16 (0.14) ; sil. acid, 2.98 (2.57) ; quartz, 1.55 (0.44) ; water, 11.70 (12.13) ; that is *Iron*, 57.10 (58.62) ; *Phosphorus*, 0.07 (0.06) ; or phosphorus in 100 parts iron, 0.12 (0.10).

Dr. Genth's analysis of the sand rock ribs was : Ferr. ox., 43.65 ; mang. and cob. ox., 1.55 ; al., 2.43 ; mag., 1.64 lime. 0.12 ; phos. acid. 0.27 ; sil. acid, 5.19 ; quartz, 36.52 ; water, 8.63. It contained, therefore, 30 per cent. of iron.*

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* "The above analyses show besides the mechanically admixed rounded grains of sand, which I distinguish as 'quartz', a considerable quantity of silicic acid, which is in chemical combination, probably as a hydrous ferric oxide. But as it is impossible to say what the true character of this mineral may be, whether authosiderate, or degerœite a silicate of the composition Fe_2O_3, $2SiO_2+3H_2O$ or a species not yet known in its pure state, suffice it to say that all these ores are mechanical mixtures of limonite with hydrous ferric silicate and minute quantities of hydrous ferric phosphates, perhaps dufrenite or cacoxenite ; some of the ores contain beside these,

Dr. Genth recognizes three varieties of limestone in this bank, and the results of his analyses are as follows :

No. 1. Upper limestone, dark gray, compact, slightly crystalline. The atomic ratio between the magnesia and lime is 1 : 15.

No. 2. Pale ash gray, very finely crystalline, rough to the touch like rotten stone, very friable and easily falling to powder, a true dolomite. Atomic ratio between magnesia and lime, 1 : 1.

No. 3. Yellowish gray, soft, rotten, feels rough to the touch, sandy ; crystalline ; has a laminated structure ; also a dolomite. Atomic ratio between magnesia and lime, 1:1.08.*

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small quantities of manganese ores, mostly the so-called 'bog-manganese' or wad, but also pyrolusite and Psilomelane.

"It is a very remarkable fact that, although these iron ores are, to a great extent at least, the result of the decomposition of limestones and by them precipitated, that almost the entire amount of lime has been washed out of them and only traces are remaining ; of the second constituent of the limestones, the magnesia, a somewhat larger quantity is left behind, owing undoubtedly to the lesser solubility of its carbonate in carbonic acid water." (Dr. F. A. Gen., T3, p. 434.)

* Dr. Genth's analysis of a 4′ bed of limestone capping 33′ of pipe ore in the Hostler bank (T3, p. 435) shows that it too is a *true dolomite*, but holding 4.33 of quartz and silicic acid. He adds (p. 436) : "It is remarkable that the limestones and dolomites, of which I give the analyses, contain almost the entire amount of silicic acid as quartz ; only a small quantity is present as soluble silicic acid and in combination with alumina. If the limestones and dolomites are dissolved in acid, the quartz remains often as a scoriaceous mass or in irregular sandy but not rounded or water-worn grains ; sometimes it forms large coherent slaty masses in the limestone, frequently filled with minute cavities, previously occupied by rhombohedral crystals of dolomite. Similar pieces found in the Pennsylvania bank are white like porcelain and show the same cavities of rhombohedral crystals. Other varieties of limestone in the Pennsylvania bank have a still greater admixture of quartz and are a real calciferous sand rock."

	(1)	(2)	(3)
Carbonate of iron,	1.31	0.45	.118
" " manganese,	0.18	0.06	trace.
" " magnesia,	3.98	42.39	35.51
" " lime,	72.67	51.25	45.73
Quartz and silicic acid,	18.05	5.03	15.83
Alumina,	3.81	0.82	1.75
Total,	100.00	100.00	100.00
Metallic iron,	0.63	0.22	0.57
Magnesia,	1.90	20.19	16.91
Lime,	40.69	28.70	25.61

Dr. Henderson before his death sent me a cross-section, which he had made on his own farm 4 m. N. E. of the Pennsylvania bank, see Fig. 1, plate XIV. By his calculation the Pennsylvania ore horizon lies 2200′ beneath No. III, with another ore horizon 300′ above it, and a third one 800′ above it; that is, only 1400′ beneath No. III.

Chapter XXXIII.

Nittany valley, Huntingdon county ore mines.

Before describing the banks I must continue the structure of Nittany valley through Huntingdon county to the little Juniata river. A few words and the accompanying cross-sections on plate XIV will suffice.*

If my cross-section along Warrior's Run (T3, Fig. 3) be correctly drawn it exhibits *four ore horizons* rising to the surface, one after the other, from S. E. to N. W., their outcropping rocks making parallel belts of ore banks, and their respective depths geologically beneath the bottom of formation III being as follows:

Trenton limestone, etc., etc.
Pennsylvania and Cale Hollow banks, ... *2500′*
Barren interval, 700′.
Huntingdon furnace ore banks, ... *3200′*
Barren interval, 550′.
Tollgate pipe ore range, ... *3750′*
Barren interval, 1500′.
Pennington, Town, Lovetown banks, ... *5250′*

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*The cross-sections in T3, Figs. 1, 2, 3, pp. 376, 378, 380, embody my views of the structure after my private survey of the region for Lyon, Shorb & Co. in 1872. I was assisted in a contour line survey of it by Mr. Franklin Platt, from whose field notes the contoured map was plotted and drawn and the ore banks located. In 1882, during the progress of the state survey, my topographical assistants, Mr. E. B. Harden and Mr. O. B. Harden, surveyed and mapped that most troubled and obscure part of the valley lying east of Tyrone forges and Birmingham to get the faults in Bald Eagle mountain, and the true location and character of the Nittany axis in Pennington ridge. The following year Mr. d'Invilliers went over the ground in furtherance of his own work in Centre county; and his criticisms on my sections of 1872 will be found in the report on Huntingdon county, T3, pp. 443 to 445, his chief objection being to my little Logan creek synclinal, as he would prefer to consider the S. E. dips along Logan creek as *overturned N. W. dips.* Nor am I at all positive that my original construction of the rise of the limestone mass over the Bald Eagle mountain at the Tyrone gap is the correct one, although my observations along Logan creek were long, close and carefully studied, and my section was drawn in full view of the fact that a downward brush of the edges of the limestones against the opposite (N. W.) side of the fault was rather to be expected.

PL. XVI

Nittany Valley Cross Sections in Huntingdon Co.

Fig. 1.

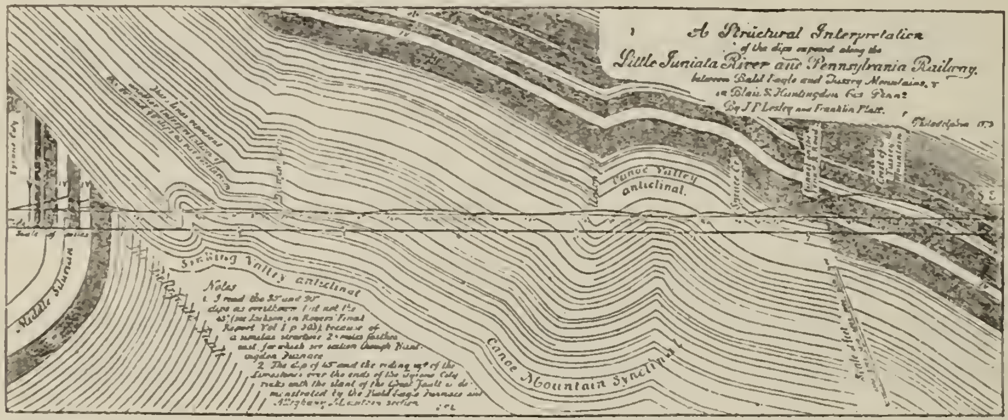


Fig. 2.

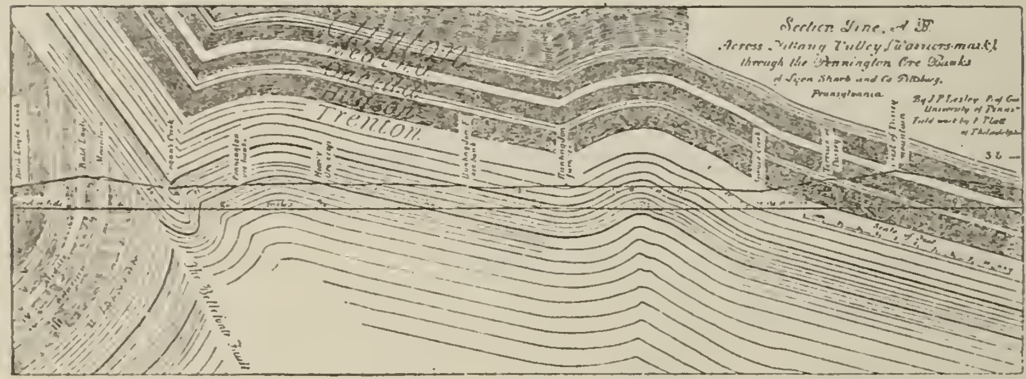


Fig. 3.

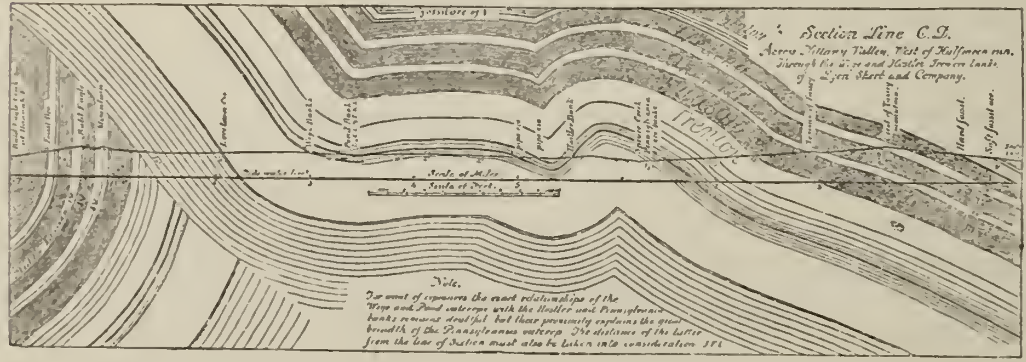
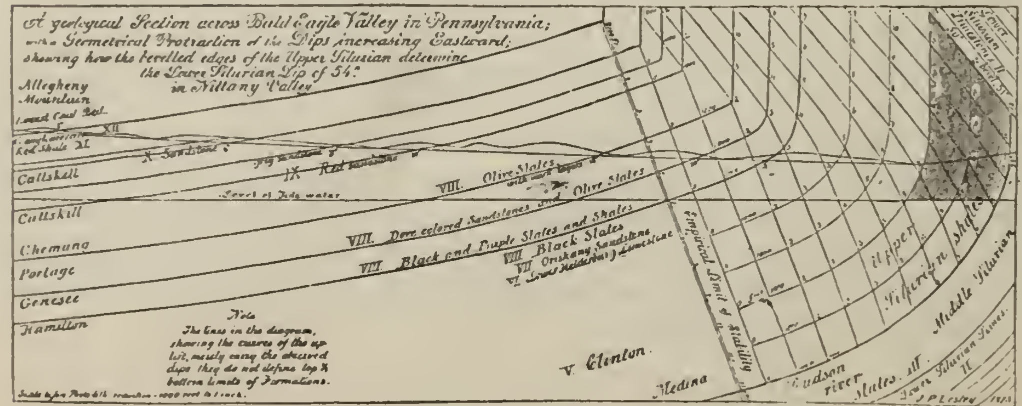


Fig. 4.



Pl. XVII.

Nittany Valley.

A topographical sketch map in 20′ contours made in 1873
locating the Ore Banks of Huntingdon and Centre Cos
By J. P. Lesley. Field work by F. Platt.

Pennington range in Huntingdon County.

The lowest range of ore banks is described in T3, p. 388; and pl. XIV, f. 8, gives their arrangement.* It commences 2 m. from the Juniata and runs 2 miles to the RR. 1 m. W. of Warrior Mark village; the N. W. face of the ridge covered with *wash ore, underneath which lie sheets, belts, and masses of rock ore between ribs of undissolved lime-sand rock, with interstratified beds of lime-shales turned into white clay.*†

That rich ore masses descend N. W. in a series of irregular but continuous floors and layers between the clay beds was proved by the gallery work driven in wavy ore. Great quantities of salable ore and wash ore also existed.‡

The main open cut 700′x100′x15′ to 25′ deep has wash ore walls, 15′. A shaft struck (at 15′) *manganese ore* 5′. In this pit stands a solid rib of half decomposed limy-sandstone strata, carrying more or less ore, dipping gently N. W.; bunches of good ore in ferruginous sandstone. *It is an admirable place to study the genesis of our limonite ores.*

The West Pennington bank (Fig. 10), ½ m. from the last, 550′x120′ is wholly in wash ore; yielded richly for 7 years as an open cut to a depth of 40′; then worked by galleries (Fig. 12). Another open cut 200′ further west, 300′x45′x 25′ deep (once much deeper) in wash ore. Another, 400′ fur-

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*The *Pennington ridge anticlinal* loses itself in the hill N. of Warrior Mark village and in the great fault further on. Obscure dips of 80°, N. W. in limy sandstone 500 yards N. W. of the village, might very well be mistaken for 30° to 60° S. E. dips on account of the innumerable cleavage planes; but 80°, N. W. dips are seen in blue limestone 450 yards further up Warrior Run. All the outcrops N. E. of Warrior Mark village belong to the S. E. side of the Pennington ridge anticlinal, as any one can see who travels along the road to Lovetown. Therefore the *Pennington ore range* is a short one; but the next ore range to the S. E. of it runs on through Warrior Mark village and Lovetown into Centre county.

†Fig. 9 is a reduced copy of Böcking's map of the underground tunnel workings, shafts, etc., in the Old or East bank. Water stopped most of the old mining. One old shaft 30′ deep was deepened to 60′ and struck the *sandstone floor*. Another shaft in 1865 reached the ore bottom at 45°. For further details see T3, p. 392.

‡Thus the first pit near the RR. 200′x50′x15′ deep yielded 5000 cubic yards of wash ore without solid lump. Shaft No. 1 near it went through top wash 15′, rich lump 5′, barren clay 25′, good lump 15′. Shaft No. 2, lean ore on top, clay to 40′, good lump 10′.

ther west (*Old Phillips' bank*), 300′x90′x20′; once deeper and drained by a tunnel, 420′ long.* The *Beck bank*, ½ m. N. E. of old Pennington bank, is 120′x60′x15′ deep. The *New Town bank* (also *Beck's*), 1 m. further N. E., stopped by water, ore in floor.

Warrior Mark and Lovetown range.

From Warrior run, N. E., we have almost a continuous series of shafts and open cuts on thes ame lowest lime-sand horizon as the Pennington, but on the S. E. dip; thus—

Old Town (½ m. E. of Warrior run); *Romberger's* (1½); *Hannah* (1¾); *Waite's* (2¼); *Braunstetter's* (2⅔) with pipe ore outcrops to the S. E. of it; *Disputed* (4¾); *Hannah furnace* (5); *Hannah furnace* and *Beck* (½ m. N. of the last two, and less than a mile W. of Lovetown); *Pipe ore pits* (½ m. S. of Lovetown); *Saw mill ore crops* (2 m. N. E. of Lovetown); *Hannah furnace* and *Bryan* (2⅔); *Curtin* (5).†

The ores, when rich, are black or very dark, much of it pitchy lustrous, often inclining to cold shortness;‡ the leaner ore of a lighter brown; clay predominating over sand in the deposits; perhaps some of them somewhat higher in II than the Pennington, but still very low in the formation.

Dry Hollow range in Huntingdon County.

Under this head in T3, pp. 404 are described, figured and mapped:—*Pond bank No. 2; Wrye bank; Old Sandy;*

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* This range, with its lean layers and sand masses so low in II (Cal. SS.), "holds purplish, easy smelting ore, mixed with day and without discernible regular veins" (Böcking). Plenty of wash ore; but dry screening impossible. It is evident that a vast quantity of ore is still to be won, but it can only be won by scientific stoping and washing. The extensive dry tailings covering the slope north of the cuts can be profitably washed and got out of the way of deep mining (J. W. Harden). When powerful pumping machinery is employed many hundred thousand tons will be won at a market profit.

† Their descriptions, with local map figures, can be found in my report embodied in report T3, pp. 400 to 404. The description of the Lovetown banks will be found in T4, pp. 354 to 360, with local map Figs. 20 to 25.

‡ See Dr. F. A. Genth's analyses in T3, pp. 427, 429.

Pl. XVIII.

Nittany Valley limonite ore banks. 1873.

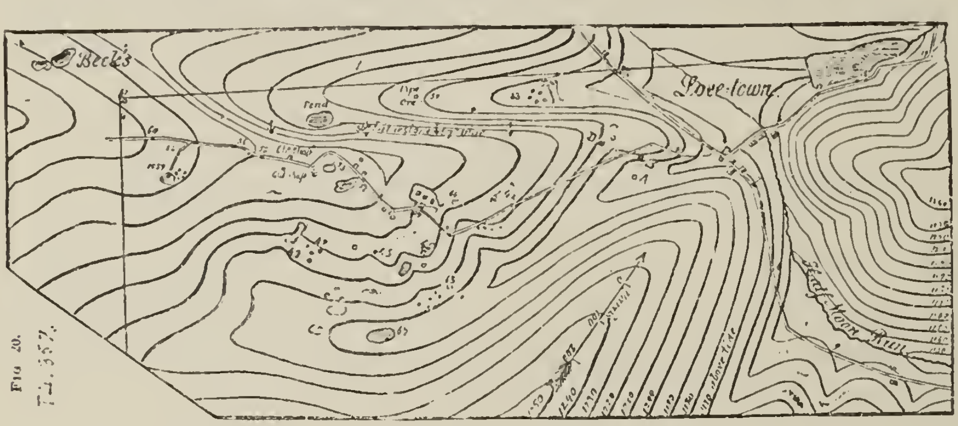
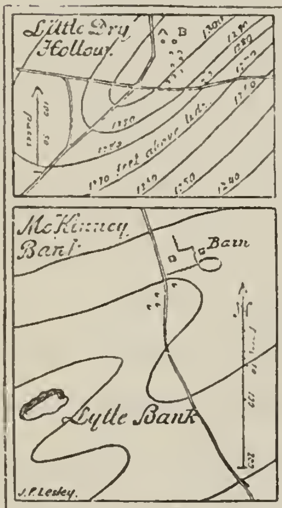
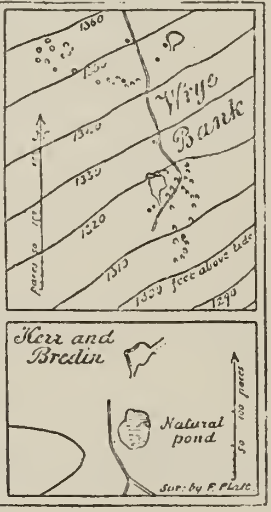


Fig. 20. T4.357.

Figs. 21, 22. T4.359. Figs. 23, 24.





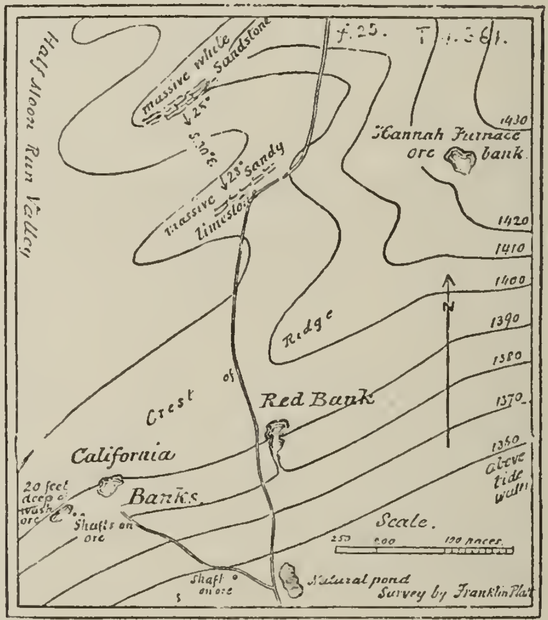


Fig. 26. T4.364. Fig. 27.

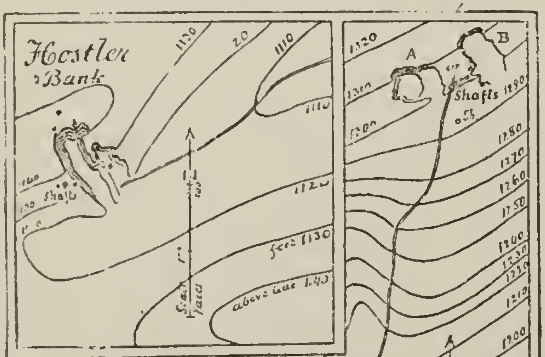


Fig. 34. T4.365.

A PART OF KERR & BREDIN BK.

Pl XIX.

Nittany Valley ore banks in Huntingdon Co.

Fig. 5.

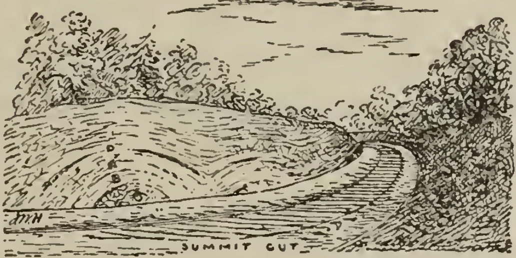


Fig. 8.

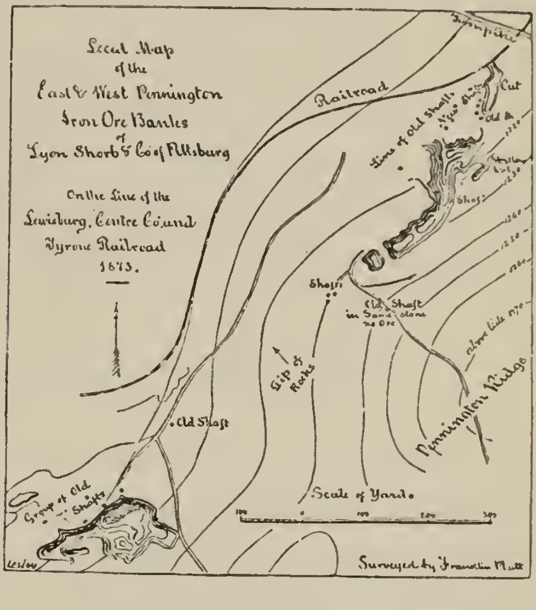
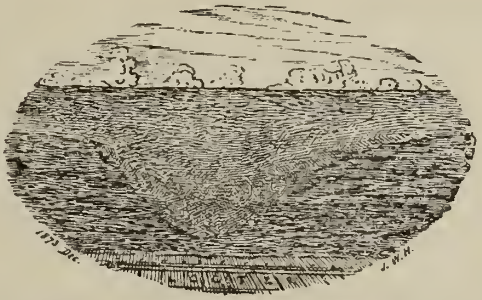


Fig. 6.



Summit Cut, in siena-colored Wash-Ore, exhibiting erosion (?) & débris of pulverized Calcif: S. S.

Fig. 9.

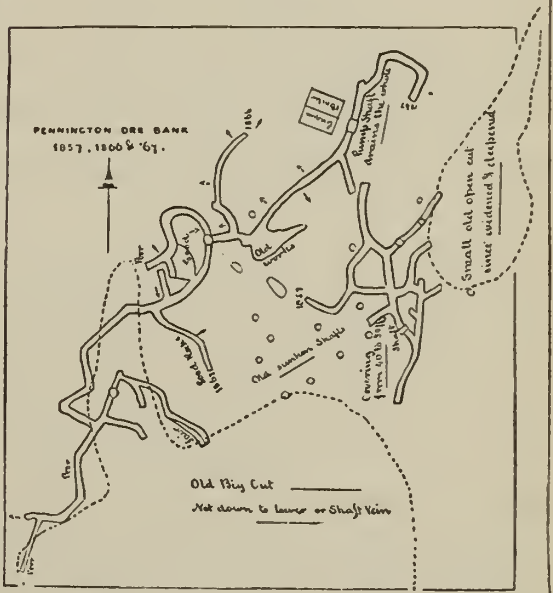
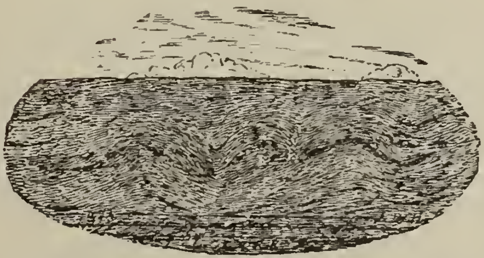


Fig. 7



Summit Cut in Washore with Ore-streaks One foot thick.

Fig. 10.

Fig. 11.

*Simpson's; Dixon's; Little Dry Hollow; Dry Hollow; Old Red bank; Bean bank; Bressler's.**

The great breadth of the Dry Hollow belt is sufficient evidence that it covers more than one geological horizon; and to this is added another proof, the different character of the ore in (for example) the Pond and Wrye banks. It is quite certain that the banks of this group or belt are in geological range with the Kerr and Bredin, Hosker, and Pennsylvania Furnace banks.

Cale Hollow range in Huntingdon county.

This is separated from the Dry Hollow range by Hickory ridge and its ores lie in a deeper and narrower trough, but at the outcrops of the same rocks, therefore of the same horizon, and of the same character, except that an abundance of *pipe ore* has been mined from Cale Hollow and very little from Dry Hollow.

The banks of this range described in T3, p. 413, are the *Kerr and Bredin bank*, of high reputation for its "*gun*

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*I can only extract a few sentences of most note, and refer the reader to the reports. In the Wrye bank an old miner said they went through *worthless* wash ore 26′ and then 18′ good lump ore, and still in the floor. What the charcoal furnace men called *worthless* is now valuable to hot blast coke and anthracite furnace men. It is also reported that the top of the ore mass at one place sank to 50′, thinned away and rose again. Rich solid ore still stands 45′ beneath the surface. In Jos. Kreider's fields the surface show indicates a heavy mass of rich solid ore underground.—The Dry Hollow pits occupy a great space and have had formerly a great output; mostly of fine wash ore in clay; shafts going down 60′ through wash and lump ore, and always drowned out for want of adequate pumping power; only the lump ore marketed, the small wash ore despised. The connection of Dry Hollow with Red Bank solid ore ground under the surface wash is certain. The RR. cut exposes wash ore for 300′ or 400′, in some places 10′ thick resting on clay, in other places 20′ or 25′ thick holding large lumps of solid ore. The varying thickness of the red clay and ore layers in these exposures teaches the meaning to be drawn from the miners' trial shafts. Some of the solid lumps weigh 300 or 400 lbs. Very few chert fragments are seen; in fact this exposure shows less silica than any other in the valley. Little or no soil covering exists.—At *Bean bank* the surface ore lumps were lifted and sent to Huntingdon furnace; and it is the practice elsewhere; no attention paid to the great body of wash ore; no effort to mine to the deep; consequently a vast amount of ore ground awaits future exploration and excavation, even within a mile of the railroad. (T3, 412.)

metal ore," much resembling that of the Bloomfield banks in Morrison's cove, Blair county.*

The wash ore ground contiuues along Hickory ridge. *Bronstetter's pits* are 1½ m. W. To the east it continues to *Little bank* in Half Moon run, with dips of 20°, &c., S. 30° E.

The Hostler bank on the N. W. slope of the Spruce Creek anticlinal, 2 m. S. W. of Pennsylvania furnace which used the ore; a large open cut in "pipe" wash ore (sometimes mixed with lump) 60′ and 65′ deep, in all the shafts; one of which struck (at 65′) solid limerock 10″ to 2′ thick; below which pipe ore 45′ deep.

It is a constant and important feature of the *pipe ore banks* of the southeastern ore range, that they do not exhibit the so-called *lean ores* of the lower geological horizons in the ore ranges to the N. W. of it, in the Barrens, &c. It has been the uniform experience at the Hostler, Pennsylvania and other *pipe ore banks* that shafts and borings have always passed through *lump ore* after having been sunk or drilled below water level; but never reached its bottom because they could not be kept clear of water owing to deficient pumping power. The underground drainage all through the valley is immensely copious, and the largest, deepest bodies of heavy ore are yet to be won by better mining.†

Red bank, and several old pits, lead on N. E. to *Little bank*, 1⅝ m. W. of Penn furnace. *Eyer's bank* is a mile further on on the E. side of Half Moon run. Then (across

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*Analysis by Dr. Genth:—Ferric oxide, 70.67 (as compared with Dr. Wuth's analysis of Bloomfield ore, 78.63); mang. ox., 0.36 (mang. 0.29); cobaltic ox. a trace; alumina 3.91 (2.50); magnesia, 0.26 (0.38); lime, a trace (0.34); phos. acid, 0.19 (0.134); sil. acid, 5.48 (7.02); quartz, 680; water, 12.33 (10.71). The extra quartz in Dr. Genth's analysis lowers the p. c. of iron to 49.47, as compared with Dr. Wuth's 55.04 (T3, 413).

†T3, 417, quoting J. P. L. in report of 1872. Mr. Böcking writes that 35′ ore will pay well for stripping 65′ to 75′ of overclays. The *Hostler pits* measure 360′x150′x30′. The ore lies in clays separating ribs of undecomposed limestone. The clays are mouldered lime shale partings between solid limestones. Shafts more recently sunk went through alternate ore clays and limestone ribs, dipping 38° N. 35° W. In the N. W. shaft 75′ wash ore lay on the first solid limestone. The wide flat part of Cale Hollow was 20 years ago after many years of "ground-hog mining" still a virgin district.

Pl. XX.

Nittany Valley ore banks, Huntingdon Co.

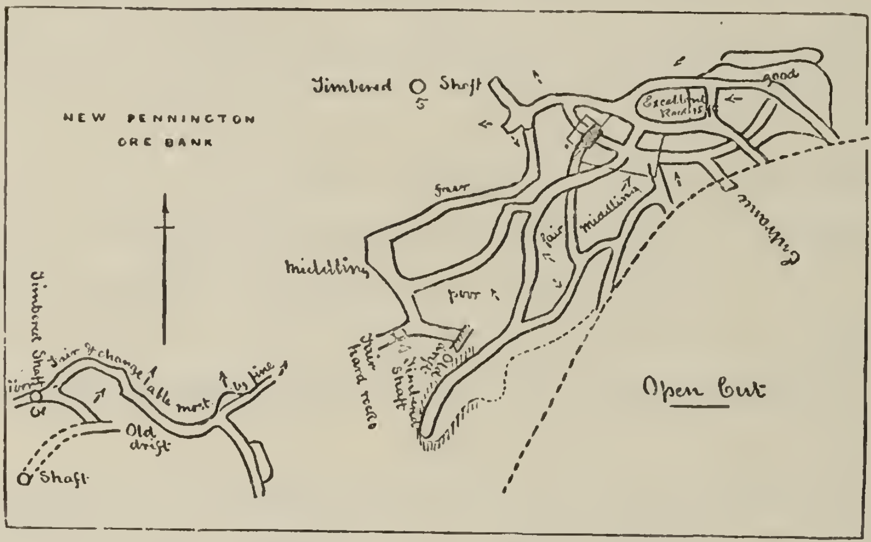
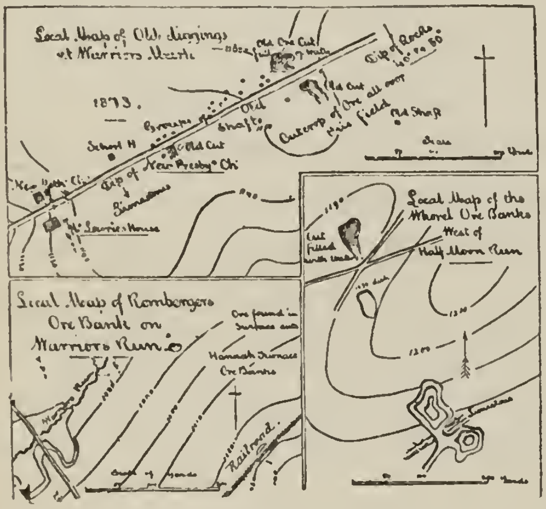


Fig. 12.

Figs. 13, 14. Fig. 17.



Figs. 15, 16. Figs. 18, 19.

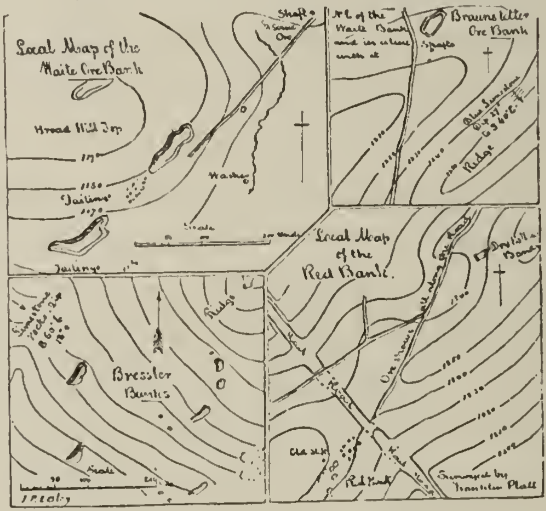


Fig. 29.

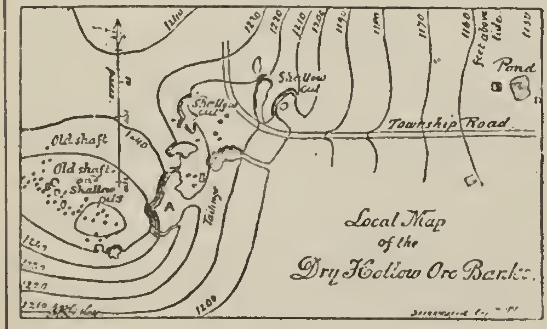
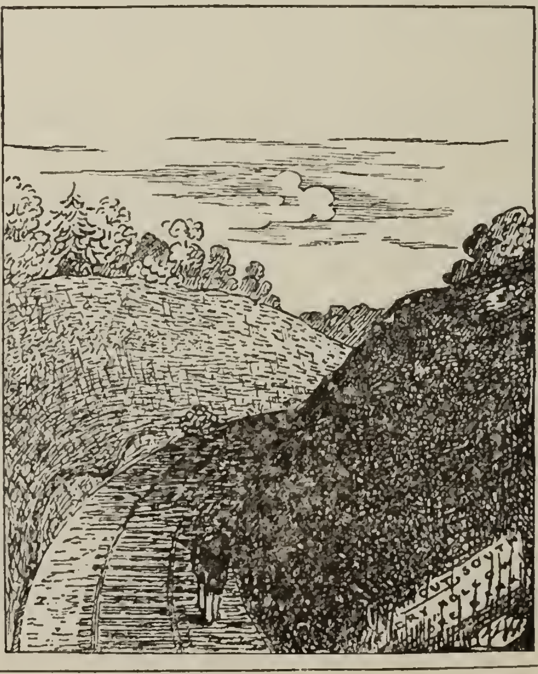


Fig. 31.

Road to Warriors Mark through Dry Hollow Bank.

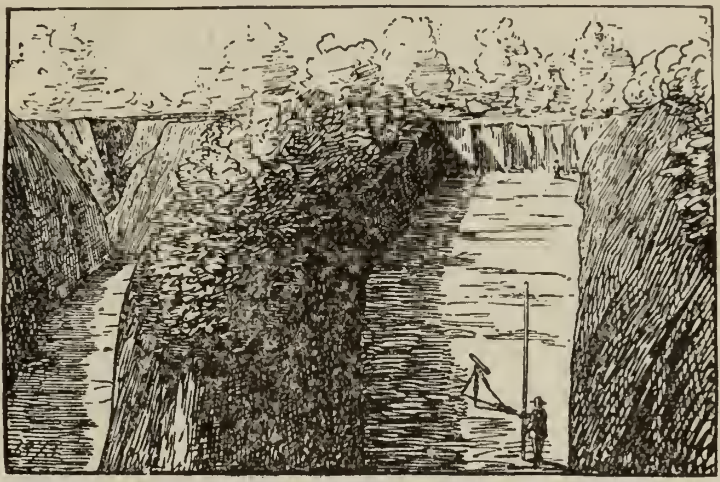
Fig. 32.



Pl. XXI.

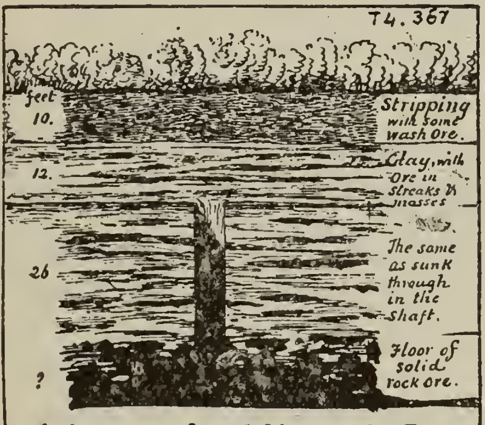
Nittany Valley ore banks in 1873.

Fig. 33.



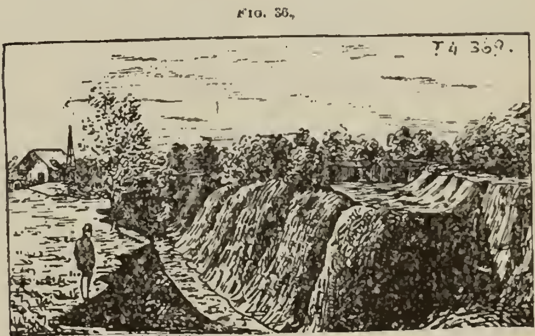
Part of the Kerr and Bredin Bank, sketched by J.W.Harden.

Fig. 35.



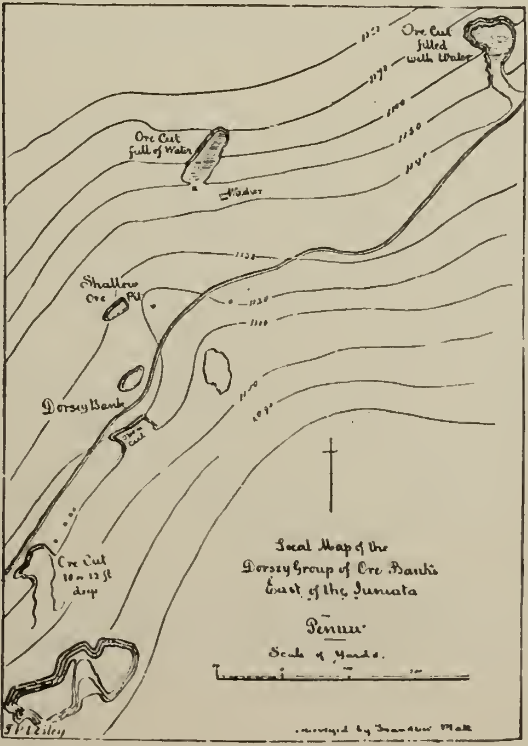
A Section at Kerr & Bredin Ore Bank.

Fig. 36.



THE HOSTLER ORE BANK

Fig. 44.



a divide) the ore follows Tadpole run in Sleepy Hollow at the head of the Beaver dams; then the dry hollow beyond is a repetition of Gale Hollow; and so the outcrops continue to McAllister's and School House cross roads, 8 miles from the Hostler bank.*

The pipe ore horizons have a geological range of at least 1250′. This is conclusively proved by a careful section of exposures along Warrior Mark run above and below the *Old Seat bank*, 2⅓ m. S. E. of the RR. bridge over the run.†

Huntingdon furnace banks.

Within a circle of two miles radius around the furnace, among 10° S. E. dipping rocks, are the *Wilson bank*;‡ the *Keefer* banks; the *Dorsey* banks;§ whole length of ore ground, 6000′; maximum breadth, 1500′; in prolongation of the Dry Hollow range before described, and in all respects for mining purposes, resembling it. Much lean ore is mingled with the rich, and much dead stripping is required; but the liver colored, sandier ore lies on the N. W. side of the belt, up the hill side, lower in geological

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*Beyond this, towards Pine Grove mills, the old Weaver banks are not regular pipe ores, but the liver colored red short ores of lower horizons brought to the surface of the broad plateau by the Brush Valley anticlinal (T3, 420).

†See full description T3, 422. Beginning at the mouth of Cale Hollow, 1 m. E. of Huntingdon furnace, an old *pipe ore bank* shows 50° N. W. (another dip is 38°).—At 2000′ N. W. the dip is 12° S. E.—At 3300′ the *Old Seat bank* worked the same pipe ore horizon; abandoned for lack of pumping power; ore lean, liver colored, like Pennington, but no sandstone; a good deal of flint, however, as at Pennsylvania.—1800′ further up run limestone 9°, S. E.—900′ further sandy limestone 10° S. E.—1500′ further, pipe ore plowed up. *Pipe ore horizon, No. 2, 700′ geologically lower than Old Seat horizon.*—1500′ further, sandy limestones, 13°, S. E.—3000′ to tollgate, no dips exposed, but, no doubt, all gentle S. E.—1500′ S. W. of tollgate, therefore on strike, old deserted pipe ore bank; *Pipe ore horizon, No. 3, 550′ below No. 2, or 1250′ below No. 1.*—From tollgate 2400′ up run to RR. bridge; 1200′ further up, *Beck* and *Town* banks, dips in interval 20°, 35°, etc., S. E.; therefore, their Pennington range, non-pipe ore horizon, is geologically 2500′ to 3000′ beneath the Cale Hollow pipe ore horizon, No. 1, above.

‡Here surface ore clays lie on limestone beds which cover lime sandstones.

§Three miles N. E. of Juniata river at Barree Forge. One, 200′x75′x20′; another, 225′x90′x12′; another, 600′ x210′x45′; in places much deeper, and wholly in wash ore, merely uncovering the solid ore in the floor.

horizon ; and the pipe ore lies down hill, S. E. geologically higher, among the non-siliceous magnesian limestones.

Sinking Valley mines.

These are on the Blair county side of the Little Juniata. Dark colored lime-slate, apparently *graphitic*, crops out near Birmingham, and near the axis of the great Nittany anticlinal ; therefore fully 5000′ beneath III.*

The McCahan shafts, ½ m. S. W. of Birmingham, and on the same geological horizon, won rich good *pipe ore enclosed in sand*, although there is a little yellow clay with the ore ; the *black lime slate* is at the bottom of the shaft.

The Robeson pit, 2 m. S. S. W. of Birmingham 100′x20′x-20′ is in Col. Galbraith's fields, where 4 or 5 acres are covered with a great ore show. Ore on the Gunnison farm also.

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*The same black slate appears on the Cogan farm 1 m. N. E. of Birmingham. The wash ore lumps in clays are all *water-worn.* Analysis of ore in T, 246.

PL. XXII.

Nittany and Canoe valleys. Their Anticlinals and Faults.

fig. 1.

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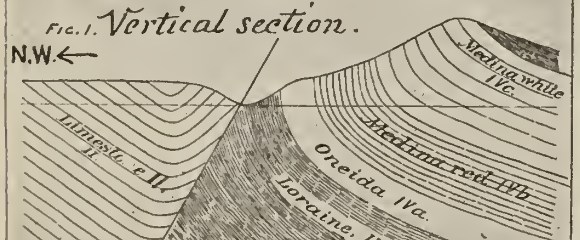
fig. 2.

Fault at Spruce creek gap of Tussey mtn.

Fig. 1. Vertical section.

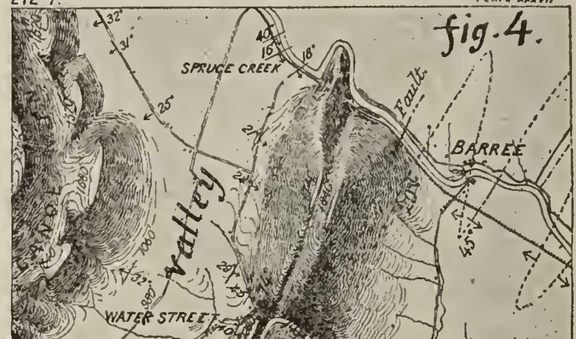
Horizontal ground plan.

Fault at Port Clinton gap of Kittatinny mtn.



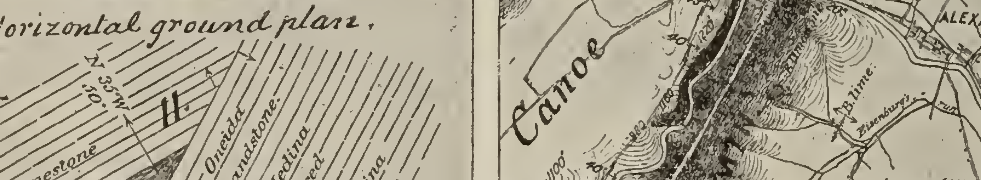
212 T. PLATE XXXVII

fig. 4.



Cross section along the Little Juniata from Spruce Creek to Barre forge

fig. 5.



CHAPTER XXXIV.

Canoe Valley and Morrison's Cove limestone and ore.

Canoe valley is not so much a southward continuation of Nittany valley as it is a long side gallery leading from the grand hall of Nittany valley into the closed chamber of Morrison's Cove. A very sharp and very high anticlinal wave, ending northward in a fault, lifts about 5000′ of No. II, between terrace walls of III and crests of IV, broken by the two Juniata river gaps; Tussey mountain on the S. E. and Canoe mountain on the N. W.

Along the foot of the Canoe mountain terrace runs Jackson's fault,* which at the Juniata water-gap above the town of Williamsburg, throws the Trenton limestone 3000′ against the Medina sandstone, lapping them horizontally past each other, and separating thus Short mountain from Canoe mountain. The fault and the anticlinal axis converge eastward at an angle of about 15° and die a little beyond the Little Juniata.

Another fault runs along the south edge of Canoe valley. and is an interesting study in a topographical sense, because it has determined the course of the river and the place of its water-gap at Waterstreet; cutting off another "Short Mountain," between the two rivers.† This is the fault struck in Spruce Creek Tunnel on the line of the P. R. R. It throws the middle beds of II up against the middle beds of III in the gap at Spruce Creek Tunnel; but being

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*Studied and described by him in 1838, but wrongly located in direction and length until our instrumental surveys of 1876 and following years, at which time I extended it to the Little Juniata at Spruce creek station and discovered its real relation to the central anticlinal. See my small reduced sketch map in T3, plate LXIV, page 346, reproduced on a still further reduction in this volume, plate XXII. fig. 1.

† Fig. 4 shows the curious and beautiful topography of the Narrows, and the narrow throat of the Canoe valley at the Little Juniata. Here the anticlinal is destroyed by the fault; as shown in Fig. 5, at the bottom of the plate, along section on line of Little Juniata.

oblique to the valley strike, it carries the top of II against IV by an horizontal slide movement, so as to enclose a triangular point of III between them; as shown in the vertical section and horizontal ground plan, fig. 2, on plate XXII.*

In Canoe Valley proper are the old *Clark mine*, 1 m. S. of Etna furnace; the old *Etna mine*, 2½ m. N. of Williamsburg; the *Brower mine*, 3 m. N. W.; the *Short Mountain mine*, 2½ m. N. W. (and 1½ m. N. of Franklin forge); *Dean's bank*, 1¾ m. S.; *Patterson's bank*, 1½ m. S. W.; and the *Williamsburg M. Co.'s Red Ore mines*, 1¾ m. S. W. of Williamsburg.†

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*I have added (as fig. 3) a vertical section of the fault in Schuylkill county for comparison, and have reversed it (N. for S.) in order to make the comparison easier for the eye.

† Described and figured in T, pp. 231 to 244. The figures are reproduced, reduced to half size, on plate XXIII.—The *Clark mine*, small and long abandoned; ore rather red short.—The *Etna bank*, on the central barren sandy ridge, 1200′ above tide, 400′ above the river level, looks down from the N. point of the ridge upon an amphitheatre of cultivated country 150′ below it; 5000′ geologically below III; abandoned years ago, 1000′x200′x50′ deep; exceedingly rich wash ore (not water worn); much *manganese* ore in sporadic irregular layers; shafts 112′ deep said to have worked rich lump ore; water totally wanting.—The *Brower mine*, 150′x50′x20′, now abandoned; on central sandy barren ridge; walls all sand, no clay visible; many masses of conglomerated angular flint fragments cemented with iron ore, and many great masses of sandstone and flint coated with ore, as at Springfield mine: no limestone fragments visible. Limestone strata between it and the Canoe mountain dip west, and if it were not for Jackson's fault the ore horizon would be only 2500′ beneath III, as given in the text of T, p. 241; but this is a great mistake, for the ore is evidently the Springfield and Etna ore, and we must understand that 2500 of II are swallowed by the fault, placing the ore at 5000′ beneath III.—The *Short Mountain mine*, described in the text above, is still worked. Yellow, red and white clays in heavy masses, many of them without any ore; ore clays apparently in three stories, with barren clay partings: (1) upper "sparry ore" in W. wall of E. large open pit; (2) 40′ and (3) 60′ deep in W. wall rising rapidly to the surface at top of E. wall. West pit 60′ deep now abandoned. See analysis of *ore* T, 239; and of *limestone flux* for Etna furnace, in which is C. Mag. 3.9; sulphur, 0.053; phosphorus, 0.011. (T. 240.)—*Dean's bank*, 250′x10′ to 50′x10′ to 15′ deep. Small ore in wash; at E. end cut abutted squarely against solid limestone strata; mine abandoned; ore very red short, as used in Williamsburg furnace. See analysis T. 236.—*Patterson mine*, on the Sandy Central ridge, covered with quantities of sharp sand; southern shaft 80′ deep, ore struck at 15′ and left in bottom; ore mass worked 9′ thick *descending vertically*, then at 40′ depth bending to an E. dip; north shaft 55′ deep, ore vertical, taking below an E. dip; tunnel ore work joins the two; ore of two kinds, (1) liver ore, often

It is significant of the decline of the Canoe Valley anticlinal northwards that the valley narrows and the bounding mountains approach each other closest at the Little Juniata. It follows that deeper and deeper horizons in II reach the surface successively going south along the crest of the anticlinal, which makes in many places a prominent central ridge on which are ranged the principal mines. Now, as we encounter on the map going south no mines until after passing Water street and Etna furnace, it follows that the upper horizons are wanting, and that all the mines are on horizons from 2000′ to 5000′ beneath III. Direct cross measurements based on dips verify this conclusion, and show that the *Etna bank* is something less than 5000′, and the *Springfield bank* about 5000′ beneath III; while the other side banks are higher in the series.

The Short Mountain mine is a great curiosity for those who interest themselves with geological structure; for it is situated in the narrow belt of the slates of III as they swing round the point of Short Mountain to meet Jackson's fault. But neither black slate nor black clay is to be seen in the extensive open cuts (which were still worked a little in 1876), nor any limestone, but only flints and sand in abundance in the ore-clays. No solid rock has been encountered in sinking an 80′ shaft and driving a tunnel under the old west bank; nothing but white sand and sandy clay; the tunnel entirely in white sand; yet the shaft is just south of the south end of the large open mine. The iron-coated sandstone rock in the open mine dips (obscurely) 46°. N. W. The bottom of the ore mass has never been reached and great quantities remain to be won. The only explanation of these curious facts which I can suggest is, that the slate belt is not properly located, and that the mine is probably on the line of Jackson's, or some other (branch ?) fault, like the Leathercracker Cove (Henrietta) mines; but the ores here do not in the least resemble the Henrietta ores. On the contrary all the circumstances

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silicious, (2) richer deep red or blackish manganiferous ore; output not great. See analysis, T, 235.—*Red ore bank*, on the sandy barrens; northern pit small; southern open cut, 40′ slope; red clay holds good redshort ore; much flint rock through clay masses. For analyses see T, 233.

here suggest the Etna-Springfield horizon, only that there is here even more sand and less clay masses.

The *red short* qualities of some of the No. II ores is explained occasionally by the presence of pyrites. For example, in *Dean's bank*, a shaft 15′ deep in the floor of the open cut went down through loose, partly decomposed limestone and extremely sulphurous iron ore; "in fact, *there were great masses of decomposing iron pyrites, with a hematite crust.*" "The solid rock of all kinds in the bank, whether ore pebbles or limestone pieces, are all rounded and worn smooth." The *Cavern-deposit nature* of some of these ores is shown in the *Red Ore bank* where shaft No. 1, just east of the open cut, went down 100′ through sandy limestone, although the ore mass was plunging directly towards the shaft; No. 2, just S. of the mine, went 60′ through limestone; No. 3 and 4, the same. The deep red clay which makes such a show at the surface at the mine does not extend beyond it, and no workable surface ores have been found on the barrens between this and the Springfield mine, 3 miles further south.

The Springfield mines.

These rival the Pennsylvania and Bloomfield mines. They are opened on the high, sandy, barren ridge along the center of Canoe valley,* 3½ miles south of the Juniata river at Williamsburg, 1500′ A. T. A section of the valley from Lock (Canoe) mountain on the west, across to Tussey mountain on the east, given in Fig. 13, plate XXIII, will illustrate the low horizon of the ore in II, say 5000′ beneath III, the mine being 1½ miles from the bottom edge of the slate belt (III) with dips from 20° to 70° between.

There are three pits, two on the central sand ridge, 1500′ apart, and one in the lower ground, 3000′ west of the southern main pit, and 4000′ east of the edge of the slate belt geologically. *Ore pit, No. I*, is about 4800′ beneath III, but being on W. dips, there are exposed on the crown of

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*Here already called Morrison's Cove, although it opens out into the Cove some miles further south.

Pl. XXIII.

Canoe Valley Calciferous sandstone limonites.
Etna and Springfield banks.

Fig. 32.
Aetna Furnace Ore Bank.
2 m. N. from Williamsburg.
10 foot Contour Lines.

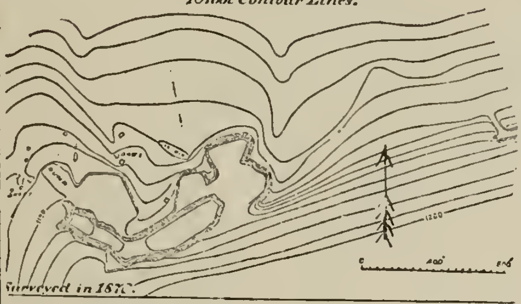


Fig. 30.
Short Mountain Ore Bank.
2.5 m. N 25 W. from Williamsburg

Fig. 29.
Red Ore Bank.
1.6 m. S. 30 W. from Williamsburg.

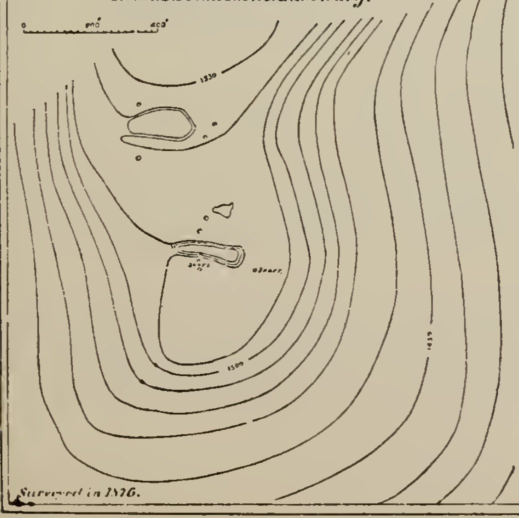


Fig. 13.
Cross Section through Springfield Mines.

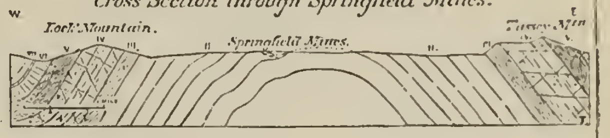


Fig. 14.
Springfield Mine No 1. Blair County, Penn'a.
Looking North.

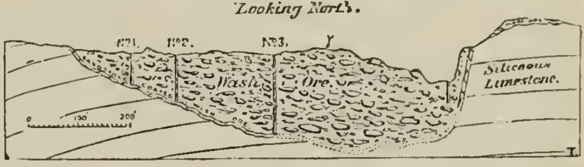


Fig. 15.

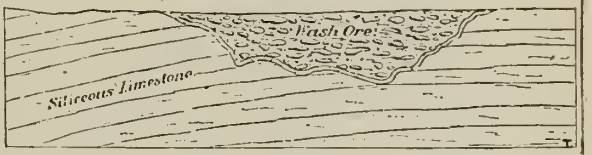


Fig. 17.
Lykens Shaft.

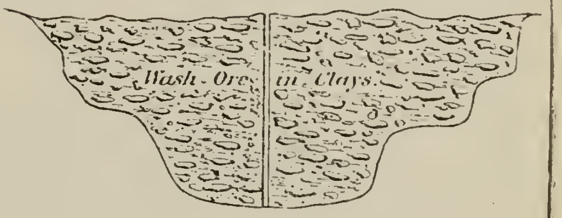


Fig. 18.
Face exposed at the Lykens Shaft.

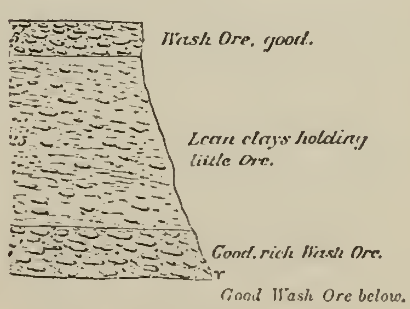
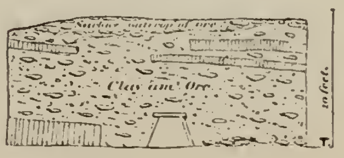


Fig. 19.
Bank Face Mine No 3.



the arch to the east of it strata more than 5600′ beneath III. How much more lie concealed in the arch can only be guessed by the little Juniata section, which measures between 6000′ and 7000′ feet and still does not expose the bottom beds of the great formation.

Mine No. 1 (*Davis mine*), is an open cut, 600′x500′x30′ to 65′ deep. It is surrounded by a well defined ore ground limit, 2600′ N. and S. by 300′ to 1450′ wide, outside of which the surface is a sandy waste without ore, as both surface show and trial pits combine to prove. The ores are of every grade of color, character and value. Fig. 14 of pl. XXII shows how little of the ore mass has been removed, chiefly wash ore. Shafts 1, 2 and 3, respectively 65′, 100 and 161′ deep, show the depth of ore mass, as they strike the sandstone floor on which the ore mass lies and crops out to the surface on the E. side of the mine, disintegrating to a sharp clean sand. The upper sandstone layer is heavily incrusted with ore, and its small cavities and irregularities are filled with ore.

The first 60′ of wash ore was mined in open cut; then a 60′ shaft went down in lump and wash ore, *pitching west against the sandstone.* The wall of the pit must be excessively steep since this 120′ shaft is only 35′ from the solid rock wall. *The mine is therefore a cavern deposit*, one of the very few cases wherein a demonstration can be obtained.*

Shaft 3 has the following record: Loose wash ore very lean in places, clay layers, 40′; block and lump ore, 2′ to 3′; worthless wash sand and clay masses, 112′; ore in white and yellow clay, 6′; sandstone, massive to bottom (161′). But this record disagrees with every other section in the mine and may, perhaps, be accounted for by the fact that the miners were in search of large lump and pipe ore only, and considered all small-wash ore-ground worth nothing to them. For on the W. side of the bank, wall and shaft prove wash ore 120′ deep. Elsewhere also the whole mass is solid but variable wash ore.

It is interesting that loose pieces of sandstone, ferrugi-

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*It is possible that it is a small synclinal on the crown of the arch. (F. Platt, in T, 162).

nous slate, and pieces of sand rock greatly resembling specimens of IV and V, and conglomerated sandstone fragments held fast by an iron ore cement, are all found in the ore mass.

Between the Davis and Lykens pits, say 2000′, is barren ground.

Mine No. 2 (Lykens'), is 600′x400′x80′ deep (once 100′) encircled by a limit of ore ground, 2200′x1000′, on the surface. It is worked for the Cambria Iron Co. The Lykens' shaft at its N. end has a great output. No bottom to the ore has been reached in the cut ; but the shaft strikes the sand rock floor at 215′. It works solid ore, that is, great lumps packed close together in the clay ; usually in two layers, the upper one reddish ore, then 1′ to 4′ sand or sandstone, then the lower one heavy black lump ore in clay, resting on the true sandstone floor. Both the ore layers and the sandstone parting vary much and rapidly in thickness, but in the main rising and falling together conformably to the irregularities of the sandstone floor. This mine is remarkable for the quantities of *bombshell ore* in it, and for the scarcity of *honey comb ore.* The bombs are sometimes of great size, some filled with soft white lime clay, others with more or less decomposed sandstone or sand, many quite hollow.*

Mine No. 3, is of a totally different character, on a geological horizon only 2600′ beneath III, separated by more than a mile of barren limestone outcrops, and in limestone hollows. Its wash ore body contains mostly only small rounded water worn ore balls.† The open pit 6′ to 20′ deep shows only wash ore in caves in the limestone separated by promontories and ribs of limestone. Fine grained waving purple or brown or white clays all carry varying amounts of the ore balls. Dark limestone walls in the whole pit, and *an occasional layer of slate parts two limestone beds.* The floor also is limestone.

But at a place where nearly solid ore made the tempo-

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*See other details and numerous ore analyses in T, 163, 167.

†Occasionally some rounded pieces of sandy limestone and limestone are noticed in this mine also.

rary floor of the pit a horizontal drift followed the ore (S. E.) for *200′ under solid limestone cover*, and soon a solid limestone floor was got also. A 45′ shaft from the surface struck the end of the drift. The *ore layer*, thus inclosed in the limestone, when mined averaged 5′, but varied between 1′ and 19′. This is very remarkable as it shows the possible production of limonite between almost horizontal strata of unchanged rock. It also shows a sort of broad shallow synclinal (or shelf?) on the western limb of the Canoe valley anticlinal.

All this agrees very well with the description of the ore production at the Pennsylvania banks in Centre county, which are also on the same geological horizon, viz: 2600′ beneath III.†

The *Prussia mine*, small, abandoned, 1500′ S. W. of Springfield No. 2.—*Tar Hole bank* 600′ N. W. of the Prussia.—*McPheese bank* 3000′ S. W. of Springfield No. 2, but separated from its ore-area by barren ground; a small pot of wash ore.

Canoe valley, at Williamsburg, and at Springfield, is 4 miles wide, measuring between the two edges of the limestone floor, and 5 between the crests of its bounding mountains. At Rebecca furnace mines (10 m. S. of Williamsburg its width is but 3 miles. Here Canoe (or Lock) mountain swings round to the west, and projects as a broad round synclinal knob southwards into Morrison's Cove. The slate on its flank runs on south, in the synclinal as a narrow belt, past Martinsburg two or three miles. At Martinsburg and Fredericksburg the limestone land is 3 m. wide; this is 12 m. S. of Williamsburg. Millerstown is

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† See further description and numerous analyses in T, pp. 171 to 177. No limonite mines are more extensive, valuable, or better worked than these and that is my excuse for so largely extracting from the Report. It seems that traces of *cobalt* appear also in these ores, T, 172, 173. See accounts of plant, machinery, etc., T, 177.

14; Henrietta furnace mines, at the entrance to Leathercracker Cove, 15; and the head of the cove 17 m. S. of Williamsburg. Between Fredericksburg and Millerstown a belt of slate 2½ m. long and ⅓ m. wide splits the limestone land into two belts; the eastern one lying along the foot of Tussey running S. to the head of Leathercracker cove; the western one running on S. past Curry, Woodbury, Waterside and Enterprise, to the south end of Morrison's cove. The slate belt is a sharp and faulted synclinal between the Henrietta (Leathercracker) anticlinal and the Curry-Woodbury anticlinal.*

Leathercracker Cove ores.

The Henrietta mines in Leathercracker Cove have been described in a previous chapter on the Limonite ores of the top of II, but only in such general terms as might state their possibly very exceptional horizon at the contact of II–III. This was once considered by others as well as by myself the true theory. But I am more and more confirmed in the belief that this is a mistake, and that they belong to *middle* horizons of the formation brought by the faults into contact with III, as in the case of the Path Valley mines in Franklin county.

It only remains to notice here the character of the Henrietta ores, referring the reader to Mr. Platt's full details in T, 183 to 202. Pl. XXIV, f. 20 maps the main pit, 600′x200′x60′ deep, all in ore clay. *Projecting boulders of limestone, much rounded by chemical decomposition, stand up irregularly on the floor*, from around which (as also from around masses of barren clay) the wash ore has been removed.†

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*On the great map sheets of the Morrison's Cove Survey, in Atlas to T, this is improperly named the Morrison's Cove anticlinal, and the other the Canoe Valley anticlinal. In fact, however, both represent the great Canoe Valley anticlinal in its southern course where its crest is split by a synclinal roll. The Bloomfield anticlinal is a great wave of the western half of Morrison's Cove. The Woodbury-Curry half of the Canoe Valley anticlinal becomes the great wave of the eastern half of Morrison's Cove; the two being separated only by the wide shallow synclinal of Lock Mountain.

†Some of the main features of the mine are similar to features found in nearly all the brown hematite deposits of the lower Siluro-cambrian lime-

Pl. XXIV.

Canoe Valley and Leathercracker Cove ores. at Rebecca and Henrietta furnaces.

Fig. 28.
Rebecca Ore Mines
3 m. N. 70° E. from Martinsburg.
Contour lines 10 feet apart.

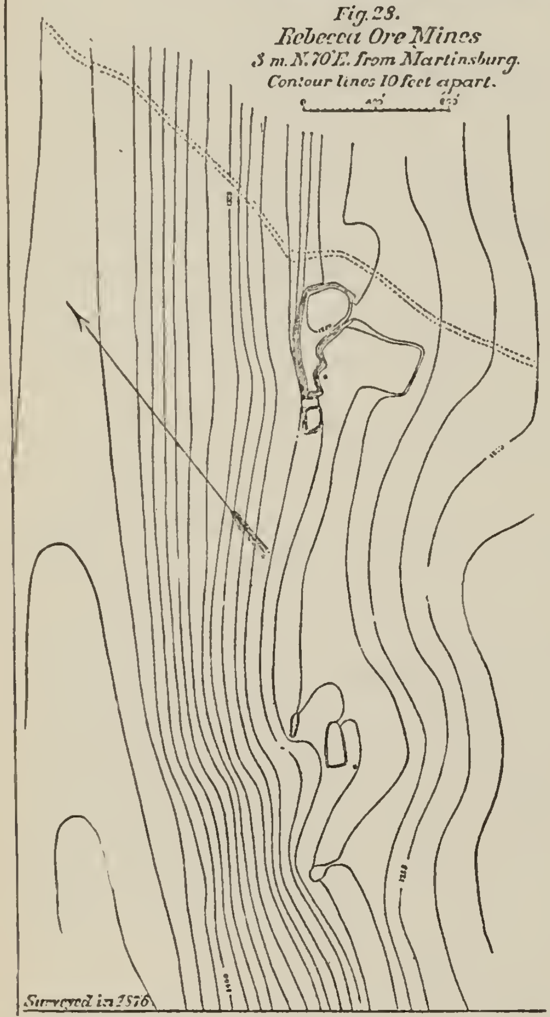
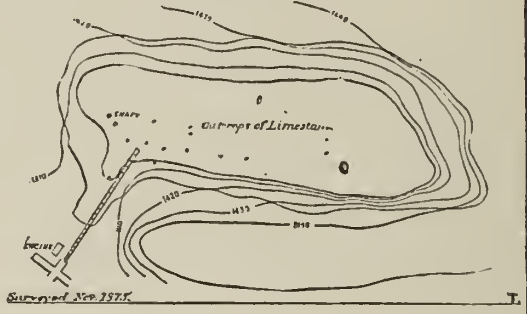


Fig. 20
Henrietta Ore Bank.
main cut.



Henrietta mine No. 1. (east face)
Fig. 21.

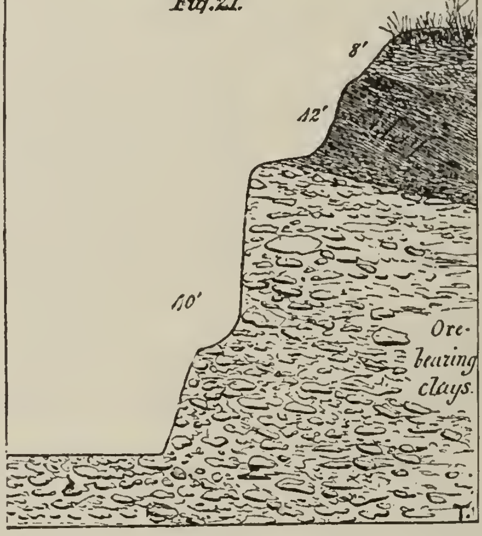


Fig. 27.
Rebecca Ore Mine.

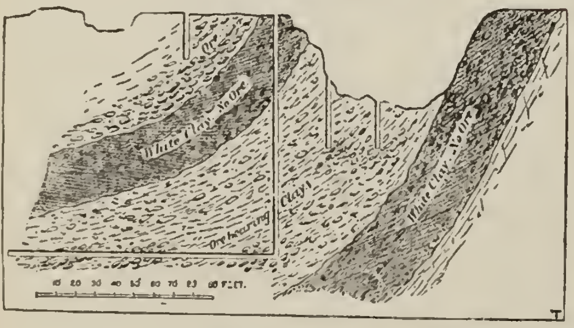


Fig. 22.
Falkner Shaft ore bed

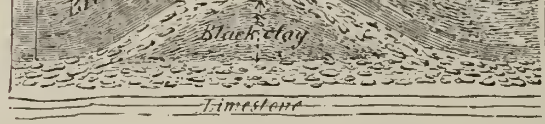


Fig. A.

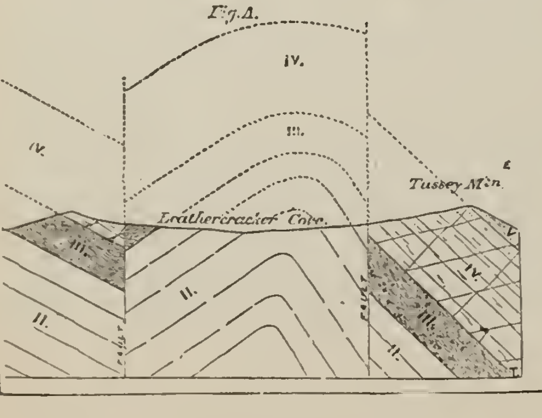


Fig. 22a.
Section from Schoolhouse Mine to Tussey Mountain.

Always on the E. side of the pit is the *black clay which overlies the ore mass*;* always on the W. side the *underlying limestone clay;* solid limestone W. of the mine, dipping nowhere more than 30°, S. 70° E. But *the slope of the ore* from crop to bottom is *much steeper;* but the pot which holds the ore is evidently not shaped by the limestone dip, but is excavated in the limestone, the un-

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stones. At times the ore runs in great masses, packed together and like a regular ore bed; and this fades out more or less gradually, plainly in sight, into a clay, carrying perhaps not so much as 10 per cent. of ore in it. The streaks of clay follow no dip; they are folded and rolled in all shapes; come in suddenly and as suddenly entirely disappear; are in places white and perfectly free either from ferruginous coloring matter, or from wash ore; and are again deep red or brown, and sticky.

"*But the mine differs* from many, in fact from most, ore banks of Morrison's Cove, in that it shows no sand, no sandstone, no flint, and no rock of any kind but blue limestone. But in place of rock and flint some of the clay layers are unusually sticky, and form balls which pass through the washer with the ore, and give quite as much trouble as flint in requiring to be picked by hand.

"There is much iron ore in mine No. 1, which carries varying and sometimes very considerable percentages of manganese. These patches of manganiferous iron ore are very local and very irregular in shape. There is no guide to say when to expect them, or to indicate when they will run into the ordinary brown hematite ore. The manganiferous ore chiefly showed at a depth of about 50 feet below the surface; and there are now large quantities in the present bottom of the pit. The tendency to run to manganiferous iron ore is (at the present depth) much the strongest at the south end of the mine.

"The ore is usually hard and darker colored in the upper part of the deposit, or that nearer to the black slates, while it is apt to be softer and more open in the lower part, in the limestone. But while this distinction may hold roughly, yet all kinds of ore, hard, soft, manganiferous, rich and lean, may be found close together, and in fact mixed together in the same clay bands." (Platt, T, 186.)

*"The overlying non-ore-bearing dark-colored slates are much-weathered down, almost to a mud, to which condition indeed they soon come on exposure. When first exposed they show as very thin-bedded, fragile, black slates, fossiliferous in places, though the fossils are kept with difficulty on account of the fragility of the whole material. Fifteen feet of this black slate rest on top of the iron ore and clay; and on top of that there apparently commences a gray colored, soft, iron-stained, thin-bedded clay-slate, non-fossiliferous so far as seen. These slates and the surface stuff make a loose and somewhat troublesome east wall for the mine; the clays holding back the water and throwing it over the top, the effect being to make the washing down so severe as to require almost foot for foot as a safe slope for the east wall." (F. Platt, T, 190.)

equal dissolution of which waves the ore-mass backward and forward with gentler and steeper slopes alternately.*

Total excavation 270,000 cubic yards; total of ore realized 64,000 tons, or 16 per cent. of the stuff excavated. All goes to the Cambria Iron Works at Johnstown.

The Faulkner shaft, 1200′ S. of main pit; mouth 40′ higher than surface at main pit; depth of shaft 153′, with ore left in bottom; ore struck first 40′ down; output 10,000 tons; abandoned. Three monkey drifts found the descending ore mass to be 25′, 25′, and 40′ from wall to wall. Drift S. from bottom of shaft, 400′ to 500′, showed the curious structure of Fig. 22.†

The McAlister shaft, 2700′ S. of Faulkner shaft, still following line of fault; 100′ deep; *black clay* hanging wall; limestone clay foot wall; ore clay 15′ to 20′ thick, vertical, irregular.

The Hoover mine. 750′ S. of McAllister shaft; open cut 200′x125′x30′ deep; shaft, 120′, struck some ore near bottom; *black clay* in E. wall of open cut; W. wall lime clay, and back of it limestone; ‡ ore clay 15′ to 20′ thick, unusually sticky and troublesome.

This Henrietta ore range is a well defined, limited and local deposit of ore clays in a fault-trench 7000′ long, 15′ to 35′ wide and of unknown depths, between a wall of black (Utica ? or Hudson river. III) slate, on the one side, and a wall of dolomite strata belonging to some unknown, probably middle horizon of Chazy or Calciferous formation II; both walls thoroughly decomposed into black and white clays; without the intervention of any igneous rock like trap as at Cornwall, but, perhaps, by the hot waters from a great depth, as at the Hot and Warm Springs along the

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*The analysis of limestones given in T, p. 1888, show that they are almost perfect dolomites (53 : 35 and 57 : 39.

†The ore clay forked, one part going straight on, the other curving round, carrying rich ore all the way until it rejoined the other; *black clay horse (without ore) 40′ wide.—Black clay* is the hanging wall and *limestone clay* the foot wall in all the Faulkner shaft workings without exception. Ore dark and hard, especially towards the hanging wall; foot ore more cellular. See analysis T, 192. *Phosphorus too high*, 0.940.

‡Also here a *dolomite* (46:40) which of itself precludes the theory of this ore being made out of damourite slates at the contact of II and III (T, 196).

great fault in Virginia. But it is not at all necessary to suppose the water hot or even warm; for the process was evidently the same at the other limonite mines of this region where no faults exist. The ordinary solvent powers of the rainfall are quite capable of carrying on the operation, which in fact it is doing all the time at the present day.— Nor is a cavern deposit here in question; for the ore mass here is not made up of rounded pebbles; nor can any other water worn detritus be seen in these mines.*

The Leathercracker (Henrietta) ores are too phosphatic for the Bessemer process. Three analyses of samples from the three Cambria Co.'s mines, show: Sesq. ox. iron, 60, 63.6, 69.4; Sesq. ox. mang., 3.5, 1, 0.3; phos. acid, 0.822, 2.153, 1.021, etc. (T, 197). But they are high in iron, cheaply mined, and kind in the furnace; were in great demand for stock mixtures so long as iron rails ruled the market; but have declined in value in this new age of steel rails. Thomas and Gilchrist's basis process may, perhaps, restore their old value.

The Schoolhouse mine on the W. side of Leathercracker cove, on the other fault line, is described in T, 199. See Fig. 22a.

The Soister mine of "neutral ore," 3½ m. N. of Woodbury; two open pits, separated by the road, 100′x60′x20′, long abandoned and a smaller pit; ore rich, very sulphurous; *great masses of decomposing pyrites;* unusually red clays; no water; no solid rock; ore lumps not rounded; many rounded flints and limestones; *geological horizon about 2500′ beneath III*, that of the Pennsylvania furnace mine in Centre county.

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*"The ore is in lumps of all sizes, ranging from large and heavy masses closely packed together until they resemble a bed of ore, to fine grains thinly disseminated through various colored clays. But all the ore pieces are irregular in shape and with points and angles, sharp on the corners, and in many cases coated with little needles of ore, which the smallest friction would soon rub off. This is the unvarying character of the structure of the ore lumps and grains in Leathercracker Cove." (Platt, T. 197.)

Morrison Cove ores.

The Bloomfield mine on Duncan's ridge, 3 m. S. of Roaring spring (where its branch railroad joins the line from Henrietta mines to Hollidaysburg) is famous for furnishing stock to Bloomfield, Sarah, Martha and Rebecca furnaces, making the best gun metal for the U. S. foundry at Pittsburgh.

Halter's creek flows between Duncan's ridge and Dunning's mountain. The Lock mountain anticlinal of Morrison's cove runs E. of the mines; very gentle E. dips into the Martinsburg shallow and broad synclinal; overturned steep E. dips (instead of normal W. dips) at the mines and in Halter's valley and in Dunning mountain. A slip fault is probable but not demonstrated. Depth of ore horizon beneath III, (calculated) 3200′; therefore 700′ lower down than the horizon of Pennsylvania and 1800′ higher up than the Springfield ore horizon.*

The reader will find a fully detailed description of the mine in Mr. F. Platt's Report on Blair county T, 1881, p. 203 to 221. All along the valley between Duncan's ridge and Dunning mountain runs a belt of ore clays, from 1 m. N. of Roaring spring southward past the Bloomfield school house, Bakersville ore pit, Long's, to the Stukely farm, a distance of 7 or 8 miles; in some places slight, in others heavy, but none but that at Bakersville promising a great yield.

The Bloomfield ore clays are continuous for 7200′, from the N. end of the German bank to the S. end of the Clarke banks, with a width of 1000′ to 1500, across the top of Duncans ridge.† The larger clay masses are more than 100′ deep. The ore ground ends abruptly

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*I have placed the cross-section showing mine, anticlinal, etc., on the Bloomfield mine map, plate XXV, page 415. The Loop mountain anticlinal is described in T, p. 63, etc.; the mine in T, p. 203, etc. Dunning's mountain has a strike of N. 22° E. but the anticlinal axis runs nearly due N. into the Loop, and through to Frankstown.

†The map shows where the greatest output has been made, but many trial shafts found nothing but very lean sand and clay. The water shaft and boring, 225′ deep, went all the way through sand and clay, with no solid rock beds, and no water, and ended in sharp sand. Trial pits just north of German bank went through solid rock without ore.

Pl. XXV.

Blair Co. Morrison's Cove. Bloomfield mine. 1873.

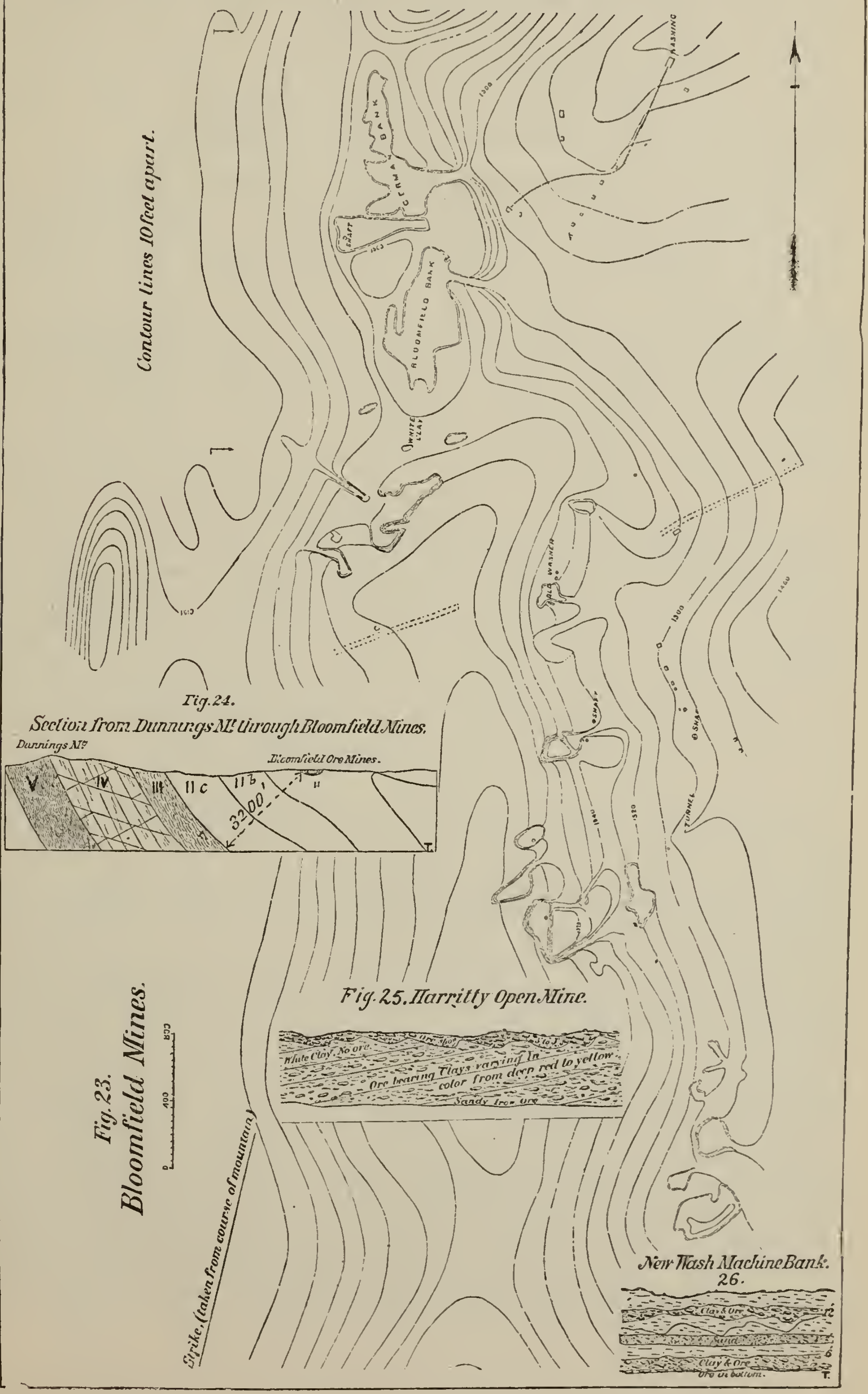

Fig. 23. Bloomfield Mines.

Fig. 24. Section from Dunnings Mt. through Bloomfield Mines.

Fig. 25. Harritty Open Mine.

New Wash Machine Bank. 26.

northward at the German bank. So also south of the Clark bank solid limestone is at the surface. But in the mines no limestone ribs are seen and none were struck in intermediate trial shafts and borings. It looks as if the ore mass were the filling of a vast cavern, which has lost its roof. In spite of the long time working of the mine, only a portion of its wealth has been extracted.*

The mine shows the usual great and sudden changes in the character of the ore bearing mass ; a non-ore-bearing clay will suddenly change into a rich wash ore deposit,

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* *The Main bank*, including the *German*, is 1800′x 100′ to 400′ x80′ deep. In 1880 it was being worked with renewed vigor (See T, p. 205).—*The Harrity open cut* is 350′ long. Its clays are beautifully stratified, dipping 10°, E. *white clay caps the ore-bearing clays with the same dip*, and requires 25′ of stripping. *Over the white clay ore-clays are worked* for 200′ along the strike (N. and S.). This same white clay is struck in shafts N. and S. of the bank. No better evidence of change of rock *in situ* could be got ; and yet the sudden N. and S. termination of the field does not look like it ; unless a change in a character of the anticlinal is taken into consideration. Some of the clays are blood-red ; occasionally they hold manganese, as, for example in shaft 500′ S. of main bank, from which manganese ore was shipped for spiegeleisen. Usually these shafts brought up manganese ore that was too sandy for use.—*The New Wash Machine bank.* Here 2′ of sand makes a layer between ore-bearing clays, and as regular as a sandstone bed. *The Sand bank* in a sandy barren surface soil, has 15′ siliceous ore in sandy clay, 15′; underneath which yellow and brown clays holding not much ore ; then brown clay holding *excellent manganiferous limonite masses* packed in the clay so as to warrant the miners in calling it a 4′ bed.—*The Ridge banks* are numerous pits S. of the Sand bank ; the main one large ; ore outcrop heavy ; sand and flint on the surface but very little in the bank itself ; good ore in yellow clay goes deep ; shafts 60′; lump masses closely packed in clay still in bottom ; miners merely followed these lump streaks. In a new pit *white clay has many scattered quartz crystals in it.—The Kroft banks* are further south.—*The Clarke banks* come next ; ore mass solid 4 to 9′ at 40′ beneath surface ; in S. Clarke bank another at 100′ deep. (T, 211.) If the surface lean silicious stuff 15′ to 20′ deep were stripped, systematic mining here would yield an enormous quantity of good ore.—*The Old Barley bank*, 1½ m. S. of Clarke bank, abandoned.—*Stuckey and Leidig* banks, 2½ m. further S. shallow and hopeful. The Bloomfield plant, machinery, washing and method of working the mine, are all described in T, pp. 212 to 214. For numerous analyses of the ore (as received at the furnaces) by McCreath, Wuth, and Salom, see T, pp. 214 to 219. The Rodman Furnace "gun metal" pig, made in 1872, 1874, showed : Silicon 4.004, 3.184, 2.713 ; Sulphur, 0.035, 0.082, 0.123 ; Phosphorus, 0.195, 0.195, 0.192 ; Manganese, 0.144, 0.864. It was used in the Bessemer flasks of the Pa. Steel Co. at Baldwin. Captain Rodman, U. S. A., urged the U. S. Government to secure by purchase the whole Bloomfield ore field. (T, 229.)

and vice versa; while masses of sandstone, coated with oxide of iron, or flint pieces large and small come into the ore mass and leave it without any visible law. Sometimes there are huge walls of tough sticky clay in sight bearing no iron ore; and again almost everything is washable. The mine therefore does not differ from the other ore deposits of Morrison's cove in the *character of its deposit*, but only in the unusually enormous *quantities* of iron ore in sight and in their *freedom from phosphoric acid*." Consequently the Cambria Iron Works at Johnstown was taking (March, 1879) all the *jigged Bloomfield ore* although they called it only *a 39 per cent. ore.* Phosphorus is not wholly absent from any of the analyses, and *traces* of both *cobalt* and *nickel* appear in some of them. *Sulphur* is usually present in small quantities, but in some is quite absent.

It is noteworthy that both *sulphur* and *phosphorus* appear in all three of the Rodman furnace *limestone* flux analyses given in the Report (T, 218) thus:—Carb. lime, 78.2, 91.9, 54.6; carb. magnesia, 10.7, 2.9, 44.2; ox. iron and al., 1.8, 0.6, 0.2; Sulphur, 0.149, 0.096, 0.002; phosphorus, 0.029, 0.022, 0.003; insol. residue, 8.6, 4.4, 1.3.

Other mines in Morrison's Cove.

The Bakersville mine, 2 m. S. W. of the Bloomfield mine, is in the valley W. of Duncan's ridge, and therefore on geologically higher outcrops, but in a heavy surface *wash ore deposit* 1500′ N. and S. by 400′ E. and W. No solid rock in place has been struck by any of the trial shafts 75′ deep. The deep, narrow valley has probably once been an immense cavern, like Sinking Creek cavern in the northern part of Blair county. The open cut is 300′x45′x15′, in sand and sandy clay, yellowish, sometimes reddish, holding ore balls from top to bottom; not a single piece of loose *limestone* ever found; many large pieces of *sandstone*, coated with an iron crust, not rounded and worn (as a rule), nor are the rounded ore chunks; nor do they follow any line, nor make layers, but are scattered through the whole sand-clay mass ; ore, of all varieties, water-worn rich dark lumps, porous honeycomb ore, dark red solid somewhat sandy ore, light brown lean sandy ore, and light brown rich ore. (T, 220.)

The Millerstown Red Ore bank, 1½ m. N. E. of the village, large, shallow, long-abandoned ; wash ore, in which knobs and masses of undissolved limestone make an irregular floor ; clay deep red ; ore, limestone and flint pieces generally if not always rounded and *water-worn*, usually small, never in large masses ; shafts reported 100′ deep in ore to bottom. Belt of red clay surface extends several miles N. & S. but no trial pits have ever found ore except at this one spot, the size of the mine ; evidently a cavern deposit. Analysis by McCreath : Iron, 54 ; manganese, 0.065 ; sulphur, 0.017 ; phosphorus, 0.085.—*Calculated ore horizon only 1100′ beneath III.*

The Rebecca ore mines, 3 m. N. 70° E. of Martinsburg, were worked for 60 years for Rebecca furnace.* An open cut 800′x125′ to 300′x70′ and more (now only 50′) parallel to to Tussey mountain ; W. and N. walls solid non-ore-bearing white clay dipping (apparently) 70°, E. S. E. *over which* clays holding masses of bombshell ("copper shell") ore, lean, brown, sandy, worthless (because only 15 per cent. iron and stained with copper oxide). Worked 4 years by shafts, as shown in section, plate XXIV, fig. 27.†

The Thompson mine, 1 m. S. of Martinsburg ; shallow holes furnishing cellular, fibrous and sometimes pipe ore ; many honeycombed ; somewhat red-short. *Horizon (calculated) about 2500′ beneath III, i. e.*, about the horizon of the Pennsylvania bank in Centre county.

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* Described in T, 223 ; surveyed in 1877. See map and section of it in Fig. 27, 28, plate XXIV. Worked continuously for Rebecca from 1817 onwards ; consequently a very large output.

† Barren white clay 80′ deep at top of main shaft (*i. e.*, 50′ or 60′ thick) ore clay, 50′ ; ore mass, 15′. East shaft found only white sand and no ore. The ore is not in water worn or rounded pieces, but in irregular masses and chunks, *sharp pointed*, surrounded by clay. Ore has always made a first-class metal ; much of the war gun metal was made from it.

CHAPTER XXXV.

Other anticlinal limestone valleys and coves in the middle counties: Friends cove; Milligen's cove; Kishicoquillis valley; Black Log valley; McConnellsburg cove; Horse valley.

Friends cove.

Friends Cove in Bedford county is connected with the southern end of Morrison's Cove by a narrow, anticlinal strip of slate No. III between Dunning (Evitts) and Tussey mountains*. Itslimestone floor is 15 miles long, by 3 miles wide; ending northward in a point 4½ m. N. E. of Willow Grove; and southward in two points, at Rainsburg, a village on the contact of Utica slate (III*a*) and Trenton limestone (II*c*). The lower Medina sandstone (IV*a*) makes a terrace all round the Cove, as in Morrison's Cove and Nittany Valley. The limestone rocks at Rainsburg dip 20°, S. 55° E. At Charlesville near the N. W. side of the Cove, a local 8°, S. 55° W. dip shows that the formation is disturbed. The Cove is divided by a middle ridge of very sandy limestones, which proves the general steep dips by bringing up the lower portions of the formation; and the sand eroded from these outcrops covers the surface of the Cove to a great extent, concealing the outcrops, and any deposits of limonite ore which they may hold. Occasionally a piece of ore may be picked up. Cove creek flows along the S. E. edge of the limestone; has a broad bottom reaching to the foot of Tussey mountain; and shows no exposures, only here and there a little water-worn limestone; but is covered with bowlders of limestone and sandstone from the mountain. Some limonite was seen by Prof. Stevenson on Weisel's farm 1 m. S. of Koons' mill.†

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* See Geol. Atlas of Counties, Report X, 1885, Map No. 5, preface description, p. 24.

† A specimen from Koons' quarry gave carb. lime, 90.6; carb. mag., 1.9; ox. iron and alumina, 0.6; sulphur, 0.02; phosphorus; 0.005; insol., 6.41. McCreath in T2, 163. Of course the quarry is in Trenton IIc.

Much chert occurs on the central ridge in irregular fragments, with here and there a bed of limonite ore, evidently little of it. On L. Whetstone's farm ore is said to be plenty; cindery chert is abundant; and the sandy soil is full of Medina sandstone fragments, and also pieces of Hudson river slate. On the adjoining Diehl place and in A. Whetstone's fences there are plenty of pieces of ore.

Between this and the Juniata river many exposures of limestone show dips of 27° to 35°, S. 35° to 40° E. and lime is burned for manure.* The road along the S. side of the river has plenty of limestone exposures; and shows a good deal of ore where it crosses the middle barren sandy ridge. From the railroad cuttings Prof. Stevenson obtained the following section.

Limestone (45° E.) dark above, lighter below; some beds magnesian; very little chert; fossils few (*S. alt.*, *Lep. ser. Cal. sen.*); 430′; Limestone, (40° E.) light grey to blue above, growing silicious and cherty downwards, until at the bottom the chert makes ½ the mass; 1350′; Concealed, 420′; Limestone, (dip 45° E.) 420′; Concealed, 400′?; Limestone, silicious, 175′; Concealed, 150′; Limestone, very cherty, 300′; Concealed, 90′; Limestone, sandy, with very little chert; a true *Calciferous sandstone*, 175′;—total, 4520′ of measures not reaching the bottom of No, II.†

Milligen's cove.§

Milligen's Cove in Bedford county, is about 10 miles long and a mile wide, very long and narrow, floored with Hudson river slate (III*b*), except at one spot in its center, where the sharp anticlinal brings up the upper beds of Trenton limestone (II*c*). The Utica slates (III*a*) are exposed at Miller's dipping 35°, S. 35° E. near the exposure of Trenton limestone. Of course there are no limonite mines in this cove.‡

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*Trenton limestone, holding the fossils *Strophomena alternata* and *Calymene senaria* (T2, p. 163).

†Stevenson's Report T2, pp. 93, 164.

‡Stevenson's Report T2, p. 108.

§Also spelled Millikin's and Milligan's

Kishicoquillis valley.

Kishicoquillis Valley, making the N. W. half of Mifflin county, is a beautiful, fertile valley, secluded between Jack's mountain and Standing Stone mountain. At its eastern end it is split by two long promontories into three narrow parallel vales, each of which has an anticlinal floor of the slates of III. The limestone floor of the valley itself is about 27 miles long by 2½ wide opposite Reedsville and Milroy, 2 at Belleville and Menno, and 1½ at Allenville near the Huntingdon county line.*

Two anticlinal waves lift the valley limestones ; a third passes behind Milroy. The Greenwood fault cuts obliquely through Stone mountain, N. of Belleville, and throws the terrace of IV*a* against the mountain of IV*c*. †

The limestone beds along the center belt of the valley lie remarkably flat, so that erosion has not yet gone deep into the formation. In Logan Gap, through which Kishicoquillis creek escapes from the valley to join the Juniata near Lewistown, there is a well exposed section of S. E. dipping Medina and Oneida strata (IV) measuring 2,722 feet. Under these lie Hudson river slate and sandstone in four divisions, 425′, 190′, 140′, 182′; and Utica shale in three divisions, 210′, 302′, 855′ ; making III in all 2304′ thick. Under these are exposed only 320′ of Trenton limestone at the surface.

The *Greenwood ore banks* were excavated on the anticlinal axis south of Belleville. At Belleville are dips of 15° to 20°, N. W. and 10° near the mine. Much pipe ore was got here and carried across Stone mountain to the furnace to mix with fossil ore there mined. But the bank was abandoned many years ago, partly on account of the cost, and partly from lack of ore, which was only found in pots and pockets in the limestone. Many such pockets were exploited in early times in other parts of the valley; but all

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*See Geol. Atlas of counties, Report X, 1885, p. 77, and the map of Mifflin county in the same Atlas, No. 41.

† Described in detail and with special maps in Report T3. The valley is described by d'Invilliers in his report F3 and the fault on p. 239. It will be hereafter described in the chapter on Oneida and Medina sandstone formation N. IV.

mining was long ago abandoned. No doubt there is this good geological reason for a scarcity of ore, viz: that the valley erosion had not been carried down deep enough into the magnesian (Chazy) part of the formation.*

The fact is, the Trenton is so thick and the dips are usually so low, that the Chazy has but little chance to reach the present surface. On the other hand the limestone quarries of the valley are all excellent, and the Trenton beds furnish also hydraulic limestone, on which at Milroy a large plant is now (1891) being established.†

Black Log valley.

Black Log valley in Huntingdon county (its N. E. end in Mifflin) is 20 miles long, by 1 mile wide, and on a gentle curve.‡ It is a fine specimen of the class of valleys and coves of limestone and slate produced by the erosion of the high steep compressed rock waves of Pennsylvania. In this case the anticlinal had a double crest, which it shows at the present surface; but it is probably a single simple sharp anticlinal underground.§ The breadth of limestone at Orbisonia gap is only 2600′ feet; and the thickness of Trenton limestone about 500′; from under which rise only the upper beds of the Chazy (IIb) on the two crests of the wave.‖

The fact that no limonite ore has been found in Black Log Valley goes far to support the view that there is really

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* D'Invillier's Report F3, 1891, p. 237.

† There are, however, steep dips in some places. On the creek road from Belleville to Union Mills the beds dip 65° and 68°, S. 55° E. At the quarry on Yoder's farm the stone looks more like slate than limestone; and this is the characteristic feature of the Trenton beds in middle Pennsylvania. The Trenton is in fact a transition formation from the magnesian II to the argillaceous III. The Utica slate here dips 60°, N. W. (T3, 238).

‡ See Geol. Atlas of Counties, Report X, 1885, Map of Huntingdon No. 31, and preface descriptions, p. 57.

§ A cross-section will be given in a future chapter.

‖ The Grove quarry seems to show the limit of the Trenton beds downward, and the top bed of the Chazy, by the following analyses in Ashburner's Report F, 1876, p. 260. Carbonate of lime in top bed (22″ thick) 90.16. Then follow downwards 84.68, 89.68, 74.18, 81.18, 82.60, 80.68, 82.18, 85.18, and then the bottom bed, only 46.68, which may be assumed as the top of the Chazy.

no limonite horizon at the junction of II and III; that is, at the top of the Trenton, and at the bottom of the Utica.

McConnellsburg cove.

The McConnellsburg cove in Fulton county, is a canoe-shaped valley with pointed N. E. and S. W. ends, enclosed in mountain walls of Medina sandstone (IV), with slopes of Hudson river slates (III), and a fertile floor of limestone (II), 13 miles long by 2 miles wide. It differs from all the other coves in having along its N. W. side a profound fault, the limestone (II) being upthrown 8000′ against Devonian strata (VIII). This fault swallows up the slate (III) and sandstone (IV) and consequently destroys the mountain wall on the N. W. side of the cove.*

The limestone beds at McConnellsburg and between that village and the school house dip 55° towards the fault (W.) and are mostly silicious, with much honey-comb chert, and so red a soil in some places as to suggest a good deal of limonite iron ore. At Sargent's Rocks, in the southern end of the Cove, are the extensive old limonite banks of the *Hanover Iron Works*, worked for about 25 years, and abandoned in 1847. The annual yield of ore is said to have varied between 1200 and 2000 tons, and much ore is supposed to remain. Its horizon is high in the formation.† The furnace got also some ore from the Patterson place, on the eastern road towards the pike, and trial pits were sunk on the Nelson farm, but all such work was abandoned forty years ago; and the development of the ores of the Cove is still to be made.

The underground erosion of the limestone strata is variously illustrated in the Cove. Its south end is drained by Esther's run, heading in the high vale between Cove and Dickey's mountains. In about 4 miles it sinks, and rises again in the Big Spring; then cuts through the Me-

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* A description of the fault is given by Stevenson in his Report T2, p. 55, 56; and details of its exhibition in his subsequent chapter XIII on Ayr, Todd and Dublin townships, T2, p. 291 et seq.

† Analysis by McCreath: Iron, 46.1; sulphur, 0.115; phosphorus, 0.083; sil. mat., 21.5 (T2, p. 296).

dina ridge, and joins Cove creek between the Lutheran Church and Elysian Mills.*

Horse Valley.

Horse Valley at the S. W. end of Perry county, contains a narrow belt of limestone land, with two points or prongs at its north end, where the anticlinal has two crests, and only one point at its south end, where the anticlinal is simple. It is one of the branches of Path Valley in Franklin county, and almost its whole floor is made by the slates of III. Occasional pieces of limestone have been found near the gap.†

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* The drainage of the Cove is very curious as shown on the colored map of Fulton county in Report T2. The natural course of Esther's creek would have been around the N. end of Lowrie's Knob instead of through a gap in the ridge (IV). So also at the northern end of the Cove, the drainage ought all to flow south past McConnellsburg into Cove creek. Instead of that, it gathers itself by streams that flow N. as well as S. and W. into Licking creek, which breaks a gap through the Medina mountain (IV) at Knobsville.

† See Geol. Hand Atlas, Report X, 1885, Map No. 45, and Preface p. 85. Dr. Henderson made the top beds of II reach the surface. But Prof. Claypole could not satisfy himself of the fact, and drew his cross-section as if the limestone did not. See his Report F2, page 352, and his section on page 350, which I reproduce in a future chapter.

CHAPTER XXXVI.

Caverns and sinkholes in II.

The whole surface of the limestone belt of the Great Valley is pitted with sinkholes in the farmers' fields. By these holes the rainfall escapes into caverns, which ramify in all directions both along and across the stratification, and reappears in springs in the beds of the deeper valleys. This explains the scarcity of brooks and creeks on the maps of the limestone belt in the Great Valley; and on the maps of Kishicoquillis and Nittany valleys and their branches, and the limestone coves of Fulton and Bedford counties.

Many ancient caverns are now dry, the drainage having opened for itself new ones. Others have been deserted because completely choked and filled with lime-iron clays and ore. Others have been exposed to the sunlight by the falling in of their roofs, and converted into vales by the solution of their walls. Those which were filled with deposits and then uncovered form the limonite iron mines of the present day.*

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*A most instructive case is described by Prof. Ewing in his special report embodied in Report T4 on Centre county, at page 418. I give his description verbatim, as follows:

"*Cavern deposit of iron ore.* On Sinking creek, as it rounds Egg hill, in Potter township, on the *Wagner place* (A. Kerr, in county atlas), is an exposure of ore quite unique in many respects. *The ore occupies caverns* eroded out of the limestone. In this exposure most of the limestone is left intact. The ore that has been removed has been taken from openings into the solid mass where erosion has removed the material from one side. Even there it is necessary to remove large quantities of limestone in order to get the ore. Large masses of *pipe ore* are found, with *lump ore, bomb shell ore,* and *wash ore.* Most of the ore taken out has been removed from one large triangular space, having sides about 20 feet in extent, and a depth of 15 feet, one side forming an opening from the bank of the creek-bed. Besides this, several small test-holes, drift, and slant openings have been made. Those within a range covering not more than 20 or 25 feet in thickness of rocks strike ore of the same character; those out of this range show but little ore. The ore is found in the worn joints imbedded in a tenaceous red or yellow clay.

"As pipe ores are undoubtedly formed by the evaporation of chalybeate

Sinking creek in Blair county offers a fine example of the extensive underground chemical erosion of limestone beds in the upper part of No. II. Its Arch spring became famous among the white settlers at an early date.* The

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waters, which percolate through the mass, one might expect to find in a place like this evidence as to the time of the formation of these pipes. The fact that all are broken off—none being attached to the limestone—implies that they were formed at a sufficiently remote period for subsequent waters to dissolve away the attachments. The fact that the pipes are straight and generally parallel, implies that they were formed while the rocks were stationary, and not during a gradual upheaval. It is inconceivable that they were formed while the rocks were in their original horizontal position; hence, it is altogether probable that they were formed after the Appalachian upheaval, and while the rocks were in their present position, that is, dipping 45° S. E.

"One very interesting specimen from this region *has one of the pipes at an angle of 40° with the rest.* I think it probable that in this case the pipe had broken in falling, and had been cemented by subsequent depositions of the same material, as there is abundant evidence of later depositions *in thread-like pipes at right angles with the larger ones.*

"As previously remarked, the probable condition of the ore while in solution, and at the time of deposition, was that of a ferrous carbonate. It is probable that oxidation began at the time of, or soon after, deposition. When the deposition was rapid, masses of carbonate and semi-carbonate were doubtless formed, which have subsequently been oxidized. Evidence of this is seen in the larger masses found, especially here, of ore containing cavities, giving it a porous appearance, often called *bomb-shell ore;* for as the carbonate of a low specific gravity changes to the oxide of a higher specific gravity there is a loss in volume. The change naturally beginning from without forms concentric layers of the oxide and leaves cavities within. Even the pipe ore is more or less porous."

* Captain John S. McKiernan, who moved from Blair into Clearfield, sent to the Tyrone *Herald*, March 11, 1886, the following slip from a very old newspaper: "Among the other curiosities of this place, is the swallows which absorb several of the largest streams of the valley, and after conveying them several miles under ground, in a subterraneous course, return them again to the surface. These subterraneous passages have given rise to the name 'Sinking Spring Valley.' Of these the most remarkable is called Arch Springs, and runs close upon the road from the town to the fort. It is a deep hollow, formed in the limestone rock, about thirty feet wide, with a rude natural stone arch hanging over it, forming a passage for the water, which it throws out with some degree of violence, and in such plenty as to form a fine stream, which at length buries itself in the bowels of the earth. Some of these pits are near 300 feet deep; the water at the bottom seems in rapid motion, and is apparently as black as ink, though it is as pure as the finest springs can produce. Many of these pits are placed along the course of this subterraneous river, which soon after takes an opportunity of an opening at a declivity of the ground and keeps along the surface among the rocky hills for a few rods, then enters the mouth of a large cave, whose ex-

creek rises on the high ground of the Kettle at the south end of the valley, and flows along the exis of the anticlinal for 3½ miles; then works over to the east side of the valley and flows in the upper limestones at the foot of the mountain for two miles; disappears in a large sink hole and flows underground a mile, its "hollow" or surface channel being dry. Another creek, heading near the Bald Eagle mountain, on the west side of the valley, and flowing square across it to the hollow, meets a brook descending from the east mountain terrace and flows one or two miles further along the hollow, according to the wetness or dryness of the season, and disappears *gradually* through a succession of sinkholes. A third creek starts in the center of the valley five miles north of the last mentioned, flows across eastward 1¼ miles, enters a large cave, flows under its roof 4200 feet, issues from a picturesque arch at the N. E. end of the cave, and thence flows through a flat to the river at Union Furnace.

Elk run follows the opposite or N. W. outcrop of the same limestone beds at the foot of Bald Eagle (Brush) mountain, cutting a deep narrow trench to the river at Tyrone forges; and this trench merely represents a similar series of sink-holes and caves which have lost their roofs. All the brooks descending from the terrace further south than the head of Elk run, for a distance of two miles, sink as soon as they pass the edge of the slate belt and enter the limestone land. Of course their waters rise somewhere to

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terior aperture would be sufficient to admit a shallop with her sails spread. In the inside it keeps from 18 to 20 feet wide. The roof declines as you advance, and a ledge of loose, rugged rocks keeps in tolerable order on one side, affording means to scramble along. In the midst of this cave is much timber, bodies of trees, branches, etc., which being lodged up to the roof of this passage, shows that the water is swelled up to the very top during freshets. This opening in the hill continues about 400 yards when the cave widens, after you have got round a sudden turning point (which prevents its being discovered till you are within it) into a spacious room, at the bottom of which is a vortex. The water falls into it, whirling round with amazing force; sticks, or even pieces of timber are immediately absorbed and carried out of sight, the water boiling up with excessive violence, which subsides by degrees until the experiment is renewed."

augment Elk run; just as all the waters of the Sinking creek system issue at Arch Springs.*

A cave in Gregg township, Centre county, is described by Prof. Ewing as typical of the many which ramify beneath Nittany and Brush valleys. It is about a mile west of the end of Brush mountain; on the 43° S. E. dip of that synclinal; in dark blue limestone, possibly near the middle of formation II.†

The "Hollows" of our limestone country are not ordinary valleys of erosion but unroofed ancient caverns. This is apparent from their peculiar shape, and the fact that many of them are dry, that is, have no flowing streams, but are studded with sink-holes into which the rainfall disappears to caverns beneath them which have been subsequently formed. Prof. Ewing describes one known as the Big Hollow, in Centre county.‡

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*Fine pictures of these arches and caves were made by Prof. Rogers' accomplished Swiss artist, Mr. Lehman, and published in the Geology of Pennsylvania, 1858, Vol. I. They will be found (reduced) in a future plate.

†In Report T4, p. 442. "The entrance is from a deep sink. It extends along the strike of the rocks and contains deep clear water. It is sufficiently large to allow navigation in a large row-boat. Its height in places is 20 or 30 feet, and its breadth about the same. The roof of the cave is formed for the most part by one thick stratum of limestone. In places, however, this has fallen away, leaving exposed the strata above. The cave extends 1200 feet beneath the surface. At the far end the rocks dip in a more easterly direction, so that the roof comes down to the surface of the water. About 300 feet in, the cave divides into two parts, one wet, the other dry, the same stratum forming the roof of both. The side toward which the rocks dip contains the water, the more open side apparently having its bottom filled by the *dĕbris* fallen from above. The two arms are separated by a natural partition of uneroded rocks. The dry cave may be reached by another sink in line with the opening alluded to. Within the cave are stalagmites and stalactites of every variety of form.

"About 80 feet from the far end of the cave is a deep ravine, and the *Fathomless Spring* known as the source of Penn creek. As the water in the spring stands at the same level as that in the cave, the two are probably connected; and the cave is no doubt only one section of a much larger system of underground drainage; for, a short distance nearly west of the cave a stream sinks beneath the surface, and is probably identical with that which appears as Penn creek."

‡T4, p. 442. "*Several beds of ancient streams* are noticeable in this locality. One of the most extensive of these appears to originate near *Johnston's ore bank.* Here several indistinct depressions converge into one ravine which crosses the road passing northeast of *Struble's bank.* The Bellefonte and Buffalo Run RR. grade follows this ravine to the curve near Thompson's,

Of the innumerable limestone caverns of Pennsylvania very few have been explored, most of them are inaccessible, and the existence of a great number of them is only indicated by sink holes in the farm fields.

One of the most interesting is the *Hartman cave* (now the *Crystal Hill cave*) in Monroe county, which was explored in 1880, and found to be floored by 10′ of clay, on which was spread a thin layer of stalagmite, and on this again a foot of black earth containing the teeth and bones of animals of both extinct and living species, mostly broken, splintered and gnawed by large and small carnivorous beasts which at one time made the cave their home, dragging into it their prey to be devoured.*

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where a branch ravine joins it; which the grade follows upward, diagonally, through the *Barrens.* This ravine is traceable to the vicinity of the *Pond bank.*

"The main ravine, known as *Big hollow*, continues in a sinuous course northeastward until it reaches Spring creek, one mile below Houserville. Big hollow has a distinct course of about five miles; its banks are in places from 50 to 100 feet high, here sloping and gradual, there steep and precipitous. As in the case of real river channels, the steep banks are on the inside of the curves.

"The whole topography of Big hollow indicates that it is the bed of an ancient stream. An extensive area slopes toward this ravine. Several smaller ones join it on its course, yet I know of no evidence that water has flowed through it since the first settlement of Centre county; but I have found numerous *sink-holes* along the channel; and gravel deposits and other *débris* in the vicinity of some of them indicate that large quantities of water have flowed into them in times of freshet; and this makes it probable that there exists beneath the Big hollow an *underground channel* joining Spring creek."

*The report of the exploration, made by Mr. Paret, Prof. Porter and Dr. Joseph Leidy, was published in the Annual Report of the Geo. Sur. Pa. for 1887, pp. 1 to 20, with two plates by Dr. Leidy, who identified the remains of the living lynx, gray fox, wolf, skunk, weasel, raccoon, mole, dusky bat, little brown bat, woodchuck, porcupine, beaver, muskrat, gray squirrel, ground squirrel, meadow mouse, white footed mouse, wood rat, gray rabbit, deer, elk;—no domestic animal, except perhaps a pair of imperfectly developed teeth of a horse;—many bird bones, especially of the wild turkey several kinds of turtles and snakes;—snail shells, a valve of the river mussel, and two other shells;—some small fragments of charcoal; many seeds of dogwood, pignut, walnut;—works of man, a bone fish hook, harpoon head, 5 bone awls, a bone needle, a bored cone shell, a chipped spear head of argillite, a black flint knife and a piece of brown pottery.

But with all the above were found remains of the extinct peccary (*Dicoty-*

A vertical cavern in the limestones of II was exposed by quarry work in the Chester county valley near Port Kenneday, and explored by Mr. Wheatley, of Phœnixville; the animal remains being described by Prof. Cope. These were all of a comparatively recent geological age. This fact, taken in connection with the Tertiary *lignite beds* of the Pond bank in Franklin county, and the Ironton mine in Lehigh county, prove that all our caverns are of geologically modern construction, and belong not at all to the remote dates of the limestone formations which they penetrate: that they are in fact the last descendants of an infinite series of caves excavated in successive ages, and unroofed and swept away as the unceasing erosion by atmospheric waters lowered the original surface of the globe to its present level. The rate at which this erosion has gone on deserves consideration.

The rate of erosion.

The rate at which the surface of our limestone valleys has been lowered is hard to calculate. It depends (1) on the amount of rainfall from year to year and from age to age; (2) on the way the rain falls, whether in a perpetual drizzle, or in violent downpours; (3) on the slope of the beds of the water channels, whether more or less steeply inclined; (4) on the solubility of the rocks, both in general and in particular, determining the shape and size of caverns, the stability of their roofs, and consequently the amount of mechanical erosion which is in addition to the amount of chemical solution.

Undoubtedly a part of our limestone formation passes off to the ocean as lime water; but another part passes off as broken matter, floated limestone pieces, limestone sand, limestone mud. And when the new oceanic deposit is made it must represent both these forms; as we see that it does; for the microscope shows mechanical fragments cemented by a chemical precipitate.

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les pennsylvanicus); of another larger extinct peccary (*Platygonus vetus*); and of the extinct gigantic beaver (*Castoroides ohioensis.*)

This cave, not being in No. II, but in the lower Helderberg limestone No. VI, will be more properly described in a future chapter.

The chemical solution of the limestone strata of Centre county was studied by Prof. A. L. Ewing in 1883*, at the upper end of the Old Bellefonte dam, below the entrance of all visible tributaries of Spring creek. (1) The cross-section and velocity of the stream were here measured; (2) the amount of solids in the water was determined by evaporation; (3) the area of the whole water basin was calculated geographically.

1. The average width, 75′; average depth (six measurements), 2.7′; average velocity (got by bottles floated at various depths), 3263′ per hour = about 24,500 *cubic yards of water passing a given point every hour.*

2. By evaporation (two tests), 2400 grains of solid matter were got from one cubic yard of water; according to which (24,500×24×365×2400÷7000 =) 73,584,000 lbs., or 328,500 *long tons of solid matter carried away per annum.*

3. The area drained by Spring creek is rudely estimated at 100 square miles, three-fourths of which is mountain slope; the rest limestone valley. By evaporating mountain water it was found that *nine-tenths* of the solid matter in Spring creek came from the limestone valley.

Prof. Ewing calculated the annual waste of the region at 282 tons per square mile; and the waste of the limestone valley by solution at *275 tons per square mile.*

Taking the specific gravity of limestone at 2.75 (Trautwine, p. 386), a layer one foot deep over a square mile would weigh 2,140,540 gross tons. A layer of 275 tons would be only *one-eight thousandth* ($\frac{1}{8000}$) *of an inch thick.* In other words the surface of Nittany valley is lowered at the rate of *one foot* in *eight thousand years* by the loss of what is constantly running off past Bellefonte, so far as that can be calculated in the manner described above.

Other things, however, have to be taken into consideration which should vitiate the correctness of that result without substituting for it another more reliable. The loose stones in the main channel and in all its branch water ways show that annual floods play a *rôle* of great import-

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*Proc. Am. Ass. Adv. Science, 1884; copied into Report of Prog. G. Sur. of P., T3, 451.

ance in the operation; frost loosening the limestone slabs, and water breaking them into pieces, grinding them together, and sweeping them away into the Susquehanna river and so onward into the sea. The rate of this mechanical destruction of the surface is unknown, and probably cannot be in any manner calculated. If it be assumed equal to the rate of chemical solution, the surface of the country may be said to lower itself one foot in 4000 years.

But even this more rapid rate cannot be adopted for calculations extended backward many ages; for, while the chemical solution is a constant quantity, provided the annual rainfall be a constant quantity, the rate of mechanical erosion depends on the velocity of streams, *i. e.* on the slope of the water-basin. But this was much greater in past ages than it is now. When the top limestones on the Bellefonte and other anticlinals were first laid bare the general surface of the region had a topography exactly resembling that of the Shade and Black Log region at the present day; but it had an elevation above the sea at least 5000 feet higher. Of course erosion went on at its usual high rate in Alpine regions; but as we have no data for calculation, it is left to the imagination of the student of nature to adopt a mean rate between the extremes of excessive mechanical erosion at the outset and of excessive chemical solution now.

At present the water fall from the head of Spring creek (1290′ A. T.)* in Penn's valley to the dam at Bellefonte is only about 570′, and from Bellefonte to tide water in Chesapeake Bay about 720′ At the birth of Nittany valley the fall of the Spring creek which then traversed it lengthwise (as Black Log creek traverses its valley) was say 500′, and of the Susquehanna river which then existed say 5000′. The rate of surface erosion may well have been then 400 or even 100 years per foot.

All such calculations are therefore fruitless, seeing that the age of Nittany valley can be made at will either 40,000,000, 20,000,000, 2,000,000 or only 500,000 years. If we go back beyond the uncovering of the top limestones of No.

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* T4, 419.

II on the Bellfonte anticlinal to the coal age, we greatly increase the time, but not in proportion to the thickness of the overlying formations; for, the erosion must have been vastly more rapid when the surface stood 20,000′ or 25,000′ above the sea.

In fact this part of our science is nothing but a fairy tale; and the best geologist is merely the most lively raconteur.

Precipitation of limonite in caves.

The rate of deposit of limonite (hydrous peroxide of iron) in cavities is sometimes, under favorable circumstances, quite rapid. For example, at the Bennington shaft near the Allegheny mountain summit tunnel of the P. RR. in Blair county "the pump column" receives from the mine water *one inch* of such deposit each year, supplied by the decomposition and oxidation of carbonate iron ore balls in the roof shales of the Miller coal bed. And again, at Johnstown, in the Slope mine, an area of half an acre (near New Furnace No. 5) is now being filled with limonite mud from the same source (viz: decomposition of ore balls in roof) so rapidly that *a layer 18 inches in depth has been made in the course of the last eight years;* so that it looks as if the whole space once occupied by the coal bed would in a few years more be occupied by a consolidated bed of limonite iron ore.*

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*The process is facilitated in this instance by the fact that some *warm water* from the large furnace works passes through the roof of the mine. (Report T, p. 171.)

The deposit of iron rust in the municipal purifying revolvers at the Antwerp water works is accompanied by physical details of the greatest interest for geologists studying the theory of the formation of limonite deposits, including organic matter, clays of various colors from white to black, and concretions. "In March, 1885, three of these revolvers were started at Antwerp, and the original iron and gravel beds were converted into ordinary sand filters; by this change the capacity of the works was at once doubled. The total weight of iron in use at one time was reduced from 900 tons to 3½ tons, and all the expenses connected with digging over and washing the purifying materials were done away with.

"When pure water is passed through a revolver, a certain amount of iron is dissolved, and then the water flows out a light gray color. After two or three hours, the color changes to a reddish brown, and a deposit of rust

Depth of limonite deposits in caves.

The depth of a limonite ore-clay mass therefore depends on the depth of the cavern floor; and this in turn depends upon the deepest drainage level of its district.

Theoretically such a deposit of ore ought not to be deeper than the place where its ancient water course came out on the Lehigh or Schuylkill river, but, considering the chemical action of the water on the floor of the cavern, and in fissures descending beneath the floor, some slight additional depth must be allowed. It is a practical geological rule, however, that an owner of an iron bank in Berks county cannot expect to find ore below the plane of 200′ above tide, which is the level of the bed of the Schuylkill at Reading, and the level of the bed of the Lehigh at Allentown. An allowance must also be made for the grade of the descent of the underground water from the mine to the outlet. An iron bank near Reading may be deeper, therefore, than one at Kutztown or at Womelsdorf can be. Topton Junction, for example, stands at 485′ A. T. Subtract 200′ from 485′

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takes place at the bottom of the vessel. If filtered at once on escaping from the revolver the liquid will generally be clear at first, but after a time it will sometimes get cloudy and the deposit of rust will take place, showing that the iron existed in the first instance in solution, and was afterward precipitated by the action of atmospheric oxygen. If the water be impure, colored and charged with dissolved organic matter, it will issue from the revolver of a dark gray color, and this will increase to an inky black in the case of very bad water. So that it is possible to judge of the quality of the water by the color assumed during its treatment. If the impurities are not more than the iron can deal with, the liquid, on standing for some three or four hours, becomes lighter and lighter in color, a black precipitate forms, and sinks very slowly to the bottom, the color becomes a dirty gray, and then the water will filter quite clear and bright. If the impurities overpower the iron, or are of a nature which the iron cannot effectually attack, a purplish color remains, and the liquid will not filter colorless. As in the case of the Bischof filter, the time of repose and exposure to the air before filtration is obtained by providing a sufficient depth of water over the sand of the filter beds.

"In addition to its chemical action, iron possesses the property of causing the very finely-divided particles of matter, which cause opalescence and cloudiness, to coagulate to such an extent that they can be removed by filtration. The waters of the Nile, for example, which will not subside clear in any reasonable time, and which cannot be filtered bright by sand filters, yield a beautiful clear water if agitated with iron before filtration through sand." *Sci. Amer.* Supp., No. 580, p. 9260, Feb. 12, 1887.

and we have 285′ as the *possible* depth of a cave or sinkhole. But Topton Junction is 18½ miles from Reading. If we only allow a fall of 5′ per mile for the cavern waters we must take off 92′, leaving only 193′ for the possible depth of a cave, or of an iron ore deposit at Topton Junction. Beyond some such properly calculated depth sinking for iron ore *of this kind* is a hopeless affair.

The filling of the caverns, however large and numerous they may be, is easily comprehensible when we remember that an average of 93 per cent. of the magnesian limestone formation rock is soluble, and when dissolved by the rainfall passes off entirely into the sea. Of the remaining 7 per cent. of insoluble clay-iron sand, a portion would be carried away by rapid waters, but a portion would settle and remain in quiet pools in the large cavern chambers, and would entirely fill such galleries as were kept full of water by the choking up of their lower exits.

Limonite precipitated from pyrites.

Enough is said on this subject on preceding pages to suggest inquiry, for no sufficient knowledge of it has yet been obtained. Dr. T. S. Hunt has expressed his opinion strongly that all our limonite deposits have had this origin. But the frequent finding of crystals and pipes of pyrites in the ore banks is not of itself a broad enough basis for so large a generalization, and many of the facts narrated in preceding chapters seem to have no direct connection with such a process. The presence of magnetite, however, is a detail which may be connected with that of pyrites.*

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*Mr. W. B. Devereux, of Colorado, has published in Trans. A. Inst. Min Engineers, Feb., 1884, an interesting paper on the Pitkin county iron ores which he concludes with the following paragraph : "While in doubt as to the relation this ore-body bears to the limestone, I hazard the opinion that the magnetite is a direct product of the decomposition of iron pyrites, and that the ore-body at no great depth is massive pyrites instead of massive magnetite. I base this opinion upon the following facts : Crystals of magnetite are common in this locality, which are pseudomorphs, showing the common hemi-hexahedral form and characteristic striations of pyrites. Efflorescence of ferrous sulphate is also common ; and in the bed of the ravine the ore is a mixture of pyrite and magnetite, the latter appearing as a fine-grained gray matrix, and, when pulverized or broken off, being strongly

CHAPTER XXXVII.

Zinc, Lead and Barium in No. II.

New Jersey has its great Franklin zinc mine, famous throughout the mineralogical world as well as the world of commerce and the arts. Pennsylvania has its one great Saucon mine of zinc ore, also ; and two other zinc mines of no commercial importance, but equally interesting from a geological point of view ; all three being precipitations of salts of zinc in the same old limestone formation of No. II.

The Saucon zinc mines of Lehigh county.

The location of these mines is shown on plate XII, page 364, above. They have riveted the curious attention of geologists for many years, as they have given occasion to some of the most splendid exhibitions of mining engineering genius, in its efforts to overcome extraordinary difficulties in the way of drainage. The mine pumps are among the greatest in the world. The most powerful apparatus that could be constructed was required for keeping the great excavation dry enough to work. The limestone formation in the Saucon valley lies in a deep trough into which, and to the bottom of which, flows the rainfall of the surrounding mountains. The beds are uptilted and broken, the innumerable fissures which traverse them and the caverns which have been excavated in them permit the accumulation

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attracted by the magnet. This rapidly increasing percentage of pyrite, the occurrence of the two minerals in intimate juxtaposition, and the fact that no intermediate stage of hematite occurs, taken together with the testimony of the pseudomorphs, all oppose the application to this case of the ordinarily accepted theory that magnetite is a metamorphic derivative from hematite. Having enjoyed a somewhat extensive observation of iron-ore deposits, and accepting, as satisfactory in many cases the theory just mentioned, yet in this case I can see nothing which will permit its use as an explanation of the facts. This ore contains a trace of silver also, but no copper. It may be interesting to note that pieces of the limestone referred to, when struck with a hammer, emit the odor of sulphureted hydrogen."

of great quantities of water; the dissolution of the lime rocks has produced concentrated masses of zinc ore; and the phenomena of our great brown hematite iron ore deposits are here repeated, *zinc* being substituted in the place of *iron.* The geological cause of this substitution of zinc for iron may be said to be quite unknown, or at all events has not yet been satisfactorily explained on any theory; nor can we suggest a reason why some of the beds of No. II in Saucon valley are as heavily charged with zinc as are the iron-bearing beds of No. II elsewhere in the State with iron. If it be suggested that the zinc has come from a distance, whether from above or below, it is only necessary to point to certain thin beds of limestone, carrying zinc which have been mined to a small extent and without profit in the neighborhood of Penningtonville in Lancaster county, and of similar beds of limestone carrying both lead and zinc which have been repeatedly mined without profit in Sinking valley in Blair county. In the last mentioned district of the State two sorts of unwise notions have been expressed regarding these zinc-bearing beds. (1) They have been looked upon as merely veins descending into the interior of the globe. Similar veins of zinc ore do in fact exist in Sinking valley, opposite Birmingham, but they are concentrations of the zinc and lead from the limestone beds of the valley, and (2) there is no good reason for believing that they are connected in any way with the underground depths. They have nothing to do with the anticlinal structure of Sinking valley any more than the zinc ores have with the monoclinal structure at Penningtonville, or than the zinc ores have with the synclinal or basin structure of the Saucon valley. The fact is, that zinc and lead seem to be inherent constituents of all limestone formations the world around. It is probable that they were deposited with the limestone in far grater abundance in ancient ages, and were originally brought into the Appalachian sea as soluble salts, together with the lime and magnesia waters of primeval rivers. It only remains to add, that the zinc and lead ores of Pennsylvania correspond in all respects to the No. II zinc ores of Wythe county, Virginia, and to the great lead and zinc deposits in the fissures and caverns of the ancient limestone country of Wisconsin and Missouri. They all belong to the same remote age, and have been concentrated into their present form in the same limestone formations and by a similar process.

The Saucon zinc mine at Friedensburg is said by Rogers to be in a close synclinal fold.* He describes it as merely a surface quarry ; but it had only been started in 1853, and worked three years by a slope when he saw it. Its calamine ore or silicate of zinc, appeared then irregularly injected into the limestone, which stood vertical in the N. wall, and dipped 85° in the S. wall. The limestone was also injected with thin veins of quartz."†

Prof. Prime in his Report D3, 1883, p. 239, says the ore, zinc blende, associated with iron pyrite, is disseminated through a limestone which seems broken up, and its crevices filled in with the ore.

The mass has somewhat the appearance of a breccia. The zinc blende is not confined to one bed or horizon, but extends through a vertical thickness of 30 or 40 feet in some places, while at other points of the mine the infiltration seems confined to a vertical thickness of 10 to 20 feet. The mine has been worked (1877) to a depth of 250′ on the slope of the bed. The excavations are very large and extend along the strike more than 1000′; the dip of the limestone being 30° to 35°, S. 5° to 10° E.

It is evident that the source of the ore was above, and not beneath ; that the term "infiltration" is as justly used in this case as in that of our limonite or brown hematite iron ore deposits. That the zinc was an original constituent of the limestone is extremely doubtful. And yet the fact that the zinc of Pennsylvania and New Jersey, as well as of the western states occurs in No. II, seems to link the metal with limestone of Lower Silurian age. The notion of a deep-seated source expressed by Mr. F. L. Clark in his

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*Geol. Pa. 1858, p. 101. On page 236 he suggests that the synclinal may be faulted.

†The ore was smelted at Bethlehem and converted into white paint. The vein seemed to range along the axis of the synclinal or fault, 1856.

paper on the Mining and Metallurgy of Zinc in the U. S., published in the "Engineer and Mining Journal" of September 8, 1883, I cannot concede to; but his description of the mines is perhaps the best we have, and I give it in a foot-note.*

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*The zinc deposits in the Saucon valley, Lehigh county, Pennsylvania, which were once extensively worked, now produce but little ore. Their history, however, has a special interest from their connection with the introduction of spelter-making into this country, and from the fact that they belong to a class of deposits which seems to warrant a belief in their continuance to a considerable depth, and because they are a good illustration of the general effect of the characteristic feature of the ore market above referred to.

Three principal deposits have been discovered, known respectively as the Ueberoth, Hartman and Saucon mines: they occur in magnesian limestone of the Lower Silurian formation, and have many points in common, while they also present some striking differences. They were all at one time owned or controlled by the Lehigh Zinc Company, whose works were at Bethlehem, four miles distant.

The *Ueberoth mine*, which is, so far as developments have shown, the largest, was worked continuously from 1853 up to the fall of 1876. It was for many years the main dependence of these works, and produced in the neighborhood of 300,000 tons of ore. The strata of limestone are here very much disturbed and tilted up almost to the vertical, apparently by the obtrusion of the syenite ridge of the neighboring South mountain. The ore came close to the surface, and a very rich pocket was found in the clay above and around limestone boulders, which is estimated to have produced 100,000 tons of ore. When this body of ore was exhausted, the ore was followed down in crevices between the boulders. These crevices lie in planes parallel to the bedding of the limestone, or in planes perpendicular to it, and preserve great regularity in their position, and a parallel course for several hundred yards in a northeast and southwest direction; they are nearly vertical, and at the depth of 225 feet, to which the mine was worked, showed no signs of closing up. The ores at first were exclusively calamine and smithsonite; but at greater depth blende made its appearance, coating the walls of the crevices, and in some cases penetrating into them several feet; in other cases, segregated as rich seams, which nearly filled the cross-openings. At first, it was confined to the northeastern end of the mine; but at the lowest depth reached it could be traced almost continuously to the extreme southwestern end. The dip of the ore body appeared to be regular, and to the southwest. Six of these parallel crevices were worked, and about as many crossings; and where they intersected, rich bunches of ore were found, some of which were as much as 60 feet across and 20 feet thick. All the indications seemed to point with increasing certainty to the existence of a backbone or underlying deposit of blende, out of the reach of the action of meteoric waters, from the continuation of which the oxidized ores have been derived.

Timbering the mine was always a serious difficulty, but the greatest obstacle to be overcome was the water. Even at a depth of 40 feet, the flow

Bamford zinc mines in Lancaster County.

In the northern part of East Hempfield township, Lancaster county, limestone beds impregnated with almost in-

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was already very strong; at the depth of 150 feet, it was found necessary to put in what was then the largest pumping engine in the world. This engine, which is a single cylinder, double-acting, condensing, walking-beam engine, with a pair of fly wheels, has a 110-inch cylinder and a 10-foot stroke, and is calculated to work four 30-inch plunger pumps and four 30-inch lift pumps, with 10-foot stroke, and to take water from a depth of 30 feet. At the time it was stopped, it was running from six to seven strokes a minute, and was working three pairs of 30-inch pumps and one pair of 22-inch pumps, and was easily handling all the water that came to them. The pump-shaft and foundation for the engine were no less remarkable in their way. The latter was built up from the solid rock, 60 feet below the surface of the ground, of hewn blocks of Potsdam sandstone; the former, which measured 30 feet by 20 feet in the clear, was started on a small crevice, and timbered with 12-inch square yellow pine sticks, and divided into three compartments, and further strengthened by two open brattices of the same heavy timber. When the pitch of the vein carried it out of the shaft, the rest of the depth was sunk through solid rock.

The *Hartman mine* distant about half a mile, was worked at first exclusively for calamine. Its exploitation gradually exposed a central horse of blende, which the method of mining adopted made it necessary to leave for the support of the timbers which carried the roof. The increasing importance of this blende at the lowest level worked, 150 feet, caused a change to be made in the method of mining. The mine was operated for a year after the large engine was stopped, and the last work that was done was the putting in of a slope to develop this deposit of blende. The water in the Hartman was always less strong, the pitch of the crevices less steep, and the surrounding rock less disturbed than in the Ueberoth mine; the strike of the crevices was more to the west, and the blende came nearer to the surface.

The *Saucon mine*, however, affords the simplest and best illustration of this form of deposit. It is distant about a quarter of a mile, and was originally leased by the Passaic Zinc Company, by whom it was sub-let to the Lehigh Zinc Company on high royalties. When the rich deposit of calamine first discovered was apparently exhausted, this sub-lease was surrendered by the latter company, and in 1875 the original lease passed to the Bergen Point Zinc Company, by whom the mine has been worked ever since. A face of blende was uncovered at the western extremity of the open pit, and the ore followed under a heavy cap of limestone for a distance of 250 feet up to the property of the Lehigh Zinc Company on the west. On this property, it was reached at a depth of 110 feet, under 100 feet of solid limestone, and was followed 150 feet farther on the course of its strike. On both properties, it was followed to a depth of nearly 200 feet. In the fall of 1879, all the property of the Lehigh Zinc Company passed into the hands of its bondholders under foreclosure of its mortgages, and in the spring of 1880 all the mining property was sold to the proprietors of the Bergen Point Zinc Works.

The workings of these two mines, taken together, show a remarkable visible zinc blende, dipping about 70°, N. 15° W. at the surface and S. 15° E. in the deep, are described in Dr.

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regularity of width, pitch and course, and the deposit is clearly shown to be a large chimney or chute of ore of irregular cross-section, which, however, preserves a lenticular shape, the longer axis of which is about 60 feet, and pitches to the south at an angle of about 30 degrees; the transverse axis measures about 30 feet. The axis of the ore-body dips to the west-southwest with a slope of about one foot in four. The weathered outcrop has evidently given rise to the pit of oxidized ores and to certain irregular detached deposits which lie in the same course, several hundred yards beyond it.

Here, then, are three similar deposits of zinc ore, with their nearly parallel chimneys of blende and their corresponding beds of calamine, which have evidently been brought up from below, by solution in thermal springs, through crevices formed in the limestone by the gradual upheaval of the neighboring South Mountain, and have undergone subsequent alteration from the action of meteoric waters. Nearer the mountain, where the strata are most tilted and the ground most disturbed, the water is strongest and the largest deposit of calamine is found. In the Hartman mine, the strata are more nearly flat, the blende is sooner met with, and the water is much less strong; and in the Saucon mine, the blende is met with at the edge of the pit, and only moderate-sized pumps are required in working it at a depth of 200 feet. That the water in these mines comes from the same surface springs which supply the Saucon Creek, is evident from the fact that, when the big mine was abandoned, this creek shrank at once to a small fraction of its former volume, and only gradually recovered it as the mine filled up. Very careful surveys of the bed of this stream failed to discover any point at which it showed any diminution of its volume or seemed to sink into the ground. It is, therefore, very improbable that the water, having once come to the surface, found its way back into the mine. It was probably tapped in under-ground courses connected with the springs which give rise to the creek. This is the more probable, as the mine which has the most water is on the highest ground and is farthest from the creek, and the mine having the least water is nearest the creek. It is therefore reasonable to suppose that nearly the maximum quantity of water likely to be encountered was already handled, and that, if a solid body of underlying blende were developed, it could be profitably worked with the machinery already in place. The Saucon mine is still the main dependence of the Bergen Point Zinc Works, but its continued working must be attended with increasing cost and uncertain risks.

The ores of this region are remarkably free from lead, arsenic and antimony, and it is this circumstance that gives them their principal value and interest, and has been the basis of the very high reputation of the metal and oxide obtained from them. Only the richest of the ores are, in the present state of the ore market, available as spelter ores, but even the leanest of the oxidized ores produce a very fine quality of oxide. The blende is very peculiar. It is massive, and rarely shows even traces of crystallization; when pure, it has a bluish slate color, has a very characteristic conchoidal fracture, is translucent on thin edges, and gives a clear ring when struck. As generally sent to the works, it resembles broken limestone; is somewhat mixed with iron pyrites, and assays from 35 to 40 per cent of zinc. It is not

Frazer's Report C3, p. 55 At the west end of open cut No. 1, a shaft was sunk cutting two or three belts rich in

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easy to concentrate, both on account of its non-crystalline structure and of the pyrite it contains.

The causes which led to the extinction of the Lehigh Zinc Company and the abandonment of the first two-named mines were briefly these; the impossibility of competing successfully in the oxide market with the owners of the big mine in Sussex county, New Jersey, after the expiration of the patents covering the oxide process left them free to take the trade, or in the sheet-zinc and metal market with the Western smelters, using cheaper and richer ores, at a time when a general depression of all manufacturing enterprises made it unusually burdensome to carry the heavy bonded indebtedness incurred during a period of high prices and general inflation in acquiring mines and putting up machinery to work them. Under more favorable circumstances, it is probable that these mines could have been profitably worked for years to come; for although the pumping expenses were heavy, they were not excessive, considered as a royalty on the ore, and these charges per ton would diminish in proportion to the amount of ore mined. Now, however, it will probably be left for another generation to discover what value they still have.

Other deposits of zinc ore have been discovered in the same Silurian formation in Pennsylvania, Maryland and Virginia, which have been worked from time to time, but have produced very inconsiderable amounts of ore. Small oxide works were built at an early day near Birmingham, Blair county, and at Landis station, in Lancaster county, Pennsylvania, but they were soon abandoned. At the latter point, shallow beds of rich carbonate of zinc were first discovered, but were worked out. About 1876, expensive concentrating works and two blocks of spelter-furnaces were put up, to treat the grains and kernels of crystallized blende scattered through the underlying limestone, before sufficient exploration was made to warrant such an outlay of money; they have for years been lying idle.

Mr. J. Eyerman, furnished the same journal December 15, 1883, the following interesting particulars:—As the ore (calamine, smithsonite and sphalerite) in this mine is near the surface, it is not, at present, difficult to work. The calamine is found in large quantities disseminated through the limestone. It is found mostly on the north side of the mine, where it is worked by a small force of men.

This mine has furnished, and will continue to furnish, the finest specimens of calamine (or silicate of zinc) known to the world. It is very often found in botryoidal and stalactical forms. It is not seldom that sheets or plates of calamine from two to three feet square and from one-eighth to one-fourth of an inch thick, and containing thousands of little crystals on the surface, are found between the crevices of the limestone. Again, it is found as a thin coating to the inside of a quartz geode. This ore is quite scarce at the Endy mine. It seems to have been replaced by the blende. The smithsonite or carbonate of zinc is found in white scales and in granular masses, coating calamine and blende. It is also more commonly found as a brownish earth, which hardens when dry. It is found near the center and along the west side of the mine. It has often been mistaken for clay. This is also mined at present by a small number of men. The sphalerite or zinc-blende zinc. The east end of cut No. 2 showed the vein striking N. 85° E. In a small open cut ¼ m. W. of RR. bridge over Little Conestoga creek 80 tons of sandy limestone impregnated with calamine and blende, and seamed with calcite, were taken out; dip apparently 50°, N. 10° E.; but on the RR. the limestones dip 8°, N. 5° W.

The Bamford mine was worked for a white oxide between 1850 and 1860. Streaks of silver lead are found in the limestone, which is about 12′ thick.*

Mr. E. G. Spilsbury's letter respecting the mine (C3, p. 198) describes two parallel beds of the limestone, near the slate, but not at the contact of the two formations, as in Blair county, "unmistakably *bedded veins*, and not fissure or gash veins; conformable both to the stratification and dip of the inclosing rocks;" striking N. 74½° E. and dipping 72°, N. 15½° W.

The hanging wall limestone is a breccia (or crushed) partially decomposed, whitish gray, and highly silicious; full of seams, cavities, and small *caves* (15′ to 20′ long and as many broad, by 4′ to 6′ high), *all completely filled with a dark red sandy loam*, and not with mineral as in Missouri and Illinois. In none of these loam-filled "cavities have I ever found a trace of mineral." The broken condition of the roof limestone extends from the surface to the bottom of the pump shaft 110′. The foot wall is not uniformly smooth but has offsets, like layers, shelving downward over and past each other and into the ore body; or, in other words, the ore passes up between these shelving layers of dark blue limestone sometimes to a distance of 8 or 10 feet. (See figure in C3, p. 199.) The foot wall limestone is less silicious, dark blue, in places almost black, and very close and

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is not mined. It is found throughout the mine, with pyrite disseminated through it. It is not met with in as large quantities here as at the Endy mine. Greenockite (sulphide of cadmium), hydrozincite, and goslarite (sulphate of zinc) are met with in smaller quantities. The sulphate of zinc is scarcely ever found. A considerable quantity of greenockite has been mined. It is found as a yellowish powder coating blende and limestone. It was formerly separated at the Bethlehem works.

*Notes by P. Frazer, July, 1876, C3, p. 196, give details of crushing and roasting.

compact, with occasionally small holes lined with calcspar and frequently filled with specular iron ore.

The minerals in the vein matter consists of the two sulphides of zinc and lead; changed for about 18′ beneath the surface to calamine and carbonate of lead; unchanged sulphides below. The vein matter or gangue itself is a limestone very like that of the foot wall, but crystalline in spots. The *galena* (sulp. lead) is found in bunches or little strings running along on or near the hanging wall; but the *blende* (sulp. zinc) impregnates the whole vein matter, more or less thoroughly.

The percentage of silver in the galena varies wonderfully from $2 per ton in one bunch to $2,000 in the bunch next to it; a general average may be perhaps $22.*

Sinking Valley zinc and lead mines in Blair county.

These are described by Mr. F. Platt in chapter XV of his Report on Blair county, T, 1881, pages 247 to 277, only a short summary of which can be given here, the reader being referred to the original report.

Sinking valley is the triangular south end of Nittany valley, south of the Little Juniata river; 10 miles long by 5 wide at the river; anticlinal in structure, the axis sinking southward, as shown by Figs. 33 and and 34.† The limestones dip about 30°, S. E. on the east side of the axis, and

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*The bright golden "rosin blende" is very pure; only slight traces of iron and cadmium, and a small mechanical admixture of lead; average of 14 samples: zinc, 65.9; sulphur, 32.3; iron, 0.8; lead, 0.3; cadmium, 0.07. Average of a year's work showed about 18 per cent. of blende in the vein. Run of vein one mile; another, covered with 15′ soil, 1½ m. further on. Veins proved to depths of 75′ and 110′. *North vein* worked out for 300′, to a depth of 50′, with an average width of 12′. *South vein* worked out 400′, to a depth of 75′; more regular; width from 14′ to 18′; zinc in vein never exceeded 12 p. c.; richest ore from 50′ down to 75′; "at the 110′ level, although the vein is well defined, there is little or no ore in it, at any of the points where it has been opened, and what little ore is in it appears in strings and not disseminated as above." (For details of history, machinery, cost of mining, manufacture of spelter, &c., see Mr. Spilsbury's letter in C3, pp. 202, 203.)

†The axis sinks at the rate of 600′ per mile from the vein at Birmingham to the head of the Kettle; so that the zinc mines are very low down in the magnesian limestones of II.

about 80° E. S. E. (overturned), on its west side. The Keystone Zinc Co.'s mine near Mr. Kinch's house, and the deep shaft on the Borie farm are both near the axis.

Fissure veins occur in various parts of the valley, and were tried for as long ago as the War of Independence, as the old pits on the Fleck farm bear witness.* But most of the work has been done by the Keystone Zinc Co., which was incorporated in 1864, and abandoned mining in 1870. In 1875 the Tathams tried to find good working ore with a deep diamond drill hole east of the Fleck farm. In 1876 W. Arms tried to develop a vein on the Isett farm. Still later prospecting has been done, and the citizens of that district are subject to periodical excitements by vague or incorrect reports of mineral wealth hitherto concealed, or "never properly developed," as the favorite phrase is worded. But certainly enough has been done to disprove the *probability* of extensive deposits underground, and to sustain the geological theory that the metals were originally distributed through the limestone strata, set free by erosion, and concentrated in small quantities in fissures.

It is impossible to examine the closed up and decayed workings; but much can be learned from the reports of experts like Dr. Roepper of Bethlehem; Mr. Williams of Philadelphia; Mr. Dickerson, Mr. Spilsbury and others.†

The Keystone Zinc Co.'s shafts, about $\frac{1}{2}$ m. S. W. of Birmingham, were sunk from the top of a knoll 80′ above the road, and drained by an adit level, driven on 347′ S. W. One line of shafts followed the limestone strike on a vein so variable as to open out into spacious chambers, and contracting again to a mere crack. This fact alone suffices to stamp the "vein" as no true vein, but a *cavern deposit*, like any limonite bed. Were there a true vein it might be traced to the river and be found in the bank; but no trace of ore has rewarded diligent search in that direction, and

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*See Gen. Roberdean's letter to President Reed, dated April 17, 1778, in Pennsylvania Archives, Vol. 6, p. 422. Smelted lead was sent down the river in flat boats. Another attempt was made by John Musser & Robert Morris in 1795, the probable date of the old tunnel on the Keystone Zinc Co.'s land.

†Mr. Platt had access to these reports, most of them in manuscript.

no success has rewarded equally diligent research in the other direction, southwestward.*

The *zinc blende* and *galena* are combined in compact, fine-grained, dark (waxy when broken) lumps, some as large as a man's head. The sulphide of lead is always present, but always subordinate to the sulphide of zinc ; there is usually a little *calamine* (hydrous silicate of zinc) ; and the gangue is inconsiderable, consisting of magnesian limestone and a little iron pyrites.†

At the southwest end of the valley, therefore in the *upper limestones* of II, the zinc-lead deposits differ from those near Birmingham. Here the fissures run transverse to the strike of the limestones, are nearly vertical, and few of them more than 6 inches wide. Frequently, but not always, a thin coating of *heavy spar* (*sulphate of baryta*) separates the ore from the limestone walls ; and much heavy spar is associated with the blende and galena in the gangue stuff.‡

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*It must be said that no continuous trench along the outcrop of the supposed vein was ever made ; and its alleged continuity was considered to be proved by a gangway 166′ long, connecting two shafts below. More than 2000 tons were won from the shafts ; one yielding very lean ore, the others very rich ore. What remains unsmelted at the abandoned works at Birmingham is ore of even quality, analyzing up to a maximum of 30 per cent metallic zinc.

†Analysis by McCreath : Sulp. lead, 18.37 ; sulp. zinc, 76.98 ; ox. iron and alum., 1.90 ; carb. lime, 0.05 ; carb. mag., 0.17 ; water, 0.27 ; silica, 1.67 ; that is lead 15.91 ; zinc 51.63. Another specimen yields lead, 5.86 ; zinc, 30.40.—For Mr. Williams' description of the seven shafts and workings, see T, p. 258, etc. He says that shafts 5, 6, 7 had been (Nov., 1865) carried down through a heavy mass of ore and connected by a 165′ long drift all in the same mass, with an average thickness of 7′; quality excellent. He estimated that there had been an output of 1300 tons of rock ore (30 p. c.) and 2000 tons of "wash or earthy" ore (8 p. c.). He remarks that the dolomite wall rock was singularly free from impregnate particles of blende or galena ; one specimen analyzing carb. lime, 53.9 ; carb. mag., 41.3. But Platt remarks that there was abundant evidence that thin streaks and threads of both ores do occur in the dolomite rocks. On the Kinch farm, directly opposite the company's adit, runs a sandy limestone, through which much galena, blende and calamine are scattered but too sparingly to make the rock an ore (T, p. 262). This outcrop is continuous for a long distance without changing its character. The presence of calamine shows that the sulphides have been reached and converted by percolating waters.

‡See description and analysis in T, pp. 263, 264. The pits on the McMullen farm, are close to the edge of the slate belt, No. III. The Kryder pits are

All that has been said above proves that these zinc-lead veins are precipitation deposits, are not connected with any deep metallic masses in the under world, and cannot descend lower than the extreme limit of rain water percolation in any district of the State to which they belong. I cannot agree with Dr. Roepper* in looking upon them as true veins, afterwards distorted by a fault-slide pressure into chimneys and pockets like the magnetic iron ore veins (or beds) of northern New Jersey with which he was so well acquainted. I consider them as of the nature of comparative recent cavern and fissure deposits, scarcely at all changed in form by later earth movements.

Barytes in II.

Barytes (*sulphate of baryta*) occurs rather frequently in small pockets in the limestones of II (as well as in the Lower Helderberg limestones of VI) usually accompanied by small percentages of *sulphate of strontia;* but strange

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not far off. The Bridenbaugh's pits and cross cuts revealed one vein 8 in. wide with N. W.-S. E. strike, vertical and unchanged to a depth of 25′, with abundance of *heavy spar*. On the Raemy farm much scattered surface ore. The Crissman pits proved three fissure veins, one said by Mr. Dickerson to be fifteen inches, thickening downward; another 3 feet wide, and forking and reuniting around a wall horse. Of these shafts Mr. Williams afterwards expressed an unfavorable opinion. The Borie farm "*deep shaft*" (80′) was sunk on a 4-inch vein, thickening downwards to 14 inches, yielding 300 tons and then abandoned. The Fleck farm pits showed other fissure veins, in which the gangue is between rock walls, both of them lined with calcspar. The Isett farm shafts are said to have been sunk on two parallel veins, each nearly 2′ wide, and striking with the country rock. (T, p. 271.)

* "The fact that the ores are mainly sulphides, and placed in rock almost entirely unaccompanied by clay, excludes the idea of their being merely mechanically transported into already existing cavities of the rocks. The whole mode of occurrence contradicts such a supposition, and leads, irresistibly, to the conviction that the ores were formed in the place they are now found, by geological-chemical agencies; that the pocket shape of the lodes is merely the result of mechanical derangement and contortion of the hill; and that these pockets have been formed out of original true veins following the original N. E. and S. W. strike of the strata. It is only necessary to notice the shattered condition of the rock, and to observe the contortions exhibited by the section of the hill along the Pennsylvania railroad, readily to account for the transformation of regular veins into a more or less irregular system of pockets." (Roepper.)

to say no trace of the latter could be found in the five analyses made by McCreath (3 from II, and 2 from VI) published in Report M2, p. 369.

In Franklin county, in the Great Valley, 2½ m. S. of Waynesboro, on Chr. Shockley's farm, it was found in radiating columnar masses; white to bluish white; vitreous lustre; (Spec. 735) sul. baryta, 95.91; silicic acid, 2.80; ox. iron and alum., 0.24; lime, 017; magnesia, 0.11; water, 0.09. Another, found in that vicinity, granular, also slightly fibrous, generally very white, some stained with iron oxide, powder white with brownish tinge; sulp. bar., 98.05; sil. acid, 1.11; ox. iron and al., 0. 14; traces of lime, mag. and carb. acid; water, 0.20. It has been found as white lamellar barite on S. Plum's farm in Franklin county. (Genth's Report B, p. 228.)

In Blair county at Galbraith's 2 m. S. S. W. of Birmingham, the analysis being quite like the last.*

In Montgomery county, at Marble Hall, a granular grayish-white *barite resembling marble* occurs with the marble-beds of No. II.†

That *barite* must be extensively and rather abundantly distributed through some if not all the formations of the State is proved by Dr. Genth's analysis of that remarkable flow of salt water from an oil boring in Elk county, called the "East Clarion Spring Water," one gallon of which contained 419 grains of matter, of which 337 were chloride of

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*T, p. 246. Two other quite identical analyses of the mineral from the lower Helderberg limestone (VI) near Fort Littleton in Fulton county, will be given in the chapter on that formation.—Barite has also been found at the bottom of VII (*Oriskany SS.*) in Sandy Ridge near Orbisonia, Huntingdon county. (Genth's B, p. 228.)

† Barium is confined to no formation, but it affects mines of limonite, and is probably held in solution by many of our waters. Dr. Genth reports it in very perfect transparent, greenish, tabular crystals (½ in. diameter) and clusters of bluish tabular crystals; also crested, fascicular, and radiated crystals and crystalline masses at Perkiomen mine near Shannonville, Montgomery county. Also, fibrous with copper ore at Jug Hollow mine, Montgomery county. Also, white laminated crystalline masses at Phœnixville mines; and in similar manner and also crystallized with copper ores, 3 m. W. of New Hope, in Bucks county. Also, a fetid barite in brownish radiating and columnar ferruginous masses at Heidelberg, Berks county. (Report B, p. 146.)

sodium, 52 were chloride of calcium, 15 chloride of magnesium, 1.725 *chloride of barium*, and 0.128 *bicarbonate of barium*.*

It is very surprising that *strontium* should not appear in company with *barium* in the limestones of II and VI. In the East Clarion Spring water Dr. Genth only found 0.06 grains of the *chloride* and 0.005 grains of the *bicarbonate of strontia*. But, on the other hand, the *sulphate of strontia* (*celestite*) makes the famous stratified bed in Blair county, opposite Bell's Mills.†

The origin of the barite in our sedimentary rocks is an interesting problem. The masses found are evidently segregations, precipitations from water confined in cavities, but how localized is not understood.‡

It is however brought into immediate relations to the veins of zinc-lead, by the occurrence of two true veins of sulphate of baryta (heavy spar) in the hill on the Kinch farm in Blair county, one 6 inches and the other 3 inches wide, separated by two feet of sandy limestone (Calciferous, II*a*) dipping nearly vertical and striking N. E.-S. W. These veins have no other material; but some of the zinc-lead veins have in their gangue a considerable admixture of heavy spar. (T, p. 272.)

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* He adds that this mineral water contains the largest quantity of chloride of barium ever observed in any springs, and may become of great importance after its medicinal properties have been more fully investigated. (Report B, 1874, p. 27.)

† It occurs here in a series of thin seams, pale green, crystallized in columns of fibres, crosswise, containing strontia 42, sulp. acid 58. (Klaproth, 1797.)—H. C. Lewis, however, found a white fibrous aragonite in seams and crystalline crusts in the nearly pure limestone of the Water-lime division of formation VI in Mifflin county, opposite Mt. Union, 2 m. E. of Matilda furnace, containing carb. strontia 0.58; and with this Dr. Genth found groups of minute divergent needles of *strontianite*, consisting of carb. lime 15.36, *carb. strontia* 83.15, etc. (Report B, 1876, p. 229.)

‡ Dr. Genth's analysis of the green orthoclase felspar *lennilite* (or *delawarite*) of Delaware county, gave 0.57 baryta; and his three analyses of another orthoclase felspar (Lea's *cassinite*) from Blue Hill, Delaware county, gave 3.79, 3.75, 3.60 baryta. The clays produced by the decomposition of such felspars must necessarily retain much barita converted into barite.

Gypsum absent from No. II.

Plaster rock (*gypsum*, *sulphate of lime*) does not occur in formation II in Pennsylvania. In fact even as isolated crystals it is extremely rare in the State, and is only seen where the water from oxydized pyrites acts on the limestone beds, as at Van Arsdale's quarry near Feisterville, Bucks county, producing beautiful slender crystals, sometimes 2 in. long and ⅛ in. wide, or much smaller as at Cornwall. Such needles frequently are seen on the magnetic iron ore, or upon a decomposed clay-like mineral, often intermixed with arborescent copper. (Genth in B, p. 148.)

The so called "Plaster rock" of the Wilsham quarry in Nippenose valley on the Clinton county line, ground at Metzger's and other plaster mills near by, and sold as plaster at prices little below Cayuga or Nova Scotia plaster, was found by McCreath, at the Survey Laboratory in Harrisburg, to be a nearly pure limestone, with less than 1 per cent. of gypsum in it.*—The place of the beds is about 500′ beneath the bottom of the slate formation No. III.

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*Montreal plaster has sulp. acid 46, lime 33, water 20. The Nippenose plaster consists of carb. lime 95.1; carb. magnesia 1.0; silica 2.7; *sulp. lime* (*gpysum*) *0.7;* carb. iron 0.3; carbon and water 0.2. (Report G2, p. 81.)

CHARTER XXXVIII.

Trap dykes in No. II.

In Berks county, *a trap dyke*, 4 m. W. of Reading, issues from the Trias country and cuts the limestone belt in a N. E. direction. Crossing the turnpike a little E. of Sinking Springs and following down the west side of Cacoosing creek, it makes a fine show on Tulpehocken creek near Van Reed's mill. Its boulders appear on the slate soil further on near Epler's; but the dyke cannot be traced beyond this to the Schuylkill.*—It is evident that this dyke is in some way connected with the great outbursts of trap in the Trias south of Fritztown near the Lancaster county line; but the long way it runs, its straight course, and its narrowness make it difficult to suppose that the crack was invaded horizontally. The lava must have come from a great depth, and therefore could have had no real connection with the Trias. Its abundance in the Trias only goes to show that the disturbance which produced the fractures, and the filling of these cracks with lava, were events of a *post-triassic age.*—A similar occurrence on a much larger scale in Cumberland county teaches the same lesson.

In Lebanon county a small dyke issues from the edge of the Trias 2 m. E. of Campbellstown, just west of Killinger's run and can be followed half a mile across the limestone.

But N. of Lebanon city is a much more remarkable case. Three dykes appear between Mt. Ararat and Jonestown, running in parallel E. and W. lines, about a mile apart; the middle one, about 4 miles long, reaching nearly to Mt. Union P. O. They are in the slate belt. They do not touch the limestone belt; nor run N. and S. as if connected with the reservoirs of trap under the Lancaster-Lebanon

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*Rogers' Geol. Pa., 1858, p. 251. It has been omitted accidentally from the Berks county map in Hand Atlas, X.

county line. They must certainly come up from the azoic floor beneath the limestone which is beneath the slate ; that means from a depth of at least a mile beneath the present surface.*

In Montgomery county a long staight trap dyke crosses the Schuylkill river at Conshohocken 500′ N. of the bridge, where it outcrops on the west bank in a picturesque black wall 40′ thick and as many high. It runs east and west from the river in an almost absolutely straight line (about N. 23° E.) eight miles, from the Chester county line a mile W. of Mechanicsville, to Flourtown, east of which it cannot be traced continuously, if at all, into the Trias country towards Doylestown.†

For 2½ miles west of the Schuylkill it runs through South Valley Hill primal slates, which stand like the dyke nearly vertical. A mile east of the river it takes the line of contact of slate and limestone, and keeps it two miles further to Marble Hall ; for the next mile it runs obscurely in the limestone ; for the next two miles it is plainly seen in the heart of the limestone belt crossing its center line very obliquely to Flowertown. It nowhere indicates disturbance or faulting of the formations up through which it comes from some unknown depth, where an unexplained reservoir has furnished all the *dolerite traps* of the region, for they are all alike, whether they cut gneiss, primal slate, limestone, or Trias.‡

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*These dykes are represented on the small colored map of Dauphin and Lebanon, No. 22 of the Hand Atlas, Report X, as located by Mr. Sanders in his survey of the slate belt. The presence of trap is well known to the citizens of Lebanon. Whether the crushed limestone breccias of Mt. Ararat were made during the movements connected with this eruption of lava, no doubt in Post-triassic times, is a mere conjecture.

† Prof. H. C. Lewis thought he could make it continuous that far. Mr. C. E. Hall however gives on a page plate map (Fig. 4, p, 22, Report C6, 1881) a line AB in prolongation of the dyke eastward, and another line CD, 32° off to the north, passing through four patches of trap boulders on cross roads, and close to a fifth at Jarrettown. Mr. B. S. Lyman's survey of the Trias belt has taught that a connection of the Conshohoken dyke with the sporadic trap shows of the Trias is improbable. The same may be said of its continuity westward with the sporadic traps of Delaware and Chester counties.

‡ See Dr. F. A. Genth's analyses given in C6, pp. 94 to 99, Specs. 5063, '4, 5066, '7, '9, 5072, 5081, '2, '4, '6, and p. 134, Spec. 7789, which last reads: Loss

It might be supposed that this trap dyke has had something to do with making the white marble beds at Marble Hall, if that idea were not negatived by the fact that the range of white marble quarries east and west of the Schuylkill is quite independent of the dyke.

In Lancaster county Prof. Frazer has traced an extraordinary trap dyke from the Susquehanna river 3 m. above the Maryland State line, in a N. E. by N. nearly straight course, past Goshen, Quarryville and May P. O., Kinter's P. O., Boyerstown, and Springville (Salisbury P. O.), to the Welsh Mountain 2 m. E. of Mt. Airy, a distance of 25 miles. It probably passes on five miles further concealed beneath the primal sandstone surface rubbish of the mountain land, and is seen again for 2 miles *crossing the Conestoga valley limestone* 2 m. W. of Churchtown, then losing itself beneath the southern edge of the Trias, as if making for the great trap outburst in Berks county on the north edge of the Trias, S. and S. E. of Reading.

At Quarryville it cuts diagonally across the limestones of the Chester valley; at Kinzer's, Boyertown and Springville it cuts for 6 miles diagonally across the limestones of Pequea valley; at its south end it cuts diagonally across the Peach Bottom primal slates; and in other long stretches of its course it cuts the Philadelphia schists.

At Springville it is either interrupted for a short distance, jogged to the east, or is duplicated, the surface being covered with trap blocks. It branches, or is intersected by a short dyke ½ m. N. E. of Boyertown. Two miles S. of Kinzer's it cuts the hornblende gangue rock of the Gap Nickel mine; and a small parallel dyke here runs half a mile distant from it, a mile above Georgetown, both changing their course locally to S. by W. Several such local fluctuations from a perfectly straight course are noticed before it reaches the Susquehanna at the mouth of Peters creek. It may extend into Maryland but is not

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by ignition, 6; silica, 39; alumina, 32; ferrous oxide, 9; ferric oxide, 2.2; potassa, 5.3; magnesa, 3.1; soda, 2; titanic acid, 1.2; phos. acid, 0.5; niccolous oxide (with a trace of cobalotus oxide), 0.06.

traceable on the surface for six miles S. W. of Peach Bottom; then a dyke is to be seen half a mile south of the State line, and a mile south of the roofing slate quarry ridge.*

That the roofing slates have been produced by plutonic action I cannot think, for those in the Lehigh country are far removed from any such influence. It is possible that there may be a closer connection between the dyke and the nickel ore. The fountain seat of such a dyke must evidently be at a great depth.

In York county two trap dykes cut the limestone rocks, one four miles east of York, the other two miles west of York.—The *Loganville dyke*, about 13 miles long, runs in a N. N. E. direction, with a deflection and a short branch at Logansville, and a true north course from Longstown to the Wrightsville railroad, where it seems to terminate at the synclinal axis of the York valley limestone belt.—The *Staresville dyke*, six miles long, runs N. by E. from the south edge of the York valley limestone belt, across the Shortline RR. 2½ m. S. W. of York to the edge of the Trias at Staresville. If continued under the Trias 6 miles further northward it would join the great trap outburst on the Susquehanna between New Holland and Goldsborough. It cuts the Codorus limestone beds its whole visible length, and throws a short branch S. W. also in limestone.† In this case as in that of the Conshohocken dyke no production of white marble appears as due to igneous action.

In Cumberland county we have the most remarkable exhibition of trap outside the Trias region. It is like the Sinking Spring dyke in Berks county, but vastly larger and

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*See Prof. Frazer's detailed description of this dyke in his report on Lancaster county, C3, p. 28 to 31; also the colored county map in C3; also Hand Atlas, map No. 35.—On page 78 it is said that the dyke was traceable only by its boulders across Eden township. See other similar references elsewhere in C3.

†See the colored geological map of York county in Report C2. The representation in the Hand Atlas X, map No. 61, is not quite correct. There is a short dyke represented cutting the limestone area at the N. W. line of York county coming in from Cumberland county.

infinitely more instructive as to the source of the lava; locating it in fact several miles beneath the present surface; for it is incredible that lava, however fluid, could flow through a narrow crack *horizontally* a distance of 25 miles; and even if this could be done for the single dyke which crosses the Great Valley and the Perry County Cove, it would not generate the three other short parallel associated dykes in Perry county which do not appear at all in the Great Valley. Moreover the thickest part of the dyke is in the Cove. Evidently the focus of activity must be located under Perry county, and be in some way connected with the faulted, overturned, profoundly deep Cove synclinal.

As the dyke cuts the slate and limestone belts of Cumberland county, and is probably continuous (underground) through the South mountains into Adams county, (there connected with the great outbursts of trap in the Trias,) we must take it for granted that in Perry county it descends through all the formations from XI to II, into the Cambrians, and through them into the floor of gneiss. There are 19,000′ of strata exhibited in Perry, and at least 6000′ more in Cumberland, making 25,000′ to the bottom beds of II; to which must be added say 15,000′ of South Mountain Cambrian rocks. It is evident then that in Perry county the lava has ascended from a depth of from 5 to 7 miles to reach the present surface. How far it rose above the present surface of the Great Valley would depend upon the precise Post-triassic age of the dyke; for, if it reached and overflowed a surface already sculptured by erosion during the whole Triassic age, all that upper part of the dyke has been swept away, and nothing remains but its stem, from the present surface to its roots in the deep.

The dyke is first distinctly seen at Boiling Springs on Yellow Breeches creek. South of this its upper edge is probably concealed beneath the deep alluvium at the foot of the South mountains, across which it might probably be traced, for Mr. Lehman in his topographical survey found fragments of trap in the woods on the line of the dyke projected southward.*

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*On the colored map of Cumberland county in Atlas D5, a branch dyke is seen taking off from near Boiling Springs and running some distance S. W.

From Boiling Springs it runs in a slightly waving nearly straight line N. 10° E. 10 miles to the top of the North mountain 2 m. E. of Sterritt's gap. Across the limestone belt of cleared land (here 7 miles wide) it makes a continuous ridge about 50′ high, conspicuous to travelers because left wooded by the farmers' of the valley; and this leafy barrier has been adopted as a township line between S. Middleton and Monroe, and between Middlesex and Silver Spring townships. It crosses the turnpike 4 miles E. of Carlisle, and the railroad halfway between Middlesex and Kingston stations. The slate belt is here 3 miles wide and the dyke upon the township line is perfectly straight; all its deviations from a straight line take place in the limestone belt, and these deviations are undoubtedly due to the crumpled condition of the limestone formation, although the fracture was almost transverse to the general strike.

Descending the north slope of the North mountain into Perry county it crosses Fishing Creek valley and makes the divide which casts the water off east down Fishing Creek, and west into Sherman creek upper branches. Keeping on across Cove mountain and the head of Cove creek it ascends the slope of Peter's mountain and is lost near the summit.*

As the Cumberland county dyke cannot be properly understood if only studied in its course across the limestone and slate belts of the Great Valley, I will give here Prof. Claypole's description of it in Perry county, and of three

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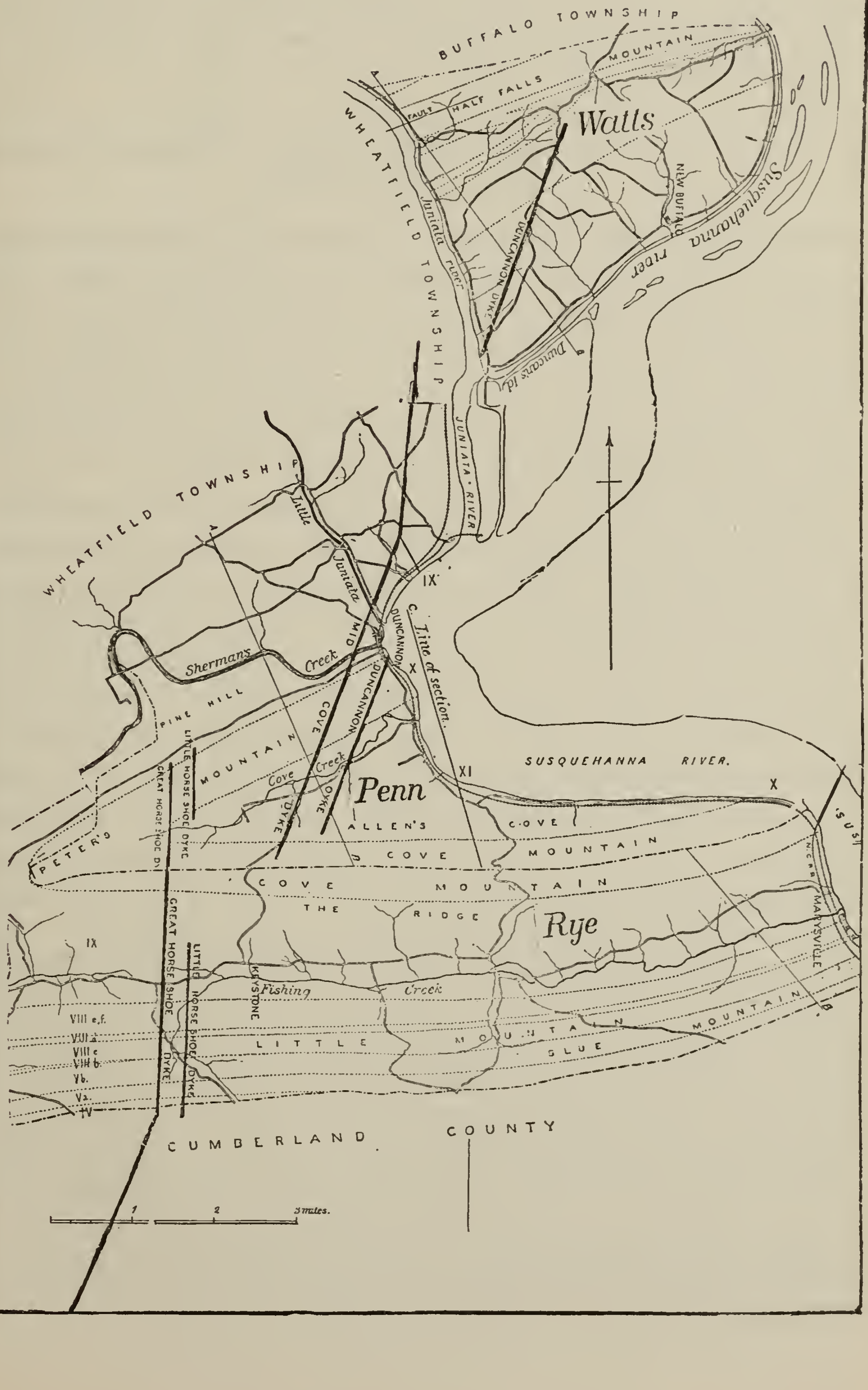
* Dr. Henderson's description of it published by Prof. Rogers in Geol. Pa. 1858, p. 366, is very erroneous, for he carries it across the Juniata and Susquehanna rivers into Dauphin county. It is but justice to Dr. Henderson, who was one of the best geologists of his day, and to whom we owe our first accurate knowledge of the complicated structure of Perry, Juniata and Mifflin counties, to say that he could only with great difficulty at that early day trace the line of the dyke upon his map; and the line which he laid down on his map was transferred to the Geological Map of Pennsylvania, made by me in 1842, and published by Professor Rogers in the Atlas to his Final Report, 1858. I am sorry to add that I embodied these errors in the small map of Perry county, Map No. 45 of the Hand Atlas, Report X, drawn by me in 1878, previous to Professor Claypole's elaborate survey of the dykes, published in Report F2, 1885. The reader is therefore referred to the *second* (revised and amended) colored geological map of Perry county in that Report.

Pl. XXVI.

Trap dykes in Cumberland and Perry counties.



other dykes in that county which probably have an under-connection with it at some unknown great depth beneath the present surface.

Plate xxvi, p. 457, shows the geographical relationship of these four Perry county dykes, named by Prof. Claypole: Great Horseshoe, Little Horseshoe, West Duncannon and East Duncannon dykes.*

(1.) *The Great Horseshoe dyke, Ironstone ridge, or Cumberberland Valley dyke.*

The line of this dyke may be detected by loose fragments on the south side of Peters' mountain about two and a half miles west of the river and between the highest terrace and the summit of the mountain. Its course is plainly indicated down the slope by the same evidence from terrace to terrace, with a bearing of S. 10° W. into the Cove at the foot of the Horseshoe and almost to the creek.

Along this part of its course it appears to be the widest of all the dykes in the Cove, but *just before it reaches the creek it suddenly and markedly increases* and assumes comparatively gigantic proportions, *admirably displaying both the trap and the accompanying rocks altered by contact with it.* The sandy beds of the Mauch Chunk Red shales (XI) which are here cut through are changed to a dark brown and chocolate colored material; the red shales themselves are in some places burnt into a mass resembling half made brick, but not usually much hardened. Some fine shale beds, however, have been so much changed that they are almost as tough and hard as the trap itself. This change in the appearance of the rocks at this point has led

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*The descriptions are in his own words, copied from his report F2, pp. 296–301. On the map I have renamed his West Duncannon the Mid Cove dyke, which extends northward into Wheatfield township; and I have ventured to give the name Duncannon dyke to the dyke in Watts township, as it is in line with the (East) Duncannon dyke in Penn township; and this doubtless deceived Henderson into believing that the Cumberland county dyke was single and 30 miles long. His belief, however, may after all be a correct one; for the most striking fact exhibited on the map is the N. 10° E. direction of the Cumberland dyke, the Mid-cove dyke, and the Watts township dyke, all three on the same line, while sending off branches to the north, as if there was but one dyke in the deep.

to considerable excavation in the belief that the dark, soft, sandy shale beds contained copper—a belief for which there is of course not the slightest foundation.

The excavation serves to make very plain the striking development of the dyke at this point. From being a dyke very much resembling the other three—perhaps rather larger—*it suddenly enlarges and becomes nearly 200 feet from side to side.* The bed of the Cove creek and the flat marshy ground alongside of it, overgrown with a thicket of laurel in some places impenetrable, is thickly bestrewn with massive blocks of the dyke up to half a ton in weight. How far this display continues through the wood I cannot say nor to what height it rises on the north flank of Cove mountain. The bearing of this dyke is S. 10° W.

The Great Horseshoe dyke passes through Rye township almost from north to south where it is well known as the Ironstone ridge, and forms a watershed across the valley. Coming down from nearly the top of the Cove mountain its track may be followed by the characteristic belt of yellow soil and heavy rounded rusty bowlders through the woods, almost along the road (hence called the Ridge road), to the middle of the valley. The land on both sides of it is so encumbered with wreckage from the dyke that it is left untilled and uncleared. But it is at the crossing of the main valley road that the most magnificent display of the Great Horseshoe dyke occurs in Perry county. Here the road for 500 feet on each side of the line is embanked with bowlders that have been removed from the land and piled up in grand disorder. The dyke itself does not probably exceed 200 feet in breadth, but its fragments strewn along both sides make it seem very much wider. North and south of this point the exhibition is less striking but the ridge may be traced without difficulty for nearly another mile, when it is lost on the slope of the Blue mountains. The nature of the trap and further details may be found in the account of Penn township.

Traces of another (the Little Horseshoe dyke) may be found about 500 yards to the eastward in a number of loose blocks of trap scattered along the road, but no ridge in any degree resembling the Great Ironstone ridge can be seen.

(2.) *The Little Horseshoe dyke.*

About a quarter of a mile east of the Great Horseshoe dyke, another parallel line of fragments can be found high up the south slope of Peters' mountain, in fact upon the highest terrace. Its first appearance, so far as I am aware, is at an old shaft sunk some years ago under the impression that the trap dyke carried an ore vein. The shaft was sunk to a depth of about 25 feet, and at the depth of about 22 feet many blocks of the hard tough dolerite (trap rock) were thrown out. This is the most northerly indication of this dyke that I have seen in the cove. Hence, it may be followed at intervals southward down the slope of Peters' mountain, forming an almost continuous line through the thickets to the cleared land in the cove below, where it crosses first a field and then the road leading west into the woods of the Horseshoe, and is lost to view at the creek, where a large meadow is almost ruined by the number of blocks which lie scattered about upon it. Beyond the creek no one, so far as I can learn, has succeeded in tracing it, so that it probably does not rise so high on the Cove mountain as it does on Peters' mountain.

I have no means of estimating *the breadth of the dyke* but judge it not to exceed *6 or 8 feet.* Its bearing is, as nearly as I could ascertain it, south 10° west.

Its southward prolongation into Rye township is only attested by a number of loose blocks scattered along the road about 500 yards east of the Great Horseshoe (Cumberland Valley) dyke; but no ridge is made by it in the topography of the surface.

The Mid Cove or W. Duncannon dyke.

Half way between the head of the cove and the river, and near the foot of Peters' mountain, a range of trap can be readily traced It crosses Cove creek close by an old sawmill pond, now dry, and then shows in a byway on the north side of the main turnpike road. Following it over a field it is seen very plainly in the bank, and then runs along keeping parallel with the same road as far as the foot of the

Cove mountain. In front of the farm-house which stands at this point is a well sunk exactly on the line of the dyke. Mr. J. M. White who sank this well informed me that he passed through the dyke, and that it is *not vertica·, but pitches to the west at an angle of about 45°.* The greater part of the well was sunk in the red shale, the dyke being left at a depth of about 8 feet. It measures here only about 6 or 8 feet, and consists of a number of loose blocks embedded in the red clay—the product of their own decomposition. In the neighboring field a pit was dug to examine the dyke, which gave the same results. Crossing the road at this point the dyke can be traced about 100 yards further through the orchard into the wood, where all traces of it are lost, nor has any one, to my knowledge, ever seen it higher on the hill.

It has not been seen in Fishing creek, in Rye township; nor in Cumberland county.

But it extends northwards from Peters' mountain into Wheatfield township, crossing Sherman's creek and the Little Juniata a quarter of a mile only from the river at Duncannon. A mile N. of Duncannon it bends and takes a nearly due N. course to the turnpike a mile S. of Losh's Run station on the P. RR., beyond which it is not seen.*

(4) *The (East) Duncannon dyke.*

About three quarters of a mile further east a trap dyke may be seen in the roadside about ¼ mile south of the mouth

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*I give Prof. Claypole's detailed account of this part of it, beginning at the north and going south :—Its first appearance is on the turnpike road about one mile S. of Losh's Run station, P. RR. Its next appearance, so far as I am aware, is on the road leading west from the Aqueduct. There is no trouble in following it from this point by an almost uninterrupted series of exposures to Duncannon. Its course is marked by the red color of the soil, for a mile due south, across fields, to the road running west from the railway station at Juniata bridge. Here a pit was sunk some years ago in quest of *ore on the western edge of the dyke*, to a depth of about 25 feet. A drift was then run for 6 feet into it in the attempt to penetrate it. *This made its thickness upwards of twelve feet.* The same discolored sandy shales were thrown out here as in the Cove.

At this point the direction of the dyke suddenly changes; but a thin vein of trap appears to continue nearly on its former course, as indicated by an occasional trap pebble in the low ground. Such pebbles have been found in of Sherman's creek. Thence it has been traced up the hillside, where its outcrop has been followed, in a vain search for iron ore, to the top, but not to the *crest* of Peters' mountain. The dyke cuts through it near the brow overlooking the river. It continues on the same course, S. 20° W. down the south slope of Peters' mountain into the Cove, and may be followed by the color of the soil and the loose blocks lying about across the fields to the main road up the Cove, which road it crosses just east of a farm-house. Running on thence with the same bearing, it may be seen alongside of the road (which here turns to the south-southwest) for about 200 yards, where it crosses a lane running off at the next angle in the road. Here its presence is marked by the usual red clay and bowlders. Beyond this point southward I have not traced it.

In Watts township between the Juniata and Susquehanna rivers may be found a dyke which is probably a continuation of this Duncannon dyke as it is in almost exactly the same line, but the interval (from Duncannon to the N. W. point of Duncan's island) is 3½ miles, no great distance for an underground connection.

It appears about ½ m. N. of Dr. Reutter's house at the Junction, and is traceable by loose blocks 3 miles N. 10° E. nearly to the foot of Half Falls mountain.* It precisely

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the run close by the place where the change occurs, near the grist mill west of Duncannon, and again at a short distance behind the nail factory. These are sufficient to indicate a faint continuation of the dyke in its former direction as far as to the north foot of Peters' mountain. An examination of the map will show that it is on the line of dyke No. 3 in the Cove before described.

But the main mass of the dyke suddenly bears away at S. 30° E. down a slope, across a field, passing under a house (as shown when the cellar was dug) and so reaching the river. It has not been seen in the bed of the river; but on the opposite or eastern river bank, opposite the mouth of Sherman's creek, and exactly on the right course, what is probably the same dyke is displayed in a cutting of the North Central railway.

This exposnre gives an opportunity of measuring the thickness of the dyke, which is about 50 feet. It does not appear to rise to the surface; and the rocks on both sides are altered as in the case of the Great Horseshoe dyke in the cove.

* "Had time allowed might have been followed further. The last trace of it seen was near the house of Mr. M. Peters." F2, p. 385.

resembles the Cove traps, a hard, tough, dark green, almost black *dolerite*, containing a small proportion of magnetic oxide of iron, rusting yellow outside.†

The most remarkable thing about these dykes is this: *not one of them has ever been detected at the top of either of the two mountains;* the East Duncannon and Great Horseshoe dykes alone rising above the highest terrace, so far as known. The West Duncannon dyke does not appear to rise into the mountain at all, its exposure ceasing sharply at the foot. It is not, however, impossible that further examination may modify this assertion which is based on negative evidence only. Not one of these dykes is yet known to appear upon the very summit of either Peters' or Cove mountain. The Great Horseshoe dyke ranges highest, running, as has been shown, up to the topmost terrace of Peters' mountain on its southern flank. This failure of the dykes to appear at the summit proves the mountains to be older than the dykes. Now since the Triassic red sandstone of York county is cut by numerous similar dykes with which these Perry county dykes seem to be connected, they must be not only later than the coal measures, but of later age than the Trias; but as no such dykes are known in the Cretaceous beds of the Atlantic seaboard, our dykes must be older than the Cretaceous age.

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† The trap of Perry county is a hard, very tough, dark, heavy and fine-grained *dolerite* containing grains of magnetic iron ore disseminated through the mass, readily discoverable by crushing a small piece with the hammer and applying a magnet, when the magnetite immediately clings to it. The presence of this material is partly the cause of the decay which takes place at the surface of the trap. Under the action of moisture the magnetite becomes rusty and passes into brown hematite. The outer layer of stone is softened and changes color to a rusty yellow. This outside layer scales off and the process is repeated upon the new surface thus exposed. In this way from year to year a red clay soil is produced by the disintegration of the other materials of the rock, felspar and hornblende, colored by the iron oxide. In consequence of the abundance of this red clay along the course of the trap it is usually called by the residents of the neighborhood "iron ore," or "magnetic ore rock." But it is not likely that any merchantable iron ore will be found along the lines of these dykes. It is often a task of great labor to dig out and carry away the fragments from the fields and pile them up at the roadsides where their subangular form and rusty color make them conspicuous objects to the passer-by. They all consist of the same tough hard *dolerite*, showing some but very little variation in composition and fineness at different places.

Effects of trap.

The alteration of the magnesian limestone rocks near the trap dykes of Berks county is ascribed by Dr. Genth to the infiltration of siliceous waters.*

Deweylite and *serpentine* are formed out of the magnesium carbonate.

Another portion of the magnesia separates as *brucite.*

The calcium carbonate crystallizes in small acicular crystals and radiating columnar masses of *aragonite;* and also in crystals and coarse granular masses of *calcite.*

The alteration of dolomite at Fritz's island has produced, directly or indirectly, not only *serpentine* and *deweylite*, but also *grossular*, a beautiful yellow and orange *vesuvianite*, *apophyllite*, *chabasite*, *gismondite* (?), *thomsonite*, *mesolite*, *stilbite*, *datolite*, etc.

Serpentine in No. II.

The limestone No. II near Reading is described by Dr. Genth as "granular, largely altered (by silicious waters) into *serpentine*,"† and coated with colorless, pearly *brucite.*‡ The *brucite* occurs also in brownish yellow thin seams.

Deweylite, white, yellowish, brownish, amorphous, also occurs in round grains, stalactites, botryoidal, plates, slabs (occasionally more than 1″) and irregular coatings.§ The slabs are often arranged in layers, white and brown, often intimately mixed with *aragonite*, which sometimes separates in radiating columns or masses (50mm long); the layers often separate easily, and the separation planes are covered with small brilliant *aragonite* crystals. The *aragonite* has often changed to *deweylite.*

The change from dolomite limestone to *serpentine* can be observed in all its stages from pure dolomite to pure ser-

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*At Fritz's island; and at Wheatfield & Ruth's mines, 2 miles E. of Fritztown, and 2 m. S. of Sinking spring. Proc. Amer. Soc. Phila. Oct. 2, 1885. See also descriptions by E. F. Smith, D. B. Brunner and I. Schoenfeld.

†Amer. Phil. Soc. Proc., Phila., Oct. 2, 1885.

‡E. F. Smith's analysis of it (in Amer. Chem. Jour., V. 281) is silica 32.52; magnesium oxide, 66.78; ferric oxide, 0.44.

§Analysis by H. F. Keller, silicic oxide, 39.32; magnesium oxide, 41.14; ferrous oxide, 0.51; water, 18.41.

pentine; which is generally a greenish yellow, greenish white, or yellow, but also sometimes brownish and grayish.[*]

Aragonite and calcite are frequently associated. *Magnetite* is occasionally disseminated in fine grains through the mass.

Olivine. Dr. Genth alludes to Dr. Wadsworth's theory that the Fritztown serpentine is an altered olivine, and to his assertion that the specimens show *unaltered olivine*,[†] and says: "I cannot imagine how *olivine* could be present in this rock, and what it is which he (Dr. Wadsworth) has taken for that mineral. As the trap is of triassic or post triassic age, it is impossible for olivine or any other kind of volcanic ash, to get admittance into the Siluro-Cambrian dolomite strata around Reading."

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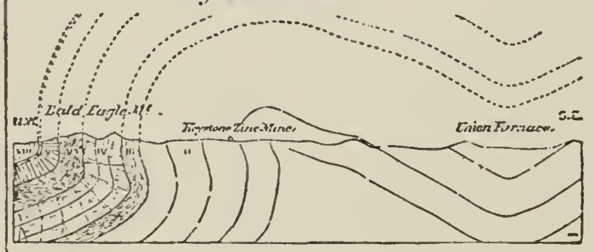
[*] Analysis by H. F. Keller. Ruth's mine: Sil. ox., 42.14; mag. ox., 41.61; ferrous ox., 2.06; water, 14.20.—Wheatfield mine: sil. ox., 41.46; mag. ox., 44.68; F. ox., 0.99; water, 14.07.

[†] Lithological studies, by M. E. Wadsworth, Cambridge, 1884, p. 152.

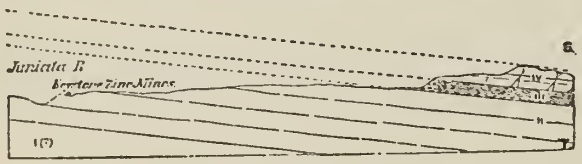
No. II a, Calciferous; b, Chazy; c, Trenton lime.
No. III a, Utica; b, Hudson river slate.

To illustrate Chapter XXXVII.

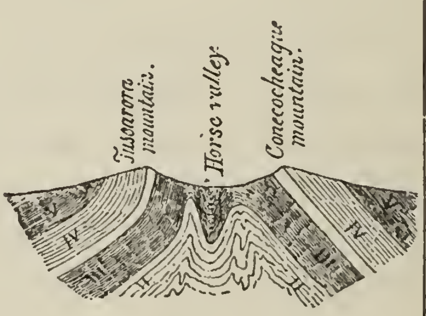
Section from Bald Eagle Mtn. through the Keystone Zinc Mine.



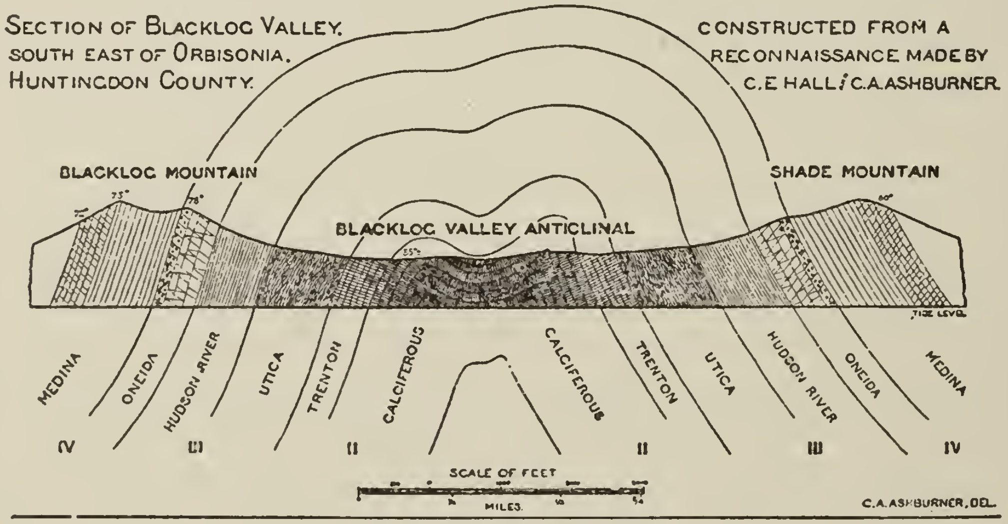
Section along the Anticlinal Axis. Showing the sinking of the measures to the south.



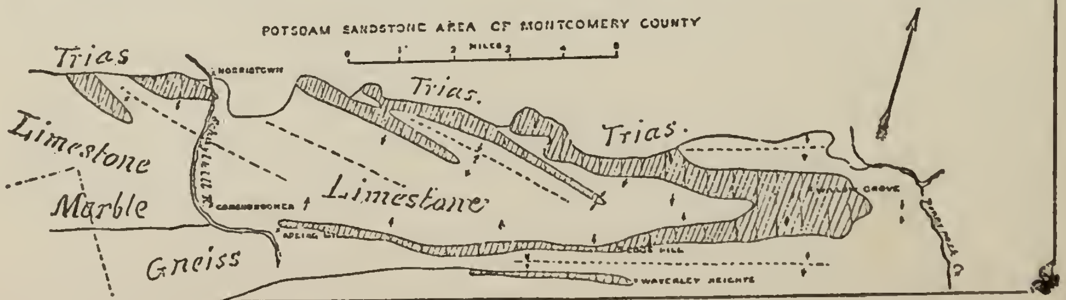
To illustrate Ch. XXXV.



To illustrate Chapter XXXV.



To illustrate Chap. XXXIX.
No. II Limestone and Marble of Chester Valley.



Chapter XXXIX.

White Limestones and Marbles of No. II, in Chester, Montgomery, York and Centre counties.

The white marble door and window caps and sills and the blue-streaked marble front door steps of Philadelphia were obtained from numerous quarries wrought along the southern edge of the Chester County valley, east and west of the Schuylkill river, until about fifty years ago, when the marble quarries of Vermont began their successful competition for the market. Stephen Girard built the beautiful Corinthian façade of his banking house in Third street of native white marble. The United States Bank in Chestnut street, * with its severely beautiful Doric porticos, was built of the same material, now rendered doubly pleasing to the artist's eye by reason of the warm mellow yellowish tint which time has given to it, and which the Greeks delighted in. One side of the superb Corinthian peristyle and cella wall of the Girard College was also built of it, the other side and the front and rear porticos being from the Vermont quarries. †

One reason for the gradual substitution of Vermont for Chester Valley white marble was the great expense of quarrying in the Chester valley, and the cheapness of freight by water from Vermont, as well as the singular development of better methods of getting out the stone there; but there was another pregnant reason. The Pennsylvania white marble beds are locally half or wholly spoiled by pyrites, which runs in streaks through them and subject

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* Now the U. S. Custom House.

† Its 57′ high columns, built up of drums 6′ long, compare favorably with those of the Madelaine in Paris, built up of drums only about 1′ long, although the College columns are spaced so much further apart as to make them look too slender; and the close-set double row of the Madelaine gives to that splendid monument something of the Doric majesty of the Parthenon, which it resembles also in its great length of side colonnades.

them to a slow decay. The front columns of the Custom House, exposed to the northeast storms in cold weather, became gradually dilapidated, and are now patched with pieces of new marble let into the decayed places ; and such periodical restorations will always be necessary.*

The marble quarries of the Chester valley, both east and west of the Schuylkill, were opened along the vertical beds next to the South Valley Hill, and the marble quality is evidently due to the same cause to which the verticality of the beds is due, namely, a great pressure from the south crushing the rocks and permitting infiltration and recrystallization. †

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* What the streaks of pyrites do to this marble under the action of the acids in the air, and of the frost, similar streaks of feldspar do to the syenite obelisks of Egypt under the sand blast of the Khamzin or desert wind of March and April.

† "It is worthy of remark, that all the marble of the limestone basin of Montgomery county is confined to the synclinal trough adjoining the anticlinal axis now described, upon the N.; the genuine marble not extending more than half a mile from the uplifted belt of slate, nor eastward in its line of strike beyond the neighborhood of the point of sinking down of the Primal slates, or past the meridian where the anticlinal rapidly loses its force. As the marble is evidenly only a highly metamorphic variety of the ordinary magnesian limestone, crystallized and changed in tint by igneous action from within the earth, it is quite natural that it should run thus parallel with and adjacent to this line of uplift, produced as this has been by the protruding forces of the interior. The whole of this belt of marble is in fact but the vertically upturned, and occasionally inverted, Northern side of this anticlinal wave, the side along which the maximum amount of igneous influence is invariably manifested. In offering this explanation of the origin of the marble by metamorphism, it is proper to observe that we must not ascribe the whole of the change to its proximity to the line of anticlinal uplift of the Conshohocken axis. There is a tendency in the *whole* of the limestone of the Southern half of the general valley to a much greater degree of alteration than belongs to the same rocks in the Northern half. Throughout this entire synclinal belt the metamorphism from heat, of course, has been far greater along its Southern than upon its Northern margin, partly because the strata of the former side are nearer the principal injections of igneous rocks of the whole region, and partly in consequence of the perpendicular or even inverted position which has permitted the subterranean volcanic vapors to pervade them more freely and exert their maximum influence."—H. D. Rogers in Geo. Pa., 1858, Vol. 1, p. 163.

West of the Schuylkill, Prof. Rogers remarks :—"Throughout the northern half of the basin, especially where the limestone observes its usually very regular southward dip of seldom more than 45°, the rock is in the condition of a sub-crystalline, and even earthy or purely sedimentary magnesian limestone, and its bedding is for the most part very uniform and

In New Jersey, Sussex county, two limestone formations surround the Franklin zinc mine, one blue and the other

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rather thick. Its color is a pale grayish blue, except in neighborhoods like that on the Schuylkill below Norristown, where a partial metamorphism has approached the northern border, and it is then, very frequently, a pale straw-yellow and bluish-white. The interleaved thin layers of argillaceous matter which so frequently separate the beds of the limestone are in the condition of an indurated clay-slate, but seldom show even incipient crystallization. In many instances wide bands of the limestone, along its northern outcrop, exhibit numerous cross-joints intersecting the beds in nearly all directions and causing the rock in certain quarries to break into a mere rubble of small angular fragments, assisting much the labors of the quarryman and limeburner; but these joints, and the before-mentioned semi-crystalline texture, are the limits to which the metamorphism of the rock has reached, a true parallel slaty cleavage being seldom or never discernible.

"But the state in which the very same beds exist, where they rise perpendicularly or with inversion to their southern outcrop after passing the synclinal turn in the center of the basin, is very different from all this, and in striking contrast. The faintly crystalline and earthy limestone is here a distinctly crystallized, often a granular marble. Its color is changed to a brilliant white, or to a mottling of purely white and dark blue, from the presence of segregated or half-developed graphite; and the dispersed ferruginous matter is here in a state of minute solitary crystals of sulphurate of iron disseminated through the body of stone. The rock, instead of lying in thick, often massive beds, is cleft into thin plates by innumerable natural fissures or cleavage-planes, not parallel with the stratification, but dipping steeply southward or acutely across it, and these fissures are filled and lined with distinctly crystalline flaky talcose and micaceous matter, sometimes talc and mica fully developed. The partings of slate between the limestone layers have been converted to laminæ of talc-slate, in which there is often a cleavage-structure distinctly discernible, much more intimate than that in the altered limestone, but dipping in parallelism with it. Viewed edgewise, a fresh exposure of the most altered limestone, such as is visible on the River Schuylkill near Conshohocken, has the aspect of a blue and mottled marble, streaked with films of talc, and shivered by innumerable cleavage-joints; but viewed face-wise, the layers and fragments have the aspect of a talcose or micaceous slate, so copious is the covering of talc and mica upon their surfaces."—H. D. Rogers, Geol. Pa., p. 213.

"The portion of the formation which enters Abington township is more slaty and fractured than that further to the W., and it also contains a larger amount of silicious or sandy matter. Those portions of the rock which are exposed, or are nearest to the surface, have in many places undergone partial decomposition, and have the appearance of a white calcareous sand. This sandy aspect of the limestones may be observed in all the quarries in the neighborhood of Sandy Run, and also at many other localities. Unless the rock has undergone partial decomposition, the limestone is crystalline and granular. It varies in color from blue to white, as a greater or less amount of carbonaceous matter chances to enter into its composition. Each of these colors is not confined to a particular stratum, but changes repeatedly in the same white. They were supposed to belong to one formation, one part of which had been subjected to some influence,

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beds; and, indeed, the area occupied by one particular color is usually very small. The dip throughout the whole formation is remarkably uniform. Near Sandy Run it is towards the S. and S.S.E. Quarries and pits have been opened on almost every farm along Sandy Run. One of the largest in this vicinity is on the farm of Mr. Fitzwater, near Fitzwatertown. The limestone is chiefly blue, the dip S.S.E., at an angle of about 60°.

"On the turnpike opposite Sellerstown, a limestone quarry of some size is wrought, the rock making an excellent lime. An extensive quarry of the same nearly white variety of the limestone exists on Mather's farm. There the beds are crossed by very regular joints, giving the appearance of a stratification in another direction; the true dip is towards the S. Near the Germantown turnpike, about a fourth of a mile above the Plymouth Meeting-house, are good limestone quarries. Much of the stone in this neighborhood is beautifully white, though some layers occur having a more or less bluish tint. The weathered surface of many beds is rough and sandy, showing some silicious matter in the rock.

"*Spring Mill.*—North of the Furnace 200 yards there is a large quarry in the limestone near the southern edge of the formation, in which the dip is 85° to S. 10° E. The southern side of the quarry is massive and jointed, and the dip planes are almost effaced; the northern side is more thin-bedded and talcose, of a bluish white color, and its structure very crystalline.

"In that portion of the Limestone Valley which occupies the southern part of Upper Merion township, especially in the immediate vicinity of the Schuylkill, there are numerous and extensive quarries, furnishing a large supply of the rock, a portion of which is transported to Philadelphia, and other places, by the several railroads and the Schulkill navigation; but a large amount is converted into lime on the spot, designed for the same markets.

"A large quarry of limestone is wrought on the west side of the Schuylkill, two or three miles below Valley Forge, where the rock is tolerably thick-bedded, and of a light color. The quarried stone is conveyed to the river by a railroad, and thence taken by boats to the various limekilns. Extensive quarries have also been opened near the Valley Church, where the limestone is very similar to that of the last locality, dipping steeply south, being of a light tint, and furnishing an excellent lime. On the road from Glassley to Valley Forge, near the county line, there is a small bed of slaty talcose calcareous rock extending E. and W. about three furlongs in length towards Valley Creek. It constitutes a small hill, over the east end of which the road passes. Near Valley Forge occurs a stratum of felspathic rock like that seen at Barren Hill. It is exposed in the creek, and occasionally appears overlying the Primal white sandstone at the foot of the North Valley Hill, a little East of the North Valley Church. The limestone near the White Horse Tavern in East Whiteland township is occasionally talcose and slaty. Near the Steamboat Tavern the more usual granular structure prevails: throughout all this range, however, the rock yields an excellent lime.

"At Downingtown the limestone is chiefly of a light color, and compact. Several quarries of compact and granular limestone have been opened in heat perhaps, or pressure, which had whitened it. But in 1863 Prof. Cook showed that the blue limestone beds, dip-

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this vicinity. The width of the formation near the East Caln Church is reduced to about three-fourths of a mile. It is somewhat variable, being dependent, probably, upon the angle of the dip, which, however, is pretty constant. At Coatesville it does not exceed three furlongs. At Bell's Quarry, Midway, the rock is of a light color. About one mile east of Trueman's Mill, we find a small bed of *white clay*, derived from the decomposition of an altered felspathic slate, lying between the limestone and the talc slates. In the vicinity of Buck's Run and Parkesburg the limestone becomes darker and more slaty. Passing Cloud's Mill into Lancaster county, it gradually declines in thickness, being at Cooper's Fulling Mill, in Strasburg township, not more than two furlongs wide. At its termination in Bart township it becomes more than usually sandy, especially near its margin. The main belt seems to terminate on Eckman's Run but another small lenticular belt shows itself a mile and a half further to the west, on the premises of Mrs. Bare, where the rock is quarried."—Geol. Pa., 1858, Vol I, p. 214.

In Montgomery county:—"The quarrying of marble in this district was commenced about 75 years ago, by Daniel Hitner. For the last 15 or 16 years the average quantity sent from the quarries of Marble Hall, owned and wrought by the present proprietor, Daniel O. Hitner, has been about 25,000 cubic feet.

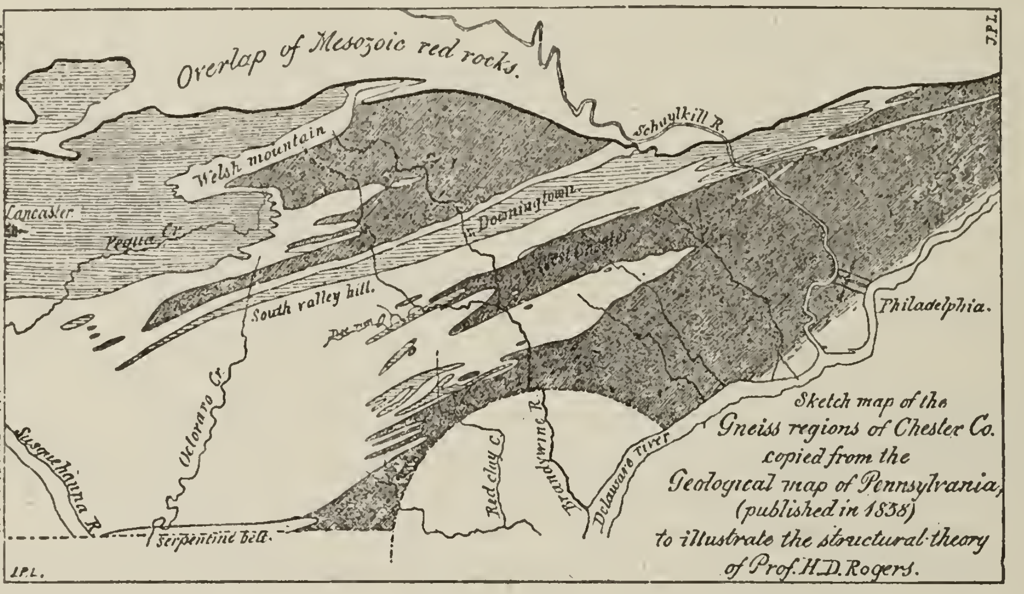
The belt of marble is nearly three-fourths of a mile wide. Marble Hall, on the Perkiomen Turnpike, is the easternmost point at which good building marble is wrought, though the belt is known to continue further. It extends thence to the Schuylkill nearly to the Chester county line.

The largest quarry of all is that of Marble Hall; here the strata dip to S. 20°, E. about 85°, presenting in one or two places a flatter inclination. This quarry is not less than some 400 feet in length, and at the top is 60 or 70 feet wide. The greatest depth to which the quarry has been sunk is 265 feet. At this depth were procured the blocks of beautiful white marble sent by direction of the State of Pennsylvania, and by the city of Philadelphia, to the great monument at Washington. At this depth the stratum of white marble, for which this quarry is chiefly wrought, has a thickness of 5 feet; but the usual thickness of this bed of pure white stone is 8 feet, that of the pure and clouded white together being generally about 20 feet. Mr. Hitner has quarried blocks 6 feet in thickness, though the general thickness of the blocks readily procurable does not exceed 2½ feet. The only saccharoidal or *statuary marble* in this or any of the quarries, is found here at a depth of 120 feet, in a layer of only 6 inches in thickness. It is of a yellowish white color and remarkable eveness of grain. The white marble is used for monuments, and for the finer architectural purposes. It now sells for about one dollar per cubic foot.

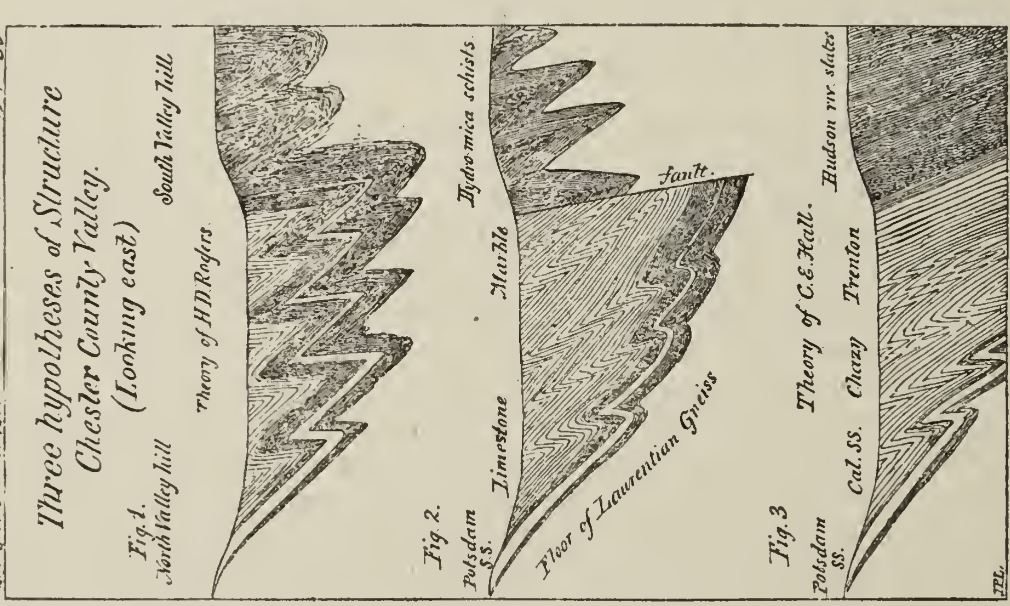
To the south of the large quarry of Marble Hall, which besides the white marble, yields much beautiful clouded or shaded stone, there is a quarry of blue and *black marble*. distant about 300 yards. This owned by Mr. Lentz, but now wrought by Daniel O. Hitner. This blue and black marble now sells for about 40 cents per cubic foot. It is used chiefly for fronts of buildings, for monument bases, etc. The thickness of the good blue marble in this quarry is 22 feet, and that of the black variety 8 feet.

XXXXV

No. II Limestone in the Chester Co. Valley.



Sketch map of the Gneiss regions of Chester Co. copied from the Geological map of Pennsylvania, (published in 1858) to illustrate the structural theory of Prof. H.D. Rogers.



Three hypotheses of Structure Chester County Valley. (Looking east)

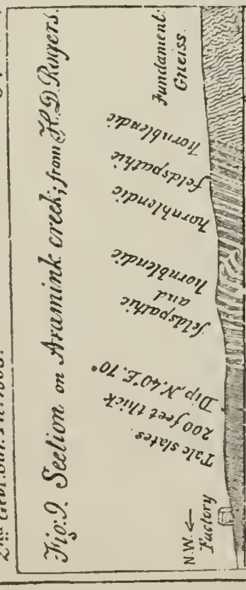


Fig. 9. Section on Aramink creek; from H.D. Rogers.

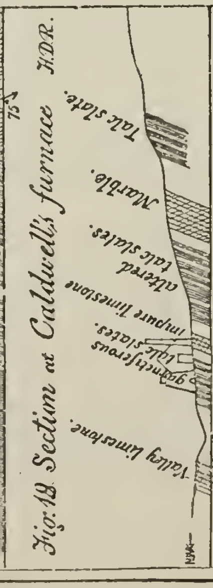


Fig. 18 Section at Caldwell's furnace H.D.R.

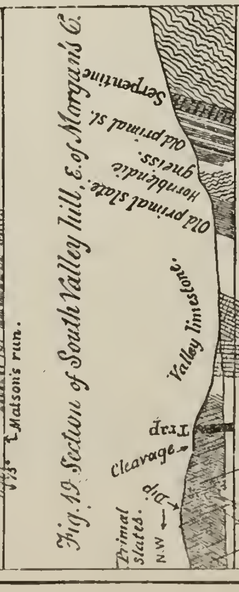


Fig. 19. Section of South Valley hill, E. of Morgan's C.

Fig. 20. Cleavage, at N. foot of Bethel hill. → S.E.

ping northwestward, lie upon the upturned nearly vertical southeast-dipping white limestone beds.*

In York county, Pennsylvania, Prof. Frazer was tempted to make the same distinction in age between the white and blue limestones of the Codorus valley.†

Besides these quarries in the vicinity of Marble Hall, there are others about three-fourths of a mile north from Spring Mill; one set owned by Robert T. Potts, another adjoining his by Mr. Peter Fritz. The marble of Potts' quarry is chiefly of the clouded variety, besides a little white and some plain blue. The annual yield of this quarry is about 12,000 cubic feet. The quarry owned by Fritz is at present but little wrought. Next in position to the westward, but still seated in the same belt, are two quarries westward of the Schuylkill; these are Henderson's and Brook's, in Upper Merion township. Henderson's the nearest to the Schuylkill, affords a plain blue marble, besides a little white. Both of these quarries are wrought at present to only a moderate extent.

A little south of the Valley turnpike, about three and a half miles E. of Downingtown, is the extensive quarry of superior white marble which has for many years supplied Philadelphia with the beautiful article employed in so many of its public and private edifices. It is on the farm of Mr. John R. Thomas. The beds on this quarry are slightly contorted. The portion worked for the marble separates into two bands. The rock occurs in massive beds, chiefly white, with sometimes a bluish tinge, and is quarried with great facility. It has been much used in the construction of the Girard College and other public buildings which adorn Philadelphia and the neighboring towns. This marble is converted into a good lime, but its crystalline or granular structure causes it to crumble in the kiln, making it a little difficult to manage. The lime from this variety is much esteemed by masons, being sold in Philadelphia under the name of *Fish-egg lime.*

The blue-mottled limestone or marble of Whitemarsh, occurring at the quarries not more than three-fourths of a mile north of the northern limit of the Primal Strata, is evidently on the south side of the trough, or folded synclinal axis of the district. This is further proved by its great steepness of dip, about 80°. It is, moreover, of the maximum degree of metamorphism or crystallization; contains talcose or micaceous laminæ, and crystals of sulphuret of iron, etc.

Strontia.—Near Mr. Hitner's House, Marble Hall, there occurs a thin bed of very ponderous rock, resembling closely a white crystalline marble. It contains however, but a moderate proportion of carbonate of lime, and consists chiefly of the carbonate of strontia." Geol. Pa. 1858, vol. 1, p. 215.

* Annual Report of 1863, p. 7.—In the course of my private survey of the Franklin mines twenty years ago, I mapped the locality, observed this nonconformability, and arrived at the same conclusion, viz: That the two formations were of very different ages, the white much older than the blue; the zinc deposits being in the white.

† See Report CC, page 132–3. Dr. Frazer says:—"In Detweiler's quarry, which is a little more than half a mile north of the Columbia bridge [in York county] there exists a conglomerate consisting of a blue limestone holding rounded pebbles of white limestone within it. The limestone exposed

In the Chester county valley, no such time distinction has ever been suggested between the blue limestone beds of the north side and middle of the valley, and the white marble beds of the south side of the valley; although the dip of the former is moderately southward, while that of the latter is nearly vertical. For, on both theories of structure, the synclinal and the monoclinal, no such distinction was necessary. In fact, on the synclinal theory the blue beds turn up as white beds; while on the monoclinal theory the blue beds, instead of overlying, underlie the white beds. But if it could be proven the white beds at Franklin and at York be the oldest, then we must suppose a fault to run through the Chester valley just north of the marble quarries. This is possible, but not demonstrable; nor is it a probable supposition since it ignores the Chiques rock; and we have no place in the Cambrian into which to put the marbles.

Since the death of my lamented friend, the State Geologist of New Jersey, an important report of recent surveys in the white and blue limestone valleys of northern New Jersey, made by Mr. Frank L. Nason, Assistant Geologist, has been published in the N. J. Annual Report for 1890, under the title: "*The post archæan age of the white limestones of Sussex county. N. J.*," in which the reader will find a large array of facts, evidently observed with great care, skilfully correlated, and ably discussed, and the conclusion arrived at that there is no geological time distinction between the white and blue limestones; that they are of the same age, belong to the same formation, and are in fact merely the same beds in different conditions; that they can be traced along their outcrops so as to be observed to change into one another, the white into the blue, and the blue into the white; that the white is merely the blue altered by heat, pressure and chemical alteration and crystallization; that the change is always at the contact of some plutonic rock, and in proportion to the quantity of the disturb-

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between this quarry and the northern edge of the belt [of York county limestone] is generally white and of a more earthy character than the average York limestone. The pebbles were of course fragments of an older limestone than that which enclosed them." See also his report C, Chapter XII, p. 305; and his analyses of six different limestones, on p. 307.

ing agent; and that all the steps of the change of the blue into white are easily observable.

The distinctive features are: (1) that the White is crystalline and sparry, a true marble; the Blue, granular, a true limestone; (2) that the White contains an abundance of graphite (plumbago) crystals; the Blue, little or no graphite; (3) the White has no fossils; the Blue has fossils.

But on the other hand: (1) The White is not always highly crystalline and sparry; nor is the Blue everywhere non-crystalline and blue. (2) The Blue sometimes carries graphite and fossils as well. (3) The White marbles graduate into a fine-grained clouded blue marble (like the door-step marbles once so commonly used in Philadelphia); while the Blue ranges from an earthy granular to a white or cream colored graphite marble. (4) The White, slightly-changed limestone holds flinty nodules nearly or quite changed to crystalline quartz; but the Blue limestone also has characteristically large flint nodules, which often, although not at all changed, have scales of graphite enclosed in them. (5) The White beds have boulder-like masses of fine-grained, banded limestone, surrounded by coarsely crystalline marble. (6) The Blue limestones are often crushed into breccia, the fragments being cemented by crystalline limestone, and both the fragments and their cement carry graphite. (7) The quantity of graphite in the White marble beds, in the Blue limestone beds and in fossiliferous sandstone beds, increases as the distance diminishes from the face of the igneous rocks which have produced these changes. (8) A last fact of the utmost importance; sandstone beds of exactly the same texture and mineral composition underlie both the White marble and the Blue limestone, and are changed into quartzite beds, holding graphite, when in contact with the igneous rocks. These sandstones are sometimes conglomerates, holding large, irregularly shaped, rounded pebbles of quartz. When changed the sandstone shows crystals of fresh looking feldspar (orthoclase?) and white mica scales, and is then hard to distinguish from the neighboring igneous granite. Hematite and limonite de-

XXXXVI

No. 11 Limestone in the Chester County Valley.

C. 4. 171.

Pictorial section along the left bank of the Schuylkill above Conshohocken. (From H. D. Rogers.

Valley limestone with vertical dip and cleavage, Conshohocken

Valley limestone without cleavage South of Norristown.

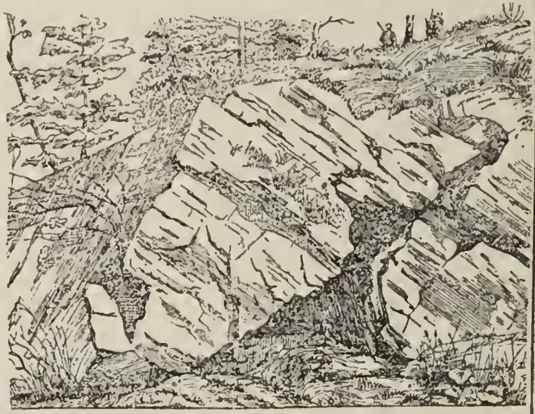


Fig. 21. Section from Diamond rock to Paoli, southeast.

C4 433

Fig. 22. Section north of Coatesville, looking northeast.

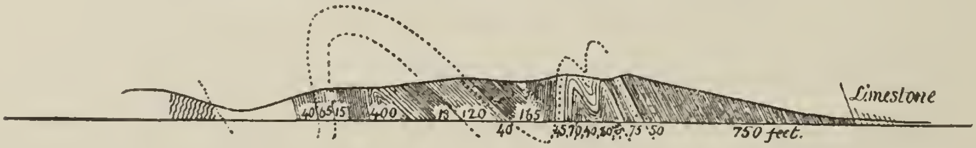
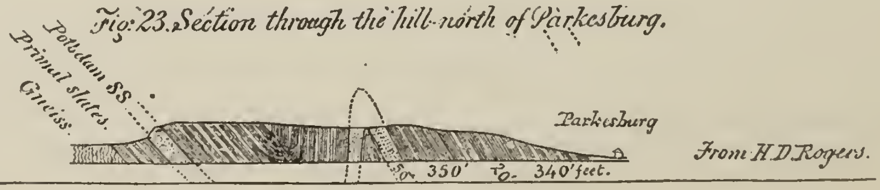


Fig. 23. Section through the hill north of Parkesburg.



J. P. L.

From H. D. Rogers.

posits are associated with both the sandstones and limestones.*

In the Chester county valley we have the same grouping of white marble beds, blue-banded marble beds, blue fossiliferous limestones, sandstones converted into quartzite, graphite crystals and limonite deposits. We have the same limited range, and local distribution of the white marbles. But we have no igneous rocks except the one narrow trap dyke which crosses the Schuylkill at Conshohocken; for the nearest granite is several miles away to the south. But the trap ranges with the marble beds; and these are wholly confined to the vertically upturned south side of the valley. The conversion of blue limestone beds into blue-banded marble and into crystalline marble may have been produced by pressure.

In fact I had pieces of white marble ground thin enough to become transparent, and then under a microscope of high power it was evident that the rock had been crushed to minute fragments and recemented with a deposit of calcite, which gave the white color and sparry appearance; and it could be seen that all the fragments had been thrust more or less round their centers, for they were minutely banded, or crossed by fine lines, which obeyed no common direction across the field of vision. I consider this a physical demonstration that the white marble was originally a common limestone, and that its formation as marble had nothing to do with either the presence or absence of any trap or granite or other heat agency, but was effected by a crushing pressure which permitted the complete infiltration of lime water, and the recementation of its fragments with precipitated calcite.

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* Report of 1890, pp. 36, 37. Prof. Dana's objections to Mr. Nason's views may be found in a notice of the N. J. report published in the July No. of the Amer. Jour. Sci., 1891. To these objections Mr. Nason replies in the September No. of the American Geologist, 1891, pages 166 to 171, by a clear and succinct restatement of his field observations, laying special stress on the fact that the change of blue limestone beds into white marble beds may be seen between two points only 50′ apart. "The graphite exists in every stage from the bright crystalline stage to cloud aggregations of carbonaceous matter which give the blue color to the blue limestone."

As for graphite, its occurrence is too general in different kinds of rocks to base a very valid argument upon its presence in any one kind of rock. It is widely disseminated in slate rocks; and the dark grey color of the Peach Bottom roofing slates is produced by so small a quantity as only 0.5 per cent. The dark limestone beds of the Lehigh valley are colored by impalpably fine graphite. At Pughtown in Chester county, beds charged with graphite have been ground to make paint. Sometimes its molecules are aggregated to form small scattered crystals or scales; as in crystalline limestone on Monocacy creek 4 m. N. of Bethlehem; in the magnetic iron ore at Siessholtzville, Lehigh county; in the limonite ore at Yellow Springs, Chester county; in bluish and other quartz in various parts of Chester county. Granular and foliated masses of it are embedded in the talc and tremolite beds of Chestnut Hill, N. of Easton. It occurs massive at Robinson's Hill, 5 m. N. of Philadelphia; and at Van Arsdal's quarry near Feisterville, Bucks county. A mine of very pure plumbago was worked a century ago near Bustleton, Bucks county.*

The disseminated microscopic graphite in slate rocks may be ascribed to an original charge of organic matter (animal or vegetable, or both) in the oceanic mud. The same origin may be suggested for disseminated microscopic graphite in the limestone formations. But when it comes to explaining disseminate crystal plates of graphite in limestone changed into marble, it would seem to be necessary not merely to call in the aid of destructive chemistry to set free the pure carbon from the organic hydrocarbons, by driving off the hydrogen to other alliances, but furthermore to call in the aid of those forces of crystallization which have operated in and upon all the most ancient and so called azoic formations, in fact upon all disturbed, complicated and crushed formations, chiefly through the medium of universally and perpetually permeating mineral waters.†

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* Vanuxem's analysis gave: Carbon, 94.4; silica, 2.6; ox. iron and mang., 1.4; water, 0.6; loss, 1.0. On the other hand, samples from S. Coventry and from Berks county gave to Genth: Carbon, only 7.20 and 10.85. (Report B, 1875, p. 8, for all the details in the text above, and in this foot note.)

† The geological reader of these remarks may be reminded of the flakes of

The white magnesian limestone of New Jersey seems to have been the only one quarried for lime burning before 1864.* One analysis gave it as much as 42.26 carb. magnesia, only 1.40 alumina and oxide of iron and 2.90 of silica and insoluble matter; while a fossiliferous limestone had only 1.98 carb. mag., 4.70 alum., etc., and 5.80 sil., etc. Yet it is well known that *pure limestone* makes a white and stronger lime, swells more in slacking, and is a better flux.

The white crystalline limestones *in the gneiss* of the N. J. highlands, along their whole northwest border, are very like the sedimentary limestones of No. II. One analysis gave 96.50 : 1.13 : 1.30 : 0.30; another, 53.00 : 42.26 : 3.50 : 0.50. Consequently one was a pure marble, the other a dolomite.†

White marble in Centre Co.

It is certainly a surprising fact that white crystalline limestone, or white marble, should have been quarried on Jac. Bahrrer's farm near Buffalo run in Patton township, Centre county, and the slabs sold in Hollidaysburg in Blair county for gravestones; the strata being at about the middle horizon of the great formation No. II.‡ There seems to be but one way to account for it, viz: by the infiltration of limewater to such an extent as to completely charge the rock with crystals of calcite.§ But such infiltration presupposes a complete crushing up of the rock, as in the case of the Chester Valley marbles, which we find in all stages of change from pure white to blue and white ribbon marble. But the Chester Valley marble strata have been pressed into a perfectly vertical attitude between a vertical slate formation 1000 feet thick, backed by gneiss and granite on

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asphalt, or anthracite, in the quartz crystals of the Mohawk valley, and other places. They seem to have been deposited in internal rifts in the crystal; but they are completely enclosed in the body of the silica, and perhaps floated in it when it was in its gelatinous condition, the crystallization going on around them.

* Cook, An. Rt. 1864, p. 8.

† Cook, An. Rt. 1864, p. 15.

‡ Prof. Ewing's special report in Report T4, page 417.

§ The dark blue Trenton limestone beds are in many places full of cracks filled with a cement of white calcite; and scattered crystals of pure or nearly pure calcite are quite common all along the outcrops. (T4, 417.)

XXXXVII

No. 11 Limestone in Montgomery and Chester Cos.

To illustrate Ch. XXXIX.

Fig. 19.

Section from Willow Grove to Paul's Brook, Moreland & Abington Townships.

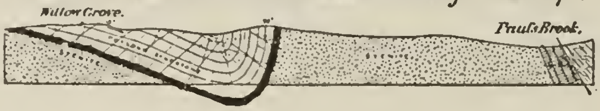

Fig. 20.

Section across the east end of the limestone valley, Abington Township.

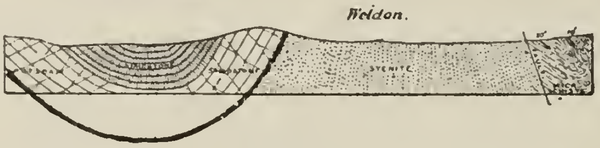

Fig. 21.

Section from Fitzwatertown to Waverly Heights through Upper Dublin, Abington & Cheltenham Townships.

Fig. 22.

Section from Fort Washington to the vicinity of Chestnut Hill.

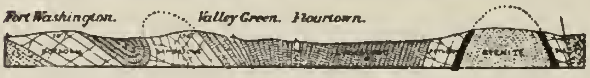

Fig. 18.

Section from Lancasterville to Chestnut Hill, through Whitemarsh and Springfield Townships to Philadelphia.

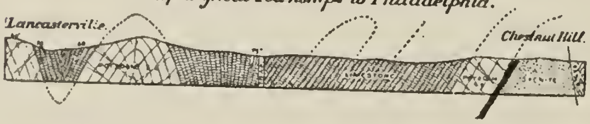

Fig. 24.

Section through Cold Point & Marble Hall, Plymouth & Whitemarsh Townships

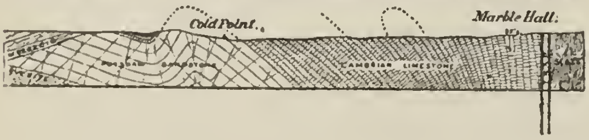

Fig. 12.

Section through Conshohocken & Spring Mill along Schuylkill River, White Marsh Township.

Fig. 11.

Section along the Schuylkill River through W. Conshohocken, Upper Lower Merion Townships.

Fig. 10.

Section from Henderson Station through Gulf Mills, Upper and Lower Merion Townships.

one side and a badly crumpled limestone formation perhaps 3000 feet thick, on the other; with every kind of evidence of oblique strains just suited to the disintegration of the mass, exposing it to easy and continuous infiltration.

In the Nittany valley the great anticlinal is indeed in places overthrown, and therefore the slip and slide movement must have been great; but the wave form is normally regular, and oblique crushing not a necessary consequence. Yet it may have occurred at particular points, perhaps many such; and must have occurred at Bahrrer's quarry. It is, however, astonishing that the infinitely varied and minute complication, distortion and warping of the limestone strata of the Great Valley should not have produced the same effect upon them as in the Chester Valley; should not have created white marble quarry-ground at least equal to that of New Jersey or Vermont.

Near Ephrata, in northern Lancaster county, a quarry was opened many years ago from which were obtained some good pieces of *marble of a very light blue tint* and some of it decidedly shaded. Geol. Pa. 1858, Vol. 1, p. 222.

CHAPTER XL.

Black marble in No. IIc.

The "black marble" of the Musquito or Oval valley in Lycoming county, Armstrong township,* is a unique rock in Pennsylvania, and very interesting because (1) it exactly resembles a Belgian black marble (with a brownish reflexion) used for the body of French mantel clock cases,† (2) it marks the depth to which this oval hole in the Bald Eagle mountain has been excavated; for the black beds are undoubtedly high in the Trenton limestone, the upper division of formation II.‡

These beds are crowded with brachiopod shells, and contain many specimens of *Calymene senaria*, Conrad, one of the most characteristic and widely distributed trilobites of of Trenton age.§

A similar *black marble* is quarried at Glen's Falls in

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* Four miles southwest of Williamsport. The quarry is owned by the Penna. Marble Co. (Col. Potts and Mr. A. D. Hepburn). The valley is 5 miles long, and its floor about 500′ above the river at Williamsport (or, about 1000′ A. T.). Quarry abandoned about 1875, because no blocks thicker than 10″ or 12″ could be got out from the 36′ of face exposed. Layers dipping only 4° N. E. representing a fall of the crest of the anticlinal arch in that direction (See Report G2, 76, 78). Curiously enough the rock has not been found in Nippenose valley.

† Much of the rock is splintery. Soft rotten layers separate hard firm layers. It burns to a fine *white* lime. It will not polish well by ordinary processes, but can be polished highly by extra care. It breaks up when exposed to the weather, but is useful for indoor furniture (Letter of J. G. Hammer, March, 1886).

‡ See however the so called black marble of Hitner's quarry in Montgomery county mentioned in foot note to p. 471 above, last paragraph.

§ Vanuxem's *Senior calymene* (N. Y. Rt. 1842, p. 56), a name which has no reference to the 6 tubercles on the buckler (Miller's Am. Pal. Foss., p. 213). Conrad named it in 1841. Green in 1832 gave figures of three casts which he called *C. blumenbachii*, *C. callicephala*, *C. selenecephala*, which J. Hall considered synonyms of *C. senaria* (Pal. N. Y., Vol. I, p. 238, Plate 64, fig. 3 *a–n*).

northern New York.* Dr. Emmons describes it as there exposed in a river cliff 65′ high, the upper rocks being *Trenton* limestone, the lower calciferous (Chazy) limestone. Between them lies the black marble formation 10′ thick.† So, at Isle La Motte the black marble (solid 12′ thick) lies under Trenton limestone. Where it occurs at Watertown on the Black river in Jefferson county it is lumpy, and lies between the Trenton and Birdseye. It is nowhere seen in the Mohawk valley, where the Trenton reposes directly on the Birdseye limestone ; and this makes the fact of its appearance in the Oval valley in Pennsylvania, and nowhere else in the state, as yet noticed, so remarkable and interesting. It makes it doubtful also whether our black marble is really the same deposit *under* the Trenton, instead of being *over* it. In fact it seems almost impossible to believe it the same ; for the Trenton is nearly 1000′ thick on the Bald Eagle anticlinal ; and the Oval valley should be much larger if eroded to the *bottom* of the Trenton.‡

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*The black marble at Glen's Falls is so checked, cracked and seamed with flints and calc spar fossils, that very few beds can be worked with profit. Its color is jet black, its grain close and fine and slightly crystalline. Being rather brittle in one direction it requires careful handling for thin tables. The natural division planes between two beds often are studded with projections like those of fibrous sulphate of strontian, fitting into each other, and sometimes kept apart by a thin film of slate, showing minute fucoidal markings, and now and then a small encrinite.

† Nat. Hist. N. Y. 1842, pp. 110 and 180. He says that the Trenton beds here are 60 or 70 in number varying in thickness from an inch to several feet, full of Trenton fossils. The bottom layers are gray and lying on the black marble are quarried with it.

‡ Emmons says that the black marble fossils are not exactly those of the Trenton. They are not very numerous in the New York quarry rock. *Columnia sulcata* is quite abundant, sometimes in masses of half a bushel. Large *Orthocerata* are common, some of them *ten feet long and a foot in diameter* (as in Birdseye).—He describes *cone-in-cone* as a fossil (p. 111).—The strontian-like crystals are half to one inch long. In the later Niagara limestone the mineral itself has been preserved ; in this black marble only its form (p. 111). Both these projections and the cone-in-cone show that the black mud remained homogeneous and quiet for a long time ; no doubt as a local marsh, but either subsequently covered with deep water ; or along an extensive shore to which storms might drive the gigantic cephalopod shells and masses of coral to be embedded in the black mud when dead, although they could not have existed even in its vicinity while alive.

Vanuxem in his Report (N. H. N. Y. Third Dist. 1842, p. 43-45) described some light grey or dark grey limestone beds, on the Birdseye and under the

Black marble in No. VI.

There is a so-called *black marble* in New York in Formation No. VI. It is the lowest, or *Tentaculite limestone* subdivision of the Lower Helderberg group, the layers of which are massive and dark colored.[*]

Trenton, at the Mohawk valley quarries (in three layers 2′, 4′ and 7′ thick, at Stanton's quarry), holding accretions, or knobs, and (at Putnam's quarry), the lower layer what seem to be 4′ *pebbles* of yellowish calciferous sandrock. The beds are as good limestone as the Birdseye beds under them but otherwise resemble the Trenton beds over them. They hold a shell (*Strophomena*), a polyp, a coral (*Cyathophyllum*), etc. Vanuxem adds, that these bottom beds of the Trenton form the surface of Nippenose (Musquito) valley in Penna.; the 30′ "marble" cliff at Frankford, Ky. (with *F. demissus* specks); and the Nashville bluff in Tennessee, where the layers are brown and thin.

Mather in his report of the First Geological district of N. Y. (1843, pp. 399 and plate 24) describes the *black marble* of Glen's Falls near Saratoga more in detail. The Hudson cuts through 70′ of beds: Utica black slate at the top, on Trenton limestone, sawed for fire places; fifty layers of very fossiliferous limestone; 2½′ grey limestone taking a fine polish; 6″ darker limestone used for door steps; 10½′ *black marble polishing brilliantly, with layers of fossils at irregular intervals, 2″ or 3″ thick, and extending 10′ or 20′ and abruptly stopping* (*i. e. shell banks*). Mather (p. 403) places the Isle la Motte black marble of Emmons in the *Black River Limestone group*, with the *Birdseye* and *Chazy*.

[*] Mather alludes to it in his Report of 1843, p. 327, where he says that most of the Helderberg rocks south of the Catskill mountain are black, dark grey, and veined with white, but massive, and susceptible of a polish. Vanuxem in his Report of 1842, p. 118, calls the Pentamerus beds mottled brown and blackish limestone full of *columnariæ*.

CHAPTER XLI.

Thickness of No. II in Lancaster county and elsewhere.

The city of Lancaster is built over the center of a great limestone plain of inexhaustible fertility, the garden of the State. It reminds the traveler of Paris seated in the center of the fertile and populous plain of Northern France, through which meanders the river Seine, as the Conestoga meanders through Lancaster county from northeast to southwest to join the Susquehanna at Safe Harbor. But here the likeness ends; for the Cretaceous strata of the Paris basin lie almost perfectly horizontal and are charged with the rainfall which has collected in them from a circle of many leagues, and which is easily brought to the surface by artesian wells.

The Lower Silurian limestone strata of Lancaster county, on the contrary, descend steeply to the bottom of a synclinal trough at least a half mile beneath the present surface, the center line of which runs east and west, crossing the Conestoga about a mile below the city's southern limit; almost all the observed dips at the surface south of this line being N. dips; and almost all of those north of the line being S. dips; the exceptions in both cases must be ascribed to local crumpling.*

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* Frazer's Report C3, 1880, page 58, 59. This description in the text does not exactly consist with the hypothetical curves of the N. and S. long section from Neffsville through Lancaster to Martinville published in Atlas to C3. The section was drawn subsequently after a careful discussion of the surface dips, and shows *two* deep basins, instead of one; the northern basin being under the city and of great depth; the southern basin being south of the city, not so deep, and with a broad rolling bed line. But geologists who had dealt much with a folded country will appreciate the difficulties in the way of an even approximately correct underground construction of curves based on surface dips most of which have angles between 60° and 90° and many of them probably overturned. The section has the merit of corresponding to the two synclinal limestone belts which cross the Susquehanna, one at Columbia, the other some miles lower down. See the colored geological map of Lancaster county in Atlas to C3.

The Lancaster section is described by Dr. Frazer in a most interesting manner in detail on pp. 145 to 158 of Report C3. The object of the section was to obtain the thickness of the formation and its depth beneath the city of Lancaster.*

Dr. Frazer remarks that the dips seem to require one complete synclinal and one and a half anticlinals, between the northern Lancaster township line and the Conestoga where the section line crosses it. Two points in the city are indicated where the limestone bottom is nearest the present surface, one just south of the north city line, the other between Conestoga and Hazel streets ; but the depth cannot be measured on account of the high loops which the strata make, and the slip of bed on bed. He then uses an ingenious mathematical (geometrical) rule discussion (p. 150) and concludes that it is only safe to say that the *total thickness of the limestone measures* before erosion in the vicinity of the P. RR. station was *not less than 2700 feet.*†

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* The section was started as far north as Neffsville because the lowe slates there come to the surface (with fragments of Chikis quartzite) and continue at the surface for 1000′. A limestone quarry is crossed 250′ further south. At 1600′ a L. crop dips about E. showing how crumpled the country must be. At 1¼ m. pale limestone dips only 6°, S. 20° E. Close by, a quarry reads 20° S. Then one reads 20° N. Then 500′ further 60° N. W. Another 24°, N. 20° W. At Myers' quarry a quartz seam 18° N. All this indicating the N. side of a gently sloping anticlinal ; the same is *indicated* for 3500′ further. At Dillersville a RR. dip reads 38°, S. 15° E. which seems to begin the descent of the beds on the S. slope of the anticlinal ; soon, 50°.; 35°, S. 25° E. Then a synclinal ; for, at the divergence of the P. RR. and R. RR. is seen an (overturned) dip of 80°, S. 15° E. (Another before crossing the township line, 75°, S. 15° E.) Then in Lancaster township 80°, S. 15° E. Then the south side of the anticlinal, 500′ from last, 30° S. Where the two RRs. cross, 70°, S. 15° E. In the cut just E. of Lancaster station, 67°, S. 15° E. No exposures for 500′. Where Vine street crosses the Quarryville RR., 70°, S. 5° W., continued for 165′ to the Soap Factory ; the rocks turning gradually into a curly hydromica schist, showing that the bottom beds of the formation here rise again to the surface. And so the record of the section runs on southward.

† From the Conestoga south to Mill creek the details of the section are narrated and the conclusion reached that the whole series of minor anticlinal and synclinal rolls are crossed.—Between Mill creek and D. Harnish's house, 5 minor anticlinals, the whole body of measures rising southward.—Then a gap in the record of 4400′ near the middle of Pequea township.—The southern portion of the section is extraordinarily difficult of construction, as both mica slate and gneiss exposures occur in it. See *C3*, pp. 156 *et seq.*

This deep basin extends from the Salisbury cove in the mountain land of Chester county westward across Lancaster county; and beyond the river is continued as the York county limestone valley to Adams county.

Another equally deep basin runs—the Conestoga valley—north of it, parallel with it, from the Berks county corner, westward, to the Susquehanna above Marietta, and so into York county.

Many other smaller basins cross Lancaster county, obscurely, in a parallel series, the exact shapes of which cannot possibly be made out from surface dips, because there are no well defined characteristic marks to distinguish the limestone beds from one another; and all the basins are so connected sideways with each other that the strata pass over the upfolds from one basin to the next; the whole being eroded to a general plane surface.*

The most southern basin which has preserved its limestone rocks is that of the Chester county valley; and this deepens eastward, and then shallows to its end in Montgomery county. The widest and probably, therefore, deepest part of this Chester county valley is between Downingtown and the Schuylkill; but the beds are so complicated by longitudinal anticlinal and synclinal waves, as shown in the sections on plates 45, 46, 47, that it is impossible to calculate with any approach to accuracy the thickness of the formation which remains at the present day, to say nothing of its original thickness before the erosion of the contents began to remove from over it the slate formation of No. III. At least 2000′ and perhaps 3000′ of it still remain. It may have been as thick as it is in Centre county;

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* There can be no reasonable doubt that the Azoic country of southern Lancaster, southern Chester and Delaware, on the one hand, and southern York and eastern Maryland on the other hand, were each and all once covered with the Lancaster limestone formation II. Nor can any reason be assigned why the formation as a whole should not have been formerly as many thousand feet thick in its extension to the Atlantic, as it is now seen to be at Lancaster and Harrisburg. Its great thickness at York, at Lancaster and at Downingtown is an absolutely satisfactory guarantee of its ancient unbroken extension southeastward over the present Atlantic coast region.

but that is not probable; for there is no part of the Great Valley in which such a thickness can be proven.

In the Great Valley we have also everywhere an excessive complication of the limestone strata of No. II. There is no section from the Delaware at Easton to the Potomac in Maryland where a fair and unimpeachable measurement of the formation can be made; and the faulting along the southern edge of the Great Valley prevents us from even estimating the amount which has been removed by erosion. Two or three thousand feet of limestone strata are evidently present at the surface; how much more we cannot tell.

In the coves and valleys of middle Pennsylvania most of the formation is concealed underground. In Nittany valley alone, along the Little Juniata river has a good opportunity been granted to measure the formation, and even here not quite to its base at Birmingham. But the locality is most favorable to the inquiry. From the Canoe mountain synclinal to the Nittany anticlinal the dips are all one way and the sequence apparently unbroken. This noble section has been repeatedly criticized and measured with the greatest care; first by Mr. Rogers in the First Survey, and lastly by Mr. Platt and Mr. Sanders in the topographical survey of the Blair county region, published (text and sheet map) in Report T, and Atlas. On the basis of this survey, which took account of all the dips of all the exposed rocks along the river on both sides of the Canoe mountain synclinal, there were counted up 6600′; subdivided thus: *Upper limestone series*, 5400′; *Middle white sandstone beds*, 40′; *Lower limestone series*, including some sandy or sandstone layers at bottom which may belong to the Chiques (Cambrian) quartzite system, 1160′=6600′.*

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* T, p. 52. Mr. Sanders has measured 3000′ of consecutive layers at Harrisburg. Mr. Prime measured only 2000′ at Allentown. In Report O, Vol. I, of the catalogue of the Geol. Museum, 1878, p. 113, is given a list of 240 specimens collected from the outcrops of II along the Little Juniata from Tyrone Gap down to Spruce Creek. These are summarized in T, page 58. These collections by Mr. C. E. Hall show an extraordinary dearth of fossils in the formation; but Trenton and Calciferous New York forms were certainly identified. Mr. Hall remarks on the special steepness of the dips, and on the fact that the dips do not correspond well on the two sides of the river (T, p. 59).

When the limestone formation No. II sinks at the foot of Bald Eagle mountain it does not rise again to the surface for 100 miles, to the Mohawk valley, in New York. The depth to which its uppermost division, the Trenton, II*c*, sinks beneath the highlands of Lycoming county is 15,000 feet.*

After the developments of gas and oil in the Trenton limestone in western Ohio and in Indiana a large number of wells were bored in northern Ohio, in Upper Canada and in western, middle and eastern New York to test the oil and gas value of the formation along the belt of country where it was known to lie undisturbed and not too deeply covered to be reached at reasonable rates of expense, say 3000′ or 4000′ feet beneath the surface.†

At Ithaca, N. Y., a test well (in the valley) said to be 3185′ deep, stopped in the middle of formation No. V, and should have gone down to 4755′ to reach the top of the Trenton.‡

From Ithaca northward the rise is very gradual to the outcrop of the top of the formation at Trenton Falls where the upper division of No. II got the name in 1835 which it has retained to the present day. It is quarried along the banks of the Mohawk, south of which it is covered by the

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*As measured by Dr. Chance, in Clinton county, Lock Haven long section, Report G4, p. 124. Its depth beneath Cresson, or Ebensburg, in Cambria county, according to the section by Platt and Sanders (Appendix A to Report F, p. 262) is about 17,000′. Its depth beneath the Mountain House on Broad Top in Huntingdon county is nearly 18,000′ (see F, p. 184). Between the last two mentioned depths it rose into the air over Birmingham 6000′. The Nittany valley anticlinal was, therefore, a rock wave 25,000′ or 26,000′, *i. e.* 5 miles, high.

† These borings have greatly enlarged and improved our knowledge of the Palæozoic formations, especially as to their varying thicknesses, and as to their condition and quality beneath different sections of country. The bore-hole records have been discussed very skilfully by the late C. A. Ashburner, and by Prof. Prosser, of Ithaca, N. Y., now of the U. S. Geol. Survey at Washington. The facts thus obtained will be frequently used in subsequent chapters of this report.

‡ C. S. Prosser, "The thickness of the Devonian and Silurian rock of western central New York," in the Amer. Geologist, Oct., 1890, p. 202, 211. The estimates from data furnished by the Syracuse well would make the depth 5172′; the estimate from maximum thicknesses in general section would make it 5708′.

Hudson river and Utica slates of III, 3500′ thick, through part of which the Knowersville gas test well, 3000′ deep, went down and penetrated the upper 120′ of the Trenton, to which Ashburner's Catskill section assigns a total of 500.′*

The Wolcott well, in Wayne county, N. Y., on the south border of Lake Ontario struck the top of the Trenton at a depth of 1950′, and stopped, still in Trenton limestone, at 2700′. When it is remembered that the greatest depth of the lake near its southern shore is about 700′, we can understand the true formation of the great valley of erosion in which its waters are held—a valley excavated in very ancient times by the chemical solution of the great limestone formation No. II, and the mechanical removal of the overlying slates of III and sandstone of IV (Oneida and Medina) the outcrop of which makes its steep, half submerged southern shore.†

Our better knowledge of a greater thickness of II and III in the Mohawk country than has hitherto been allowed them is very satisfactory on the score of bringing their distinct areas into closer harmony with their great exhibi-

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* Petroleum and Natural Gas in New York state. C. A. Ashburner, Trans. Amer. Int. Min. Eng. Duluth meeting, July, 1887, foot-note to page 49 of paper. For geologists the record of this well is uncommonly valuable, greatly increasing the traditional thickness of III, to which in W. New York only 800′ to 1000′, and on Georgian bay in Canada only 770′, was assigned. The Utica in Montgomery county, N. Y. west of Albany, has been called 250′; but the Campbell well west of Utica went through 710′ of it, Walcott calls its outcrops on the Mohawk 600′. As to the Trenton, Vanuxem only gave it 300′ in Lewis county. Emmons made it 400′. In Canada Logan measured 679′ and 750′. Walcott makes it in the Campbell well near Utica 430′ and the surface outcrops 290′ (Proc. A. A. A. S. Vol. 36, p. 212). Prosser gives a general thickness of 820′ to III, and 992′ to II (Trenton 842′· Calc., 150′).

† Lake Ontario, if drained of its water, would be a repetition of our Great Valley, with the difference that the two formations II and III lie almost flat and undisturbed instead of being crumpled and crushed; the limestone (II) rising northward out of the water, and constituting the great plain of the St. Lawrence. It must be understood that Ontario has been considerably refilled by glacial deposits, etc., since its submergence. Its old bed is far deeper than its present bed, probably 2000′, and was originally deeper towards the northern shore than towards the southern. This also irrespective of the tilt which it has suffered in recent times.

tions in Middle Pennsylvania ; and also in another respect, namely, by adding one more line of evidence for their identity with the so-called Taconic limestones and slates of the western border land of New England. For it is incredible that 4500′ of II and III should exist 15 miles west of Albany, and not be well represented in the Taconic region east of Albany.

Chapter XLII.

Oil and Gas in No. II.

Dr. Orton says that the Trenton limestone when followed northward both in Ohio and Indiana suffers a transformation through a small thickness of its upper beds, by these upper beds losing their pure limestone character and becoming dolomitic or magnesian; and that this change affects from 10′ to 50′ of strata at the top of the formation; perhaps in rare instances 100 feet. Generally the wells passed through magnesian limestone from the very top of the formation downward; but in some cases pure limestone is found at the top of the formation over the magnesian strata; and in every such instance the magnesian lying directly upon the pure limestone.*

The line along which the change from limestone to dolomite occurs, passes through Hancock, Allen and Mercer counties southwesterly into Indiana, and so onward through Jay, Randolph and Henry into Indiana; and this is the

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* Dr. Orton's language implies a theory that the formation was originally pure limestone, and has been partially changed to dolomitic limestone by the introduction of magnesia; for he adds, "In other words the change is comparatively superficial," and he speaks of "normal or unaltered limestone." This theory is much in vogue among European geologists, although it is also strongly opposed. In Pennsylvania the theory has been completely broken down by the statement of facts narrated in Chapter XXVIII, p. 327 above.

In Pennsylvania the *Trenton limestone* as a formation and judging from a very insufficient series of analyses of specimens collected at hazard in different parts of the State, has been called a pure or non-magnesian limestone; but our knowledge of its chemical composition is still extremely limited, and the only safe assertion which can be made respecting it is, that as a formation hundreds of feet thick it contrasts in a general way with the great limestone formations under it (Calciferous) in being less magnesian. I have no doubt, however, that if many thousands of analyses of Trenton specimens from the extensive outcrops in Pennsylvania were made and compared it would be discovered that the formation contained locally magnesian beds, in other words, that the same phenomenon described by Dr. Orton in the gas fields of Ohio and Indiana would recur in various places in Pennsylvania.

boundary of the new gas and oil fields. But in Ohio it extends from the present gas and oil fields northward and westward; and patches are sometimes found to the northeastward. In Indiana it appears to extend to the northern and northwestern boundaries of the State; and is presumed to underlie the entire peninsula of Michigan, on the strength of a few analyses from borings in that State.

The porosity of the rock is supposed to be connected in some way with its charge of magnesia.*

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*Dr. Orton says, "To be a reservoir of oil or gas the upper surface of the Trenton limestone must have suffered the dolomite replacement, whereby due porosity has been conferred upon it, and it must also have received in the accidents of its history the due relief by which its varied contents have been separated and accumulated," but if the magnesian limestone was not introduced afterwards but was a part of the original deposit, the porosity of the rock must be explained by the superior solubility of the magnesian carbonate above the lime carbonate. It is strange that in the abundant literature on this subject so little notice is taken of the presence of salt water in the porous rock at the lower limit of the oil and gas belt; at what is called the dead-line in the Findley field. This dead-line in the Findley field follows the hypsometric line of 500′ below sea level; every well which strikes the Trenton limestone at this level or at lower levels has found the rock charged mainly with salt water. In the Lima field a similar dead-line 400′ or more below sea level has salt water on the southwest of it, and oil and gas on the northeast of it; the productive wells striking the limestone at from 390′ to 350′ below sea level. In Indiana the dead or salt water line surrounds the productive territory on the north and west at only 100′ below sea level. The limestone gradually rising southward without any anticlinal or terrace structure, the gas production ceases abruptly and without any apparent reason. Dr. Orton proposes as a probable explanation for this fact the change of the formation from dolomitic porous limestone to pure tight limestone; but in doing this he virtually discards the reason given for the upper limit of gas production in the Findlay and Lima regions, namely, an anticlinal or rather a terrace structure.

I have just said that it is strange to notice in the literature of the subject a prevailing indifference to the value of the fact of the universal presence of salt water below the dead line. Surely some explanation of the existence of that salt water must be taken into the theory. First, a question arises respecting the age of that salt water. Is it the original sea water in which the Trenton limestone was deposited? if not, is it salt water which has penetrated from any ocean past or present? if not, is it analogous to the salt water of closed basins, seas or lakes which have no outlet? in other words, has the rain water obtained salt from salt-bearing formations and collected as salt water in this Trenton reservoir? if not, does the salt in this salt water represent an original element of the formation itself, namely, a certain charge of chloride of sodium deposited originally with the carbonate of lime and carbonate of magnesia; and subsequently through the ages dissolved out by the percolating rain water, which has ever since held it in solution?

Why no Trenton oil or gas in Pennsylvania.

To the people of Pennsylvania the practical question is simply this: Does the Trenton limestone formation in Pennsylvania hold, and will it, if bored down to, furnish a future supply of oil or gas, or both, to supplement the rapidly exhausting oil and gas pools in the Devonian oil sands of the western counties? The answer is:

Certainly not in southeastern Pennsylvania.

Certainly not in middle Pennsylvania.

Probably not in the rest of the State.

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if so, such dissolving out of original crystals of salt has of itself played a certain part in the production of the porosity of the rock. The above are important questions which, so far as I know, have never been properly presented, much less answered. And their range of application in geology far exceeds the limits of oil and gas regions; in fact, take in all brine regions.

We know little enough of the methods of nature in past time as to the deposit of sandstone strata; but we know far less respecting the mode of ancient limestone deposits, under conditions of topography and climate so different from anything we now see that arguing from the present to the past is almost impossible. The present river drainage of the world carries chiefly clastic detritus: that is, most of the land being destroyed by rain-water and transferred to sea bottom has already undergone that process once or many times. But in the Lower Silurian Age it is reasonable to believe that the larger part of the land consisted of crystalline rock and furnished by its own river drainage a very different kind of material to a sea much warmer, perhaps hot, in which chemical re-actions took place on the grandest scale. Dr. T. S. Hunt has endeavored, and with much success, in suggesting a picture of the operations of that ancient time; or rather of a time far more ancient when chemical precipitation was probably almost the only form of ocean deposit. The Lower Silurian Age indeed stands midway between the first age of nearly pure chemical precipitation and a percentage of almost pure mechanical deposit; and it therefore ought to represent by the nature of its rocks both kinds of operation, intermingled indeed in a manner to confuse very completely geological judgment.

Dr. Hunt's *crenitic hypothesis* (créné, a fountain) is an admirable attempt to solve the first great difficulty in geology, namely, the source of those elements, alumina, lime, magnesia, soda, potassa and iron, which make up almost the whole crust of the earth. Oxygen and chlorine holding these elements in solution were of course in ancient times part of the earth's atmosphere. The basis must have resided in the globe either pure or alloyed in mutual combination, but certainly not except under the condition of very high heat. The union of the gases with them must have marked the gradual cooling of the globe. But the first rivers must have been not only hot water, but mineral water; and the first deposits must have been chemical precipitates. To state the case transcendentally, we may imagine (what of course never happened in exactly that way) three rivers pouring three kinds of mineral water into a closed basin resulting in a sea; one discharging a solution of lime chloride; a second, a solution of soda carbonate; the third, a solution of magnesia sulphate. The common tank would become filled

And for the following reasons: (1) An oil rock must be porous, but not broken up; (2) it must lie flat, and have a good covering; (3) it must not be too deep beneath the sur-

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with these three solutions interfused; not homogeneously throughout the tank, but with every variety of interfusion in different parts of it according to the respective sizes of the rivers and the sea currents which brought their infusions together; so that an infinite variability of chemical precipitation would result in all parts of the sea bottom. Laboratory experiments will certainly not teach the whole story, but will indicate certain main facts, the first one being that a reaction would take place between the river of lime chloride and the river of soda carbonate; the chloride leaving the lime and uniting with the soda to make salt; the carbonate leaving the soda to unite with the lime, making limestone; and the magnesia also becoming a carbonate with different solûbility, but precipitated in like manner.

Of course such a case as this is purely hypothetical and certainly could not have occurred in Lower Silurian times, because life had already long existed; vast amounts of carbonic acid and oxygen had already been abstracted from the atmosphere; the waters were cool enough to permit molluscan and articulate life, as well as vegetation; and the rivers had long been pouring clastic material, gravel sand and mud into the sea. Nevertheless, even at that late day, compared with the still more ancient times, the rivers must have been to a considerable extent of the nature of mineral water; and therefore necessarily the sea was continuing, although in a very moderate degree, its chemical precipitations; the lime and magnesia carbonates playing the chief role; but evaporation being still probably intense, the chemical precipitation of sea salt must have played a part in the drama of deposition, and has, in fact, continued to do so through all ages from that to the present time. Hence all geological strata contain an amount of salt; and all atmospheric drainage through geological strata find, dissolve and bring to the surface amounts of this salt. But I have in another place drawn attention to the remarkable fact that soda is almost absent from our limestone strata; a fact which makes it almost necessary to find the region of the salt water in the Trenton formation outside of it, that is, in some of the more decided salt-bearing sandstones.

The facts are thus stated by Dr. T. S. Hunt in his standard work, Mineral Physiology, 1886, page 168. "The recent precipitate produced by a solution of carbonate of soda in chloride of calcium is readily soluble in an excess of the latter salt, or in a solution of sulphate of magnesia. The transparent, almost gelatinous magma which results when solutions of carbonate of soda and chloride of calcium are first mingled, is immediately dissolved by a solution of sulphate of magnesia; and by operating with solutions of known strength (titrated solutions) it is easy to obtain transparent liquids holding in a litre, besides three or four hundredths of hydrated sulphate of magnesia, 0.80 gramme, and even 1.20 grammes of carbonate of lime, together with 1.00 gramme of carbonate of magnesia; the only other substance present in the water being the chloride of sodium equivalent to these carbonates. A solution of chloride of magnesium, holding some chloride of sodium and sulphate of magnesia in like manner dissolved 1.00 gramme of carbonate of lime to the litre. Such solutions have an alkaline reaction." [Quoted from Hunt's Chem. and Geol. Essays, page 223.]

face of the earth; (4) it must either be itself very fossiliferous, or be enclosed between other strata which are so.

All of these conditions are realized in the great Trenton limestone oil and gas districts of Ohio, Indiana and Kentucky; but not in Pennsylvania.

For (1) in the southeast region of our State the Trenton has been broken and crushed and recemented, so as to be nowhere porous enough to hold oil or gas; (2) in the middle region all the formations are upturned and solidified by pressure; (3) in the western and northern regions, the Trenton lies buried 10,000 to 20,000 feet beneath the present surface, and at temperatures between 200° and 400° Fahrenheit; and (4) where it shows itself at the surface in the middle, southern and eastern counties it is remarkably poor in animal and vegetable remains.

Consequently, all attempts to obtain oil or gas from the Pennsylvania Trenton—and such attempts have been made Chester, in Montgomery, in Berks, in Dauphin, in Huntingdon, in Pike, in Susquehanna and in Erie counties—have failed.

In the deep Erie well the Trenton was reached. In the Canada well on the south shore of Lake Ontario near the Welland canal, the Trenton was pierced. Several wells in New York State penetrated it. In no case has there been a profitable return of either oil or gas. And if this happened under the exceptionally good conditions in central and western New York, where the formation is very fossiliferous, lies nearly flat, and can be easily reached, what chance is there of success for those who bore in the uptilted and dislocated and poorly fossiliferous strata of Pennsylvania? Where the Trenton is brought to the surface it shows plainly that whatever petroleum or rock gas was once distilled from its fossil corals and shells has ages ago escaped from it; as, and for the same reasom that, the gas of the once bituminous coal beds of Schuylkill county has escaped from them, leaving them in the condition of anthracite.

On the other hand, who can hope for a time when oil and gas wells can be sunk to a depth of ten or twenty thousand feet, where the Trenton may possibly retain what oil and gas it has at the boiling point of water or even at 400° F.

CHAPTER XLIII.

Mechanical deposits of No. II.

Ripple marks "on a superb scale" were seen on the surfaces of the limestone beds at the quarry close to Uhlersville, on the Delaware river, in Northampton county, by Prof. Rogers.* If there was no mistake in interpreting the undulations as *ripple marks*, if they were not the effects of subsequent pressure, and if *ripple marks* are to be taken as a sure indication of wave-action in shallow water, then the deep sea chemical theory of the formation of the great limestone must be abandoned. And this particular case is all the more important, as the rocks exposed at Uhlersville do not belong to the top (Trenton) but to the bottom (Calciferous) division of No. II, overlying the Chiques quartzite so full of worm burrows (*Scolithus linearis*) which of course imply a shallow sandy shore. In Vermont, Brainard and Seely report the whole Calciferous formation full of Scolithus, especially some of the fine-grained sandstone layers of the middle division (C) which are "pin-holed with small worm burrows" (*Scolithus minutus*). This division (350′ thick) is made up of alternations of sandstone beds and magnesian limestone beds.†

All this runs in favor of the mechanical as opposed to the chemical deposit of the limestone beds of II, as argued in Chapter 28, p. 334 above, on the Magnesian limestone alternations in the quarries opposite Harrisburg.

A peculiar sandstone.

The peculiarly sandy nature of the lower part of the great limestone formation has already been mentioned. Cases

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*Geol. of Pa., 1858, p. 242.

†Bulletin Geol. Soc. Amer., vol. 1, 1890, page 504; quoted in Report P4, Dict. Foss., Pa., Vol. 3, 1890, p. 945. See also the large worm burrow *Monocraterion lesleyi*, described from Lehigh county by Prof. Prime in Report D2, 1878, p. 79, with figures.

of isolated layers of sandstone are given in preceding chapters. The Barrens of Centre county have been described.

In Sinking Valley, near Birmingham on the Little Juniata, a peculiar ferruginous sandstone containing also traces of *manganese* and *cobalt* occurs in great abundance on the farm of Mr. Galbraith. The rock is a compact, brittle, and exceedingly fine-grained mass, streaked with different shades of light-red and pink and purple, which variations it derives from the different minerals it contains. In almost every hand specimen are numerous larger and smaller cavities, the sides of which are lined with minute quartz crystals. Some portions of the mass are not unlike calamine ; but Mr. McCreath's analysis of a specimen of it shows that there is not even a trace of zinc in its composition. Silica, 94.9 ; ox. iron and alumina, 3.3 ; ox. mang., a trace ; ox. cobalt, 0.17 ; lime, 0.06 ; magnesia, 0.18 ; water, 1. Being near the axis of the great anticlinal the beds must be very low in the series.*

Parkesburg artesian well in II.

At Parkesburg, in the Chester county valley, an artesian well was bored, 522′ deep, through very steep-dipping limestones near the bottom of the series. Not only sandstone layers but *quicksand* layers were passed through, the latter furnishing water (in one case pretty freely), and being probably the disintegrated loose grains of beds of calciferous sandstone which had lost all their soluble lime and magnesia carbonates by long continued percolation.†

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* T, p. 291.—Mr. Platt in his Report on Blair county remarks that the distinct sandstone horizons in No. II, in Nittany valley, make a show in boulders and fragments on the surface of the country out of all proportion to their size as beds in the limestone series. But this is a common geological phenomenon of erosion, well illustrated by the abundance of quartz boulders left lying on the eroded surface of the hydromica belt of York county, and the abundance of titaniferous iron ore fragments left lying on the off dip side of the veins on the demoralized mica gneiss country of Goldsboro' in N. Carolina. As the surface of the soluble formation is lowered by erosion, the insoluble massive layers accumulate on the successive surfaces. (Report T, on Blair Co., p. 60.)

† Soil, 18′; bastard or sandy limestone, 3′; quicksand, 2′; sandy limestone growing denser downwards ; quicksand ; limestone beds increasingly pure downward, and quite destitute of water veins ; fine yellow sandstone layer

To explain the sand deposits in No. II in Pennsylvania we must go to northern New York and to the Western States.

Around the Adirondacks the lowest beds of the *Calciferous sandstone* (II*a*) of Eaton and Vanuxem are a mixture of fine grains of sand in a cement of limestone, with a few fossils converted into chert, 30′; over these, reddish limestone beds with scattered plates of Cystids, 20′; over these, clay beds without fossils, but at the top oolitic, 10′; over these, red limestones, 15′; over these, clay-lime and sand-lime beds, with trilobites, 20′; over these, others with brachiopod shells; over these, red limestone, with Cystids, fine enough to polish, 15′; over these, magnesian hydraulic-lime beds, with few fossils except seaweeds (fucoids) and the upper layers (20 to 30′) blue, cherty, oolitic.

The *Chazy* (II*b*) is so similar to the Calciferous under it, as to make it hard to distinguish them. Emmons calls it 130′ thick at Chazy village. Owen recognized it in the St. Peters sandstone along the banks of the Minnesota river, where it is a remarkably white mass of transparent quartz grains, filling depressions in the upper surface of the Calciferous, which of course, had been out of water and eroded. Some conglomerate beds at the bottom of the Chazy tell the same story. The Chazy water must have been (in Iowa at least) very shallow, for there is plenty of oblique bedding. (In Pennsylvania, where these formations are so vastly thicker no such false or current bedding is reported.) Its fossils have been badly preserved; but there are often plenty of seaweed impressions, worm burrows (Scolithus) and ripple marks; all proofs of shallow or shore water.

In Missouri the sandy character of No. II is illustrated by the breaking up of the *Calciferous* (II*a*) into two magnesian limestone formations separated by a sandstone formation. The Upper Limestone interstrated with shale beds and

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with free flow of water; limestone beds (without water) all of different quality, some quite sandy, some with much mica flakes, some almost pure marble; fissure and water; limestone beds as variable in character as those above, and no sign of essential change, or approach to quartzite at bottom of well. In the samples submitted to the microscope were noticeable quartz crystals, mica flakes, crystals of pyrites, of calcite, and of feldspar.

layers of white chert, with some thin beds of white sandstone, (often lead bearing), is 200′ to 300′ thick. The Middle Sandstone regularly bedded, and ripple marked, with thin chert layers full of fossil shells, showing shallow water, is 150′ thick. The Lower Magnesian limestone, thick bedded, coarsely crystalline, with thick chert beds in some places, and the chief lead bearing formation of S. Missouri (as in Blair county, Pa.) carrying also zinc, copper, nickel and cobalt, disseminated and also concentrated in fissures and caves, ranges in thickness from 300′ to 600′. This must be a comparatively deep water deposit.

The geology of Blair, Huntingdon, Centre and Clinton counties and of the Great Valley is greatly elucidated by the facts above mentioned a thousand miles distant. Not less so does the geology of the Great Valley in East Tennessee explain our own, for the resemblance is even closer because the conditions of deposition were more alike.

CHAPTER XLIV.

The fossils of No. II.

In Pennsylvania the *Calciferous IIa*, is almost non-fossiliferous; the *Chazy II b* is slightly; the *Trenton*, *IIc*, abundantly fossiliferous, its best explored and most remunerative localities being Bellefonte in Centre and Reedsburg in Mifflin counties.

The Calciferous chert beds may be taken as good evidence of the abundance of *Sponge life.** The oolitic or fish-roe limestone beds have recently been shown under the microscope to owe their origin to minute rolled fragments of *Bryozoa*, which grew as parasites upon the outside of sedentary shells, somewhat in the style of the lichen family of plants on rocks. Early forms of *Coral* grew in bundles of prismatic columns.† The *Stone lilies* (crinoidea, cystoidea) all of them more or less stemmed, but not all rooted, have left their distracted plates in the Calciferous of New York. The first *Star fish* forms appear in the Chazy. *Brachiopod* shells, especially Lingula, were abundant in all the shallow waters, but are not found in Pennsylvania. *Lamellibranch* shells seem to make their first appearance in the Calciferous age. *Gasteropod* shells, both coiled and spired, and some like *Maclurea magna* of considerable size, were extremely abundant near the coasts. Their scarcity in Pennsylvania argues for depth of water.‡ *Cephalopod* (cuttle-fish) free

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* Sir Wm. Dawson has given us their forms; see reduced figures of *Protospongia* on Plate XXVI.

† See *Columnaria*, on Plate XXVI. Note. The figure of *Monticulipora* (*Favosites*) *lycoperdon* should be removed from this plate to Plate XXXII, as it is a well recognized Trenton fossil, growing in colonies on the Delaware and Bushkill in Northampton county, and elsewhere. See Fossil Dictionary of Pa. p. 421.

‡ See Plate XXVIII. Note. The *Murchisonia milleri* on plate XXVII ought to be removed to plate XXXVI, for it is of Trenton age. The Chazy *Euomphalus catilloides* on plate XXX was a large shell, and its cross section lines in calcite make spirals on the Great Valley limestones.

XXVI.

Fossils of Formation II a.

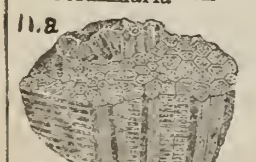
Palæophycus tubularis, Hall.

Buthotrephis antiquata.

Palæophycus irregularis, Hall.

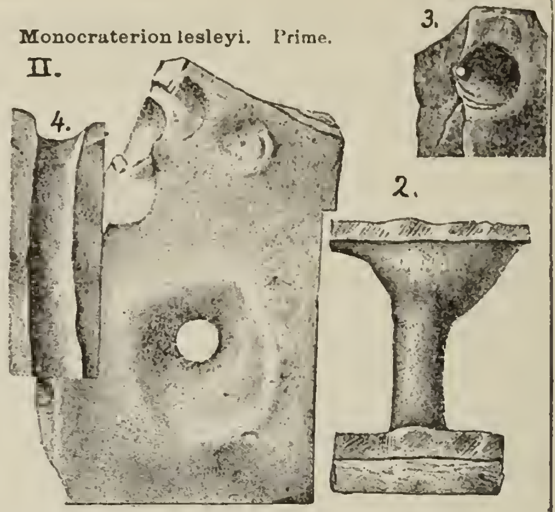
Monticulipora lycoperdon.

Columnaria ——

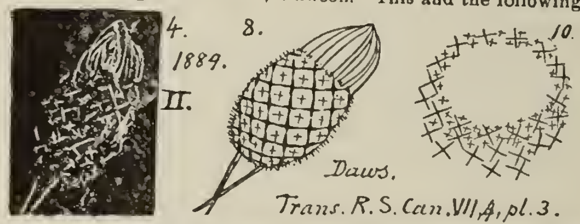


Stictopora fenestriata.

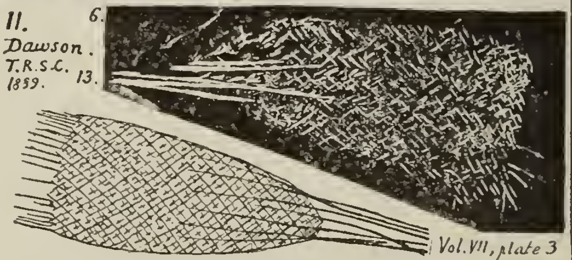
Monocraterion lesleyi. Prime.



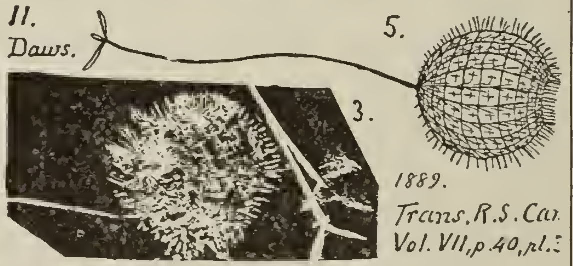
Protospongia coronata, Dawson. This and the following



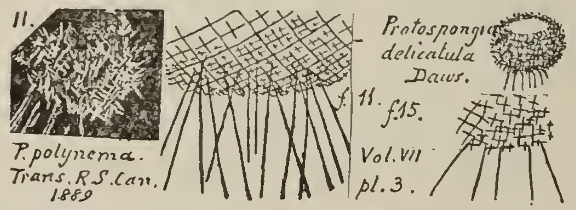
Protospongia cyathiformis, Dawson. Trans. R. S. Can



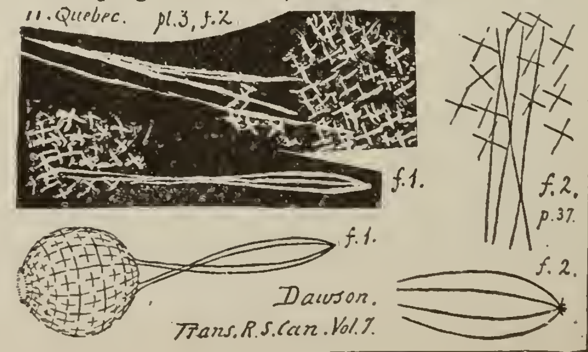
Protospongia mononema, Dawson. Trans. R. S. Canad



Protospongia polynema, Dawson. Trans. R. S. Can



Protospongia tetranema, Dawson. Trans. R. S. Canada.



floating shells like *Orthoceras primigenium* (plate XXIX) had already existed long enough to develop several species in the Calciferous, more in the Chazy, and fairly took possession of the Trenton open sea.* *Pteropod* (wing-footed) shells of several species existed in the Calciferous sea in colonies.† The *Trilobites* began in the Cambrian (or perhaps Pre-Cambrian age) and must have been abundant in the whole Lower Silurian age.‡ No higher forms of life are known, neither crustaceans nor fishes; but it is probable that they existed and their remains will some day be found, seeing that large plates of armored fishes like the Devonian *Holoptychius* (in No. VIII) were discovered three years ago with Trenton species of shells in Colorado.

It has always been considered a surprising fact that the keen-sighted and zealous naturalists of Philadelphia and West Chester have never been able to collect fossils from the Chester Valley limestones; nor those of Lancaster and York from the innumerable limestone outcrops east and west of the Susquehanna river; although the Calciferous, Chazy and Trenton age of the rocks was never seriously called in question, and their connection with the rocks of the Great Valley was evident. Nor in the Great Valley itself has any notable collections been made by the college students of Easton, Bethlehem, Allentown, Carlisle and Chambersburg. Either the Calciferous and Chazy formations were laid down on a very deep sea bottom far from the shores which we know abounded in a great variety of life, or the remains of plants and animals were afterwards obliterated by pressure, dissolution and partial crystallization, which hardly seems probable in view of the fact that the Trenton rocks in Northampton county are tolerably

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* See their chambered structure on plate XXXVII, and a specimen of the coiled *Lituites* on that plate; also a curved *Cyrtoceras* of Chazy on plate XXXI.

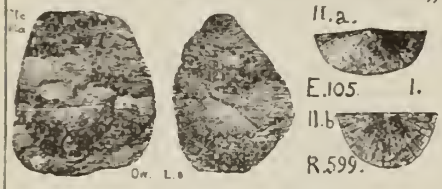
† See *Primitia gregaria* on plate XXIX. But they have not been collected at Pennsylvanian localities. They became enormously abundant in the Clinton age (*Va*) as may be seen by an inspection of any piece of fossil iron ore from Danville, Bloomsburg, Orbisonia or Frankstown.

‡ See *Asaphus canalis*, on plate XXIX, and other genera on plates XXXI, XXXVIII, XXXXIII.

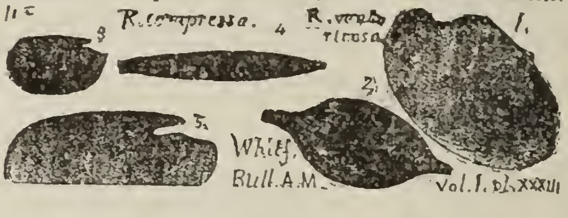
XXVII

No II a. Calciferous Sandstone (Magnesian limestone)

Leptæna sericea. (*Strophomena sericea,*).

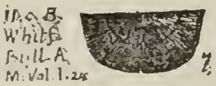


Ribeiria compressa, Whitfield, Bull. Amer. Mus. Nat. Hist.

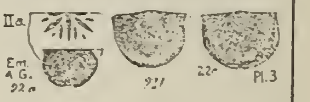


Orbiculas and Lingulas, of several different species,

Streptorhynchus ? primordiale

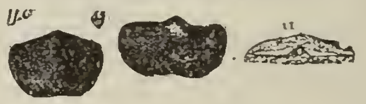


Strophomena insculpta.



Strophomena lævis,

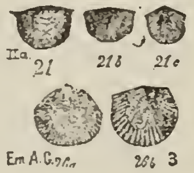
Triplesia lateralis. Whitfield.



Triplesia radiata. Whitfield. Bulletin Amer. Mus.,

Lingula acuminata.

Orthis costalis.



Tryblidium ovale, Whitfield, Bull. Amer. Mus. Nat. Hist.

Orthis macloedi. Whitfield.

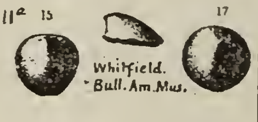
Trybiidium ovatum, Whitfield. Bull. Amer. Mus.

Orthisina grandæva,

Orthis tritonia, Bill:

Tryblidium ? acutum,

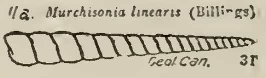
Tryblidium pileolum,



Rhynchonella plicifera.

Rhynchonella altilis. (*Atrypa*

Murchisonia linearis, B

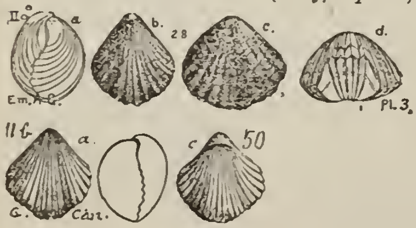


Murchisonia milleri.

Pennsyl
ton &
Y. Vol. 1
McCoy in

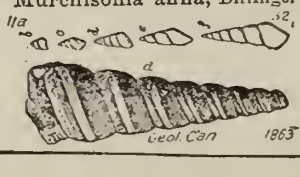
Murchisonia vesta.

Rhynchonella plena. (*Atrypa plena,*



Murchisonia arenaria, Billings, C.

Murchisonia anna, Billings.



fossiliferous, and Trenton fossils have been collected at Chambersburg, and also in the narrow up-faulted limestone belt east of Doylestown in Bucks county.*

Recently, however, an enthusiastic mineralogist, a post graduate of Haverford College in Delaware county, Mr. M. B. Stubbs, while hunting for quartz crystals near Henderson's station on the Chester Valley railroad, found a considerable number of silicified internal casts of three species of gasteropod shells and one cephalopod (Orthoceras) in loose fragments of sandstone lying on the upturned lowest limestone beds of the valley and therefore presumably from the slope of the North Valley hill of Chiques quartzite. The casts (now in the museum of the Acad. Nat. Sciences, of Philadelphia) are distorted and flattened by pressure, and their Calciferous age cannot be certified by any specific characteristics, but few who saw the specimens would doubt it.

Scolithus linearis has been reported plentiful, with waterworn pebbles, in a sand pit on the road from Barren Hill to Chestnut Hill, by Dr. G. M. Stiles of Conshohocken, at a meeting of the A. N. S. Philadelphia, May 20, 1891. These are the first discovered in the neighborhood. It is natural to suppose that they came from the North Valley Hill or Chiques quartzite, and Prof. Heilprin suggested that the sand pit is on the line of an abandoned channel of the Schuylkill river. But it is also possible that the fossils belong to some sandstone layer in the Calciferous sandstone or even Chazy division of II seeing that Scolithus is so numerous at that horizon in Vermont. Search for Scolithus in the sandy limestone series itself ought to be made.

It is hard to believe that we are never to know more of the animal life of the Calciferous and Chazy waters than from the specimen of *Maclurea magna* (?) and one or two others mentioned in the reports of Lehigh and Northampton counties by Prof. Prime. It surely only needs a sys-

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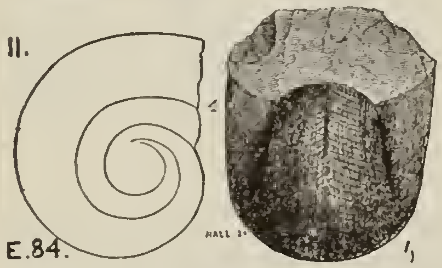
*Here Dr. Isaac Lea obtained a few shells from the building stones of a limekiln many years ago. It is not known if the Trenton has been preserved along the Chester county valley, or whether its beds have been converted into white marble.

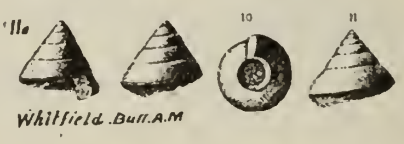
XXVIII

No. II a. Calciferous Sandstone (Magnesian limestone.)

Bucania sulcatina. (*Bellerophon*)

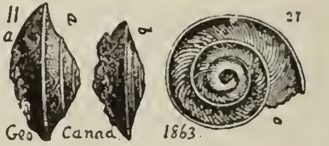


leurotomaria beekmanensis, Whit

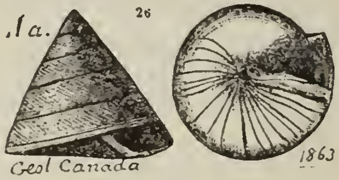


Maclurea matutina, Hall, Pal., N. Y., Vol. 1, 1847, Co

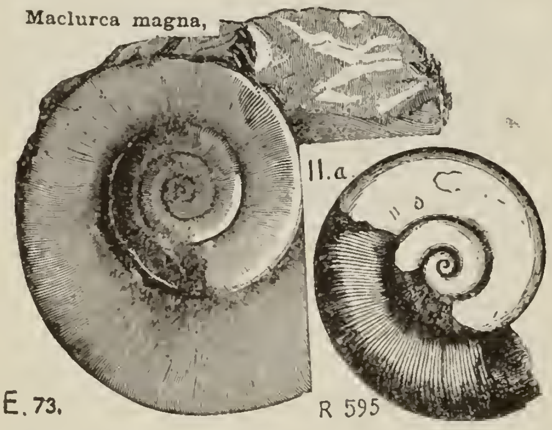
Pleurotomaria calcifera, Bill



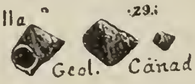
Pleurotomaria ramsayi. Bill.



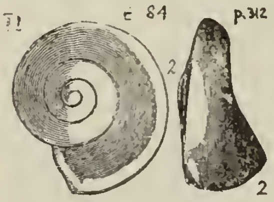
Maclurea magna,



Pleurotomaria gregaria,

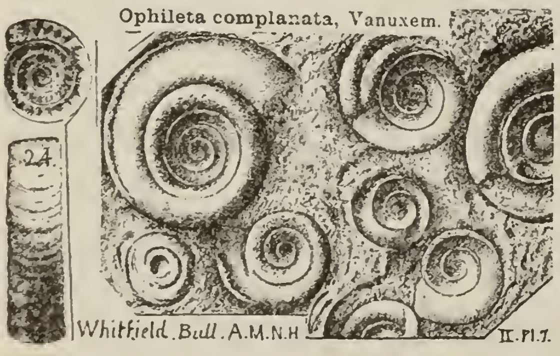


Raphistoma labiatum.

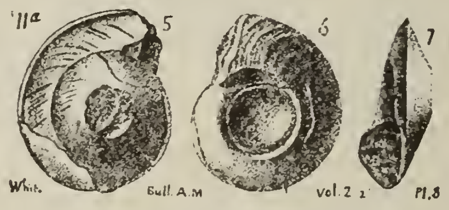


Pleurotomaria muralis

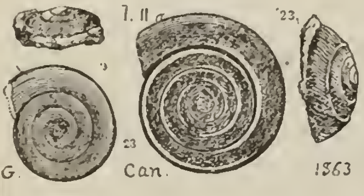
Ophileta complanata, Vanuxem.



Raphistoma prævium, Whitfield. Bull. A

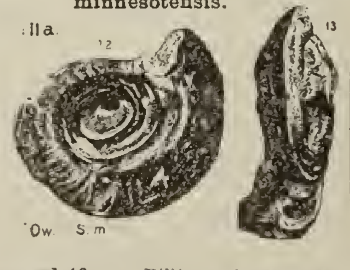


Ophileta compacta, Salter.

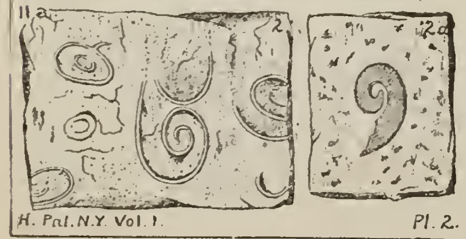


Trochonema exile,

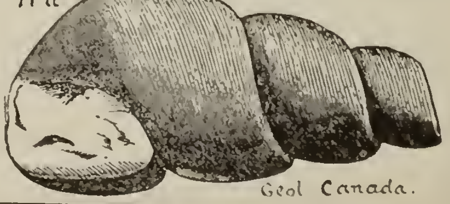
Straparollus (*Euomphalus*) **minnesotensis.**



Ophileta sordida. (*Maclurea sordida,*



Subulites calciferus, Billings, Canad. Nat



tematic search for them with the trained eyes of an expert palæontologist, or even with the untrained eyes of any college student whose zeal for natural history equals the sharpness of his youthful vision.*

There is one kind of fossil forms for which special search should be made, the so called *Conodonts*, or minute teeth, most probably of leeches. Worms were abundant in the shallower parts of the sea, as is shown by tracks and burrows, although the figures of *Palæophycus* on plates XXVI and XXXI, and *Phytopsis* on plate XXXII are almost undoubted impressions of algæ or seaweeds.

Conodonts were first found by Pander in the lowest Silusian rocks of Russia.† Mr. Hinde found them in the dark

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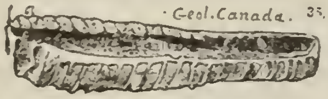
*The Calciferous Sandstone Valley of Copake, Millerton and Amenia, in Eastern New York, an extension beyond the Hudson of the Great Valley of Pennsylvania, containing the largest bodies of limonite in the Taconic region, have yielded numerous specimens of *Ophileta*, *Orthoceras*, *Cyrtoceras*, &c., to the keen search of Mr. W. B. Dwight, in 1889. (See Am. Jour. Sci. Vol. 38, page 150; Vol. 39, p. 68.) He found also in the limestone near Clove Valley Station, Dutchess county, N. Y. Calciferous fossils, including the common fucoids, with *Ophileta*, probably *O. complanata;* proving that the Fishkill belt east of the Hudson is merely a continuation of the Great Valley limestone belt of Pennsylvania and New Jersey. (Am. Jour. Sci. Vol. 39, Jan. 1890, pp. 68, 71.) Also in the so called "Taconic" limestone belt of Columbia county, N. Y. near Pulver's Station, 2½ m. north of Philmont, Mr. L. P. Bishop, in 1887, found gasteropods, crinoids, and a brachiopod shell; and in 1888, six or seven *Orthocerata, &c., Chetetes compacta*, Billings; *Monticulipora lycoperdon*, Say; *Orthis testudinaria* (?) Dal.; and *Murchisonia gracilis*, in hard limestone, a mile long, 150 yards wide, completely enclosed in highly metamorphosed schists and slates. (Am. Jour. Sc. Vol. 39, page 70. The Chatham find of a like nature is recorded in Vol. 32, pp. 438, 1886.)

†Monog. Foss. Fische d. Sil. Syst. 1856. Pander called them fish teeth. Harley found them in the Ludlow bone bed and referred them to crustaceans. Q. J. G. S. London, 1861, p. 542. C. Moore found them at various horizons from Silurian up to Permian. Report of Brit. Ass. 1869, p. 375; and private note in Hinde's "On Conodonts," &c. Q. J. G. S. 1879, p. 351 to 359, with three plates full of figures. C. J. Smith in 1875 found them in Scotch Low. Carb. rocks. Notes by Young, N. Hist. Soc., Glasgow. Dr. Newberry found them in Low Carb. rocks of Bedford, Ohio; and figured them as the teeth of Mixinoid fishes in Pal. Ohio, Vol. II. In the Hudson River formation (No. III) near Toronto a few compound cone-teeth, mixed with a great variety of grapholites, corals, worms and brachiopod, gasteropod and cephalopod shells, and a few fragments of a trilobite (*Calymene*), are found in thin limestone lenses between micaceous flags and shales; there are also some simple spine-like cone-teeth, a form not yet seen except

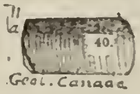
XXIX

No. II a. Calciferous Sandstone. (Magnesian limestone.)

Orthoceras becki, Billings.



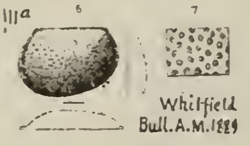
Orthoceras deparcum,



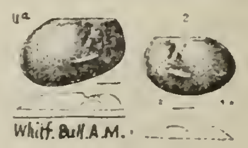
Primitia gregaria, Whitfield.

Orthoceras lamarcki, Billings. Geol. Canada, 1863,

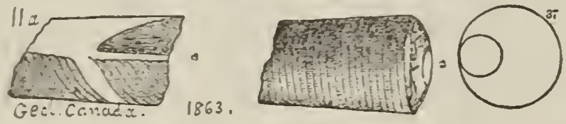
Primitia seelyi,



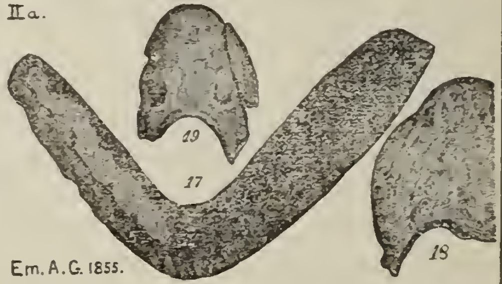
Primitia ? cristata, W



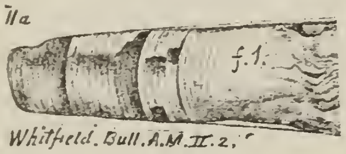
Orthoceras montrealense, Billings. Geol. Canada, 1863,



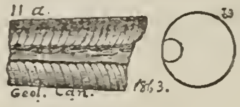
Isotelus canalis, Conrad. (Hall's Palæon. N.Y.



Orthoceras primigenium, Van

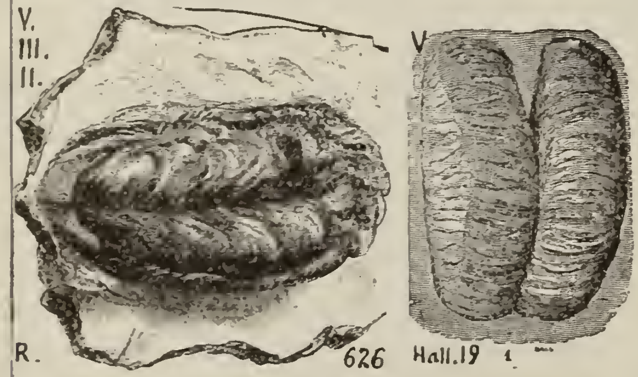


Orthoceras sordidum

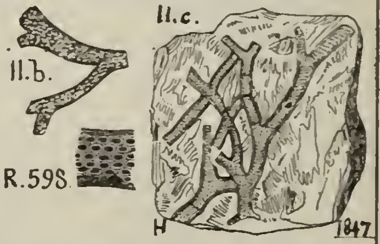


No. II b. Chazy or Middle Great Valley limestone.

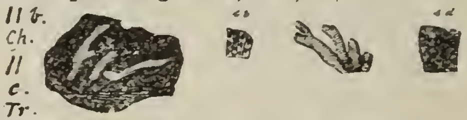
Rusophycus bilobatus (*Fucoides*



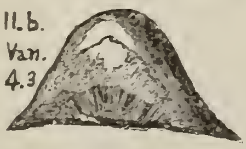
Stictopora acuta. Rogers, Geol. P



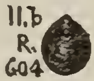
Stictopora elegantula, Hall, Pal. N. Y. Vol. 1,



Favosites lycopodites.

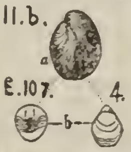


Lingula curta.



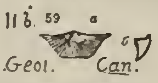
Stictopora gilberti. (*Ptilodictya gilberti*, Meek. Proc. Acad.

Camarella bisulcata.

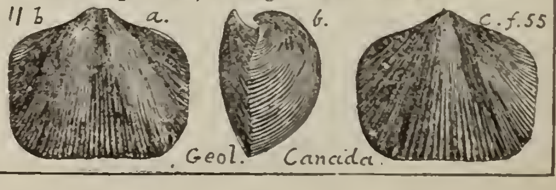


Camarella circulus

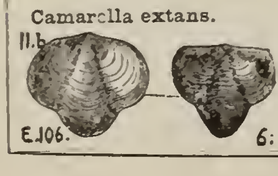
Orthis acuminata,



Orthis imperator, Billings. Can. Nat. & Geol. Vol.



Camarella extans.



Orthis callactis ?

Chazy limestone beds at Greenville on the Ottawa river in Canada, beds which are largely made up of the small shells of bivalve crustaceans (*Leperditia*) with a few small trilobites and gasteropods, for all of which the cone-teeth would be much too large, since they all belong to the largest known compound cone-tooth species.

The cone-teeth are very minute shining bodies, single curved conical teeth with expanded base, or more frequently a row of small cones with a larger one at the end or in the middle of the row, sometimes with a downward extended base carrying itself denticles.† They retain their perfect form and lustre, whether in flag, shale or limestone beds, although very brittle and easily dissolved by nitric acid. Most of them are of reddish horn color and translucent; rarely of a milky white, and only where weathered. Those at North Evans are robust and opaque, with a different lustre from those in the bituminous shales. Those from the *Chazy* differ from all the rest in the bright glossy black tint. Microscopic sections show a conical lamellar structure. Usually found scattered through the rock. Hinde has one Genesee specimen in which a compressed group of various forms of teeth and plates have evidently belonged to one animal, but too much crushed to make out

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in the Lower (Cambro) Silurian. While most of the other fossils are in the limestone beds the cone-teeth are generally found in the shales.

In Upper Hamilton lime-shales (VIIIc) finely exposed at North Evans, on the Lake Erie shore in New York State, cone-teeth are numerous, and one particular limestone bed is so filled with their fragments as to be called by Hinde *the Conodont bed;* ½″ to 3″ thick; traceable for some distance; dark, sub-crystalline, with green particles, and pyrite crystals; holding also crinoid stem fragments, fish bones and plates, *Ptycodus* teeth of Pander, but neither crustaceans nor gasteropods. The cone-teeth can only be *detected with a good lens,* and on weathered surfaces. A few cone-teeth associated with fish plates and teeth have been found in a thin Hamilton lime bed at Arkona, Lambton county, Ontario.

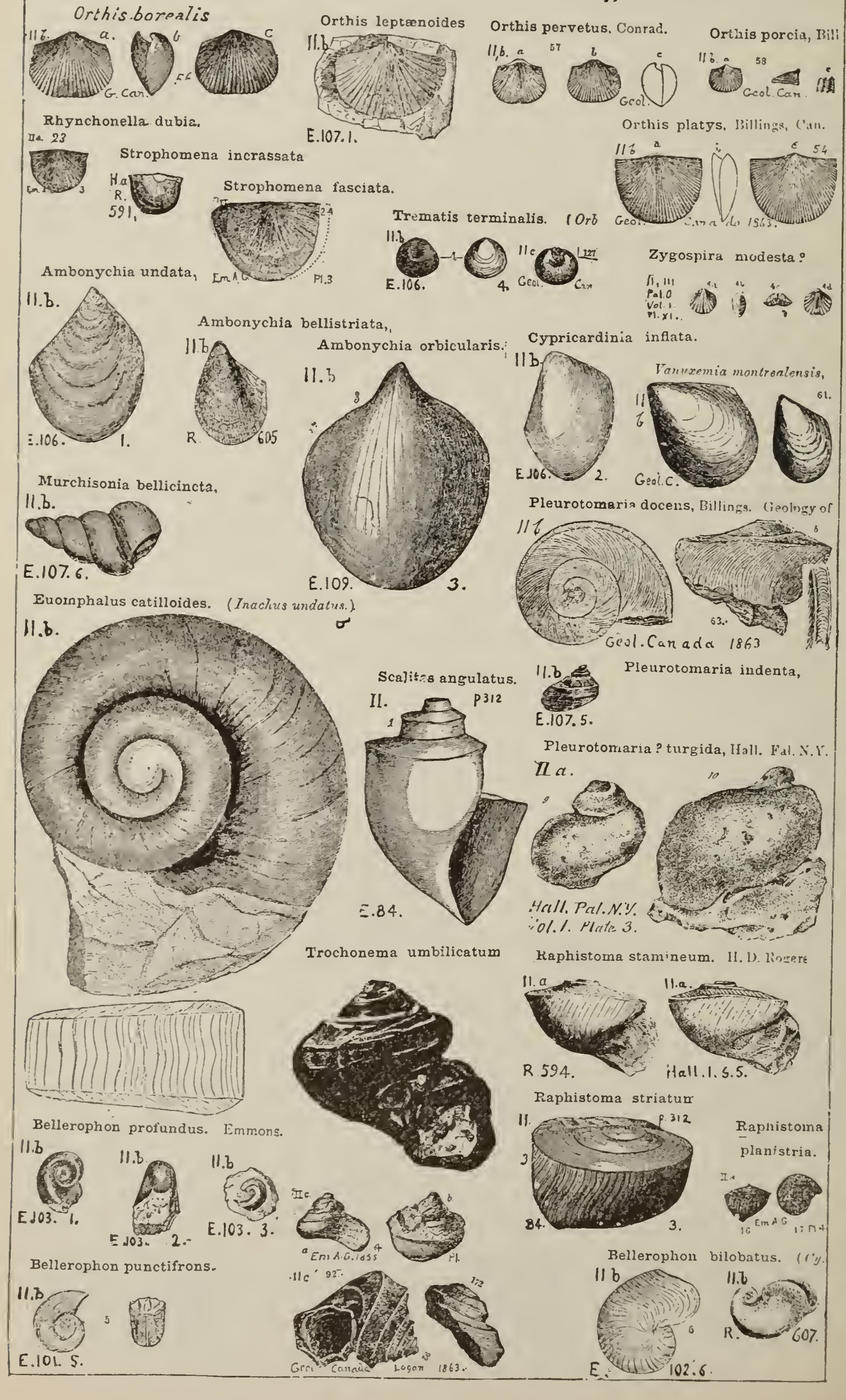
In black Genessee shale cone-teeth have been found by Hinde at Kettle creek and Bear creek, Canada West; in fragments on the north shore of Lake Erie; in the fine section at North Evans, N. Y.; and at Louisville, Ky.; mixed with a small number of Lycopod plant spores, broken plants, a few Lingulas, Discinas and Aviculas, and *Palæoniscus* fish scales; but no forms to which the cone-teeth could easily belong.

The Lower Carboniferous black shales in which Newberry's conodonts occur show nothing else than plants and ganoid fish scales.

†For other forms see Hinde's description on p. 354 and his plate figures.

XXX

No. II b. Chazy or Middle Great Valley limestone.



their arrangement. Huxley saw a resemblance to the hag fish (Myxine), but could indicate no living fish with a similar assemblage of teeth and plates. Owen at first suggested that they might possibly be toothed crustaceous claws; afterwards, that they might rather be spines, hooklets, denticles of naked shell-fish or worms. They seem to have been the only preservable part of the animal whatever it was; and they may possibly be the only evidence we have for the early existence of the soft circle-mouthed family of fishes. Dr. Woodward suggested that they might be the tongue-armor of the shell-less gasteropods (*Nudibranchiata*) which have therefore never been found in the rocks.*

Fossils of the Calciferous, IIa.

Some of the most characteristic and most widely distributed forms of this formation, are, according to S. A. Miller's N. A. Geology and Palæontology,† *Ophileta complanata*, *Ophileta uniangularis*, *Holopea turgida*, *Holopea dilicula*, and *Pleurotomaria primigenium*.

From the Potsdam ascend into this Calciferous division, *Pleurotomaria canadensis* and *Leptæna barabuensis*.

The following have been assigned to this formation (or to supposed equivalents of it in the Quebec group) *Plurotomaria calcifera*, *Pleurotomaria postumia*, *Helicotoma perstriata*, *Maclurea matutina*, *Maclurea sordida*, *Eccyliomphalus canadensis*, *Camarella calcifera*, *Lingulella mantelli*, *Lingulella irene*, *Amphion salteri*, *Bathyurus cordai*, *Bathyurus conicus*, and *Asaphus canalis;* but the identifications of Quebec and Calciferous strata are always to be distrusted.

Fossils of the Quebec group.

Of these the less said the better until the controversy over the Quebec group has been settled. The species *Lingulepis maera*, *minuta*, and *manticula*, *Acroteta gemma*, *Agnostus communis*, *bidens*, and *neon*, *Crepicephalus haguei*, and

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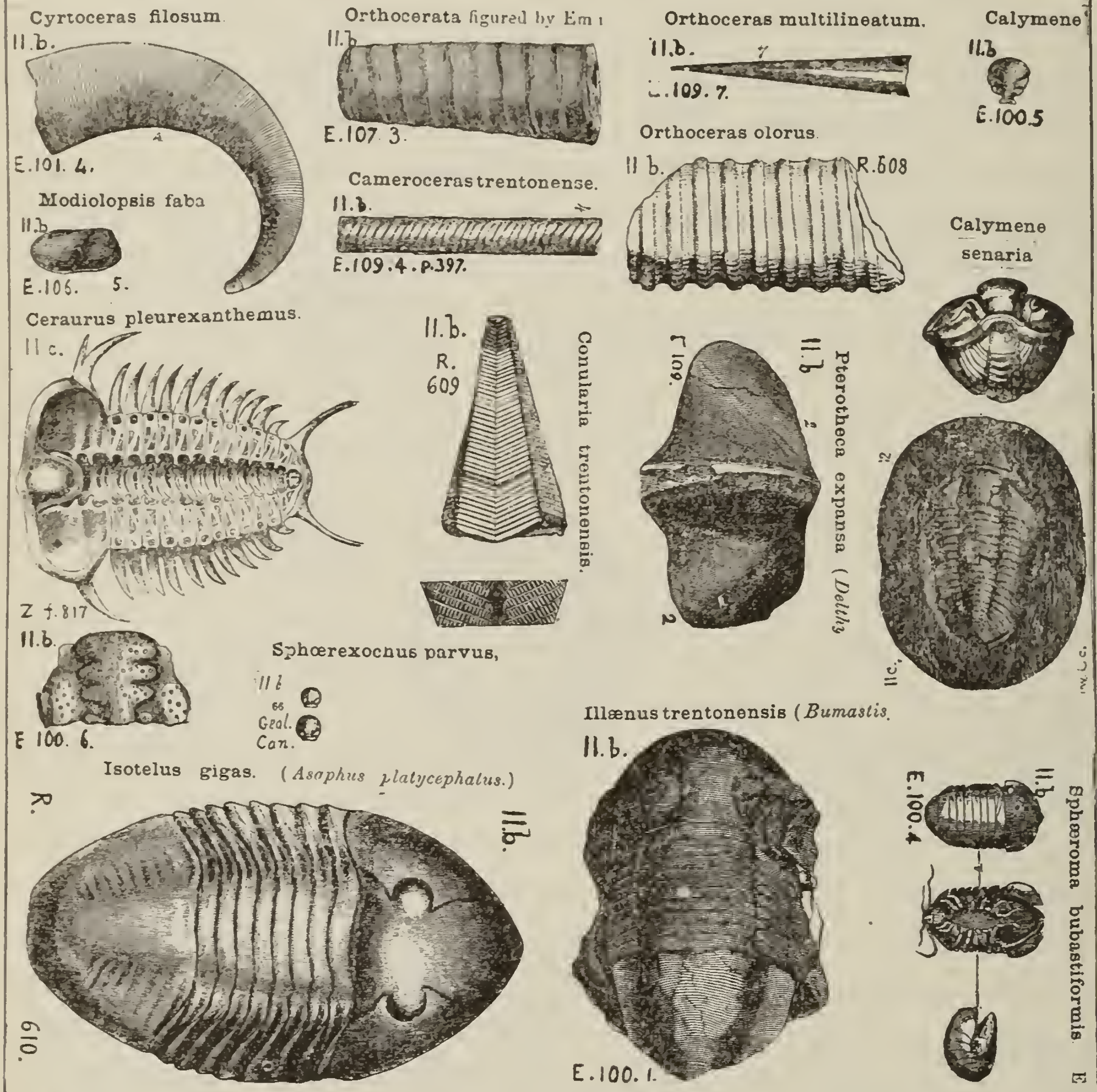
*Q. J. G. S. XXXV, p. 389.

† Second Edition, Cincinnati, 1889, page 34.

XXXI

No. IIb. Chazy, or Middle Great Valley limestone.



No. IIc. Trenton, Birdseye and Black River.

unisulcatus are confidently assigned to equivalents of the Quebec group in the Rocky Mountains. The family of Graptolites is said to reach its highest development in the Quebec group. Thirty genera and 170 species of Graptolites have been named thus far in North American rocks. *Maclurea atlantica* and *Asaphus canalis* are said to range up through the Chazy and higher.*

Fossils of the Chazy, II b.

The characteristic form of this age is considered to be the fine whorl-shell *Maclurea magna*. With this are associated others which continued to live even into Hudson River times:—*Strophomena alternata*, and *incrassata*, *Orthis perveta*, *Leperditia canadensis*, *louckana*, and *amygdalina*, *Orthoceras multicameratum*, and *bilineatum* and the lamellibranch shell *Modiolopsis nasuta*. *Scolithus* is abundant in the formation as recognized in some regions; and *Lingulepis morsei* is described from the St. Peter's sandstone of the west.†

Fossils of the Black River limestone, II c (in part).

These were defined by Vanuxem in 1842 in the bluffs of Birdseye and Trenton beds at Boonville, N. Y., but there has always been a doubt of the propriety of separating the Black river and Birdseye beds and giving two names to what seems like one formation, distinguished on the Black river by its abundance of Cephalopod shells, and on the Mohawk river by an abundance of the Birdseye fucoid *Phytopsis tubulosa*.

The vast and varied population of the sea at the beginning of the Trenton age, as shown in the Black river beds, produced by its decay the dark color of the rocks, the black marbles of Vermont and Pennsylvania. Many of the species died out however before the normal Trenton limestones were deposited. But the family of straight

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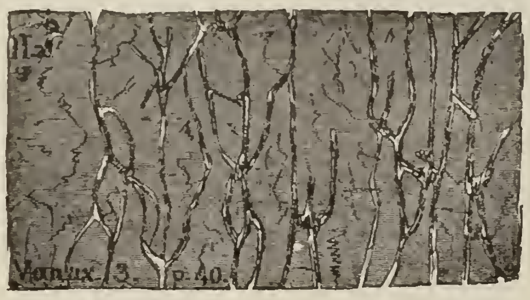
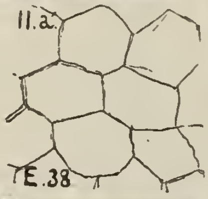
* This paragraph is a condensation of statements made by S. A. Miller on his page 35.

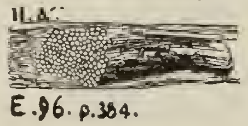
† S. A. Miller, 1889, p. 38.

No. II c. Trenton, Birdseye and Black River.

Phytopsis tubulosa ? (*Fucoides demissus.*) Vanuxem

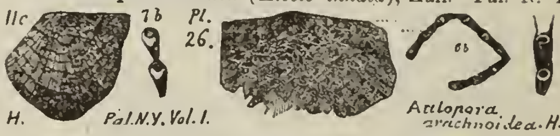




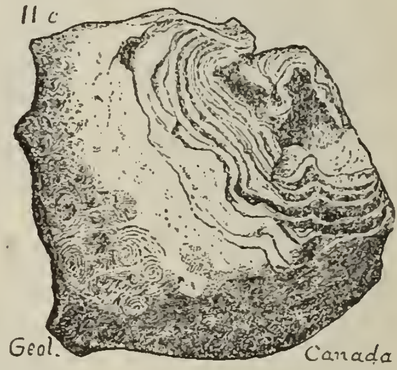


Tetradium fibratum, Safford. American Journal of Scie

Stomatopora inflata (*Alecto inflata*), Hall. Pal. N. Y.



Stromatopora rugosa, Hall.

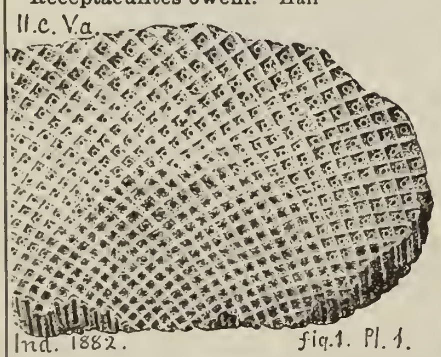


Sphærococcites sharayanus.

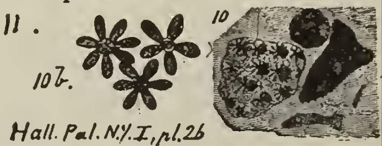
Stictopora labyrinthica. (Hall,

Stromatocerium rugosum.

Receptaculites oweni. Hall

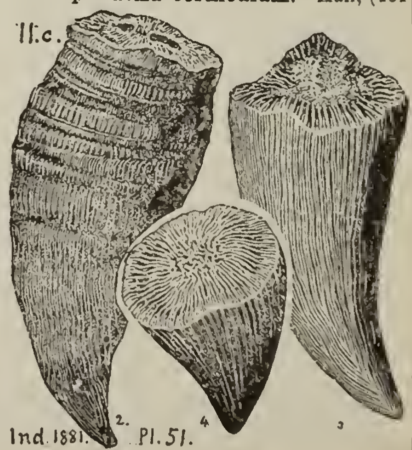


Stellipora antheloidea, Hall.

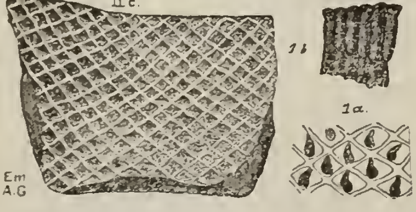


Petraia (*Streptelasma*) **corniculum**,

Streptelasma corniculum. Hall, (184

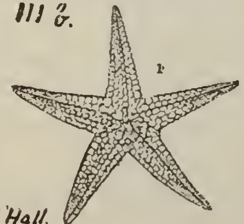


Receptaculites neptuni. (DeFrance



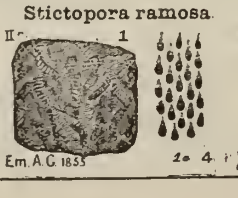
Stenopora petropolitana,

Palæaster shaefferi,



Receptaculites iowensis.

Stictopora ramosa.



shell cephalopods (*Orthoceras*) reached its climax now, not only as to the number of its species, but as to the size of its individuals, some of them having had tapering chambered shells ten feet long and twelve inches in diameter at the head. The allied *Cyrtoceras* and *Endoceras* were highly developed ; and the genera *Gomphoceras*, *Phragmoceras* and *Gyroceras* brought their species into the field.*

Corals also were abundant in places, and petroleum exudes from their fossil forms when broken, as at Montmorency in Canada.†

Fossils of the Birdseye limestone, *IIc* (*in part*).

The charactersstic fossil of the *Birdseye limestone* is a vertical, cylindrical, sub-cylindrical, angular or compressed stem of a marine plant, branched, connected, forking, radiating, looped, etc. etc. with an internal fibrous structure, as shown in Hall's figures of 1843, Vol. 1, Pal. N. Y. plates 8 and 9, which seem to exclude the possibility of these markings being casts of worm burrows, as insisted on by Salter and Etheridge, and so tabulated by Bigsby in his Thesaurus Siluricus.‡

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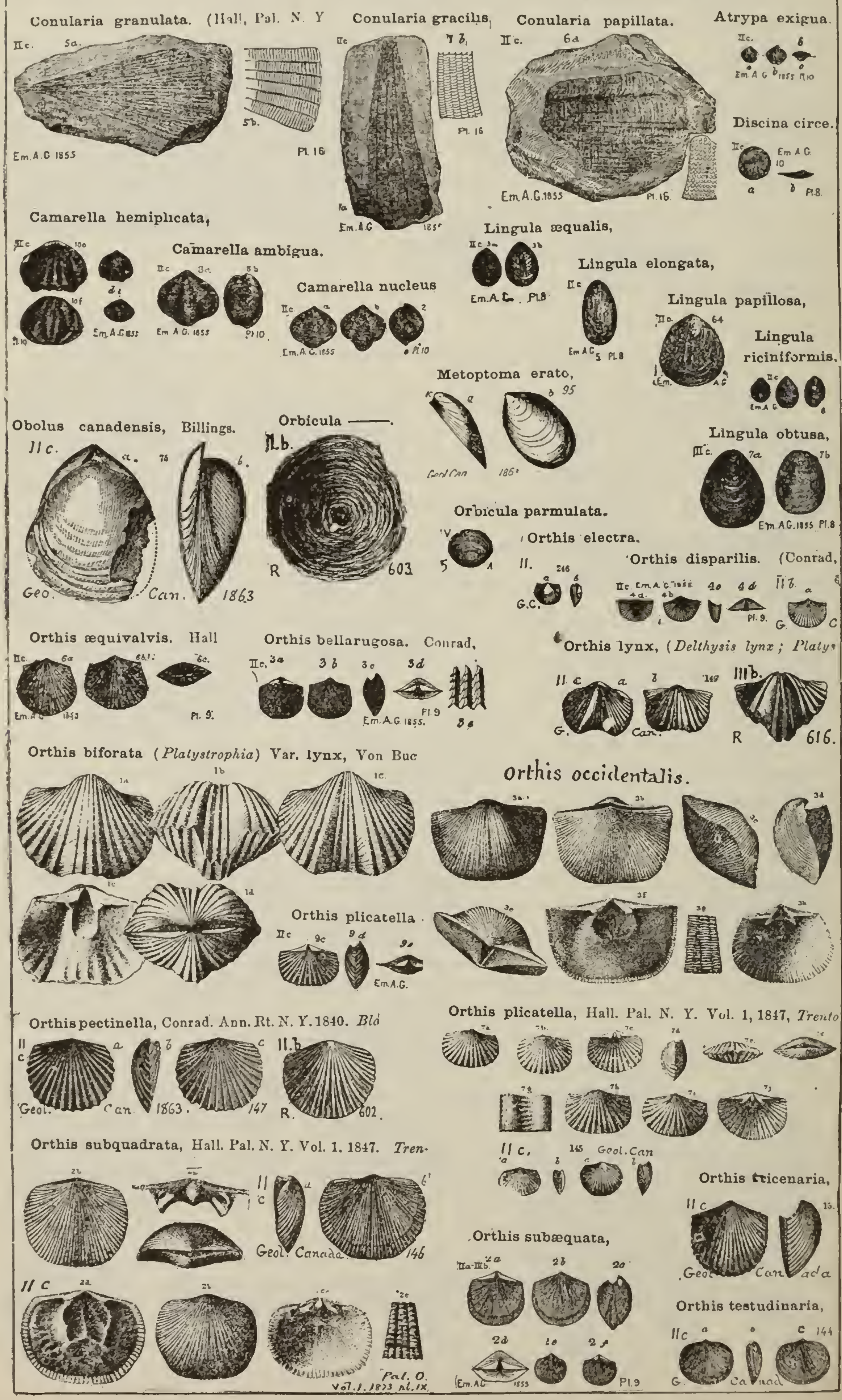
*Where were the feeding grounds of these hugh floating walking-canes of stone, ballasted below and buoyed by their air-filled chambers above, with their great eyes looking for prey, and their long arms spread out at the surface of the water to seize and bring it to their mouths? Requiring but little depth of water they probably haunted the shores of the then continents and were supplied with abundant provender by the scum of trilobites which floated like themselves as water bugs upon the waves. The brachiopod and lamellibranch shells were no doubt safe from their attacks ; yet the shore waters must have been their most profitable haunts ; and if so we can comprehend the vast abundance of their remains in Northern New York and their comparative absence from the rocks of Pennsylvania. Or, were they endowed with sails like the modern nautilus, and made voyages before the wind? It is a pity that the rocks have preserved for us no lithographs of their curiously unknown soft heads and bodies.

†The same thing happens when the corals of the Niagara rocks of New York are broken out. Such facts establish the animal origin of the older and more fetid petroleums ; the later and sweeter oils having come from the chemical change of the cellular tissue of marine vegetation, as shown by Lesquereux.

‡ See what is said in Chap. XVII on Scolithus, beginning page 287 above. See also reduced figures of the *Phytopsis tubulosa* given at the top of plate XXXII. Hall's figures will be reproduced in the Appendix to Fossil Dictionary.

XXXIII

No. IIc. Trenton, Birdseye and Black River.



Fossils of the Trenton limestone II c.

This famous formation was first described by Emmons in 1842. At Trenton Falls in New York it shows 100 feet of very fossiliferous, dark, fine-grained, thin-bedded limestone layers below, separated by black shales, passing up into coarse grey, thick, less fossiliferous beds at the top. At Chazy it is 400′ thick. In middle Pennsylvania it is 1000′ and 1200′ thick. In middle Tennessee only 500′, it is in eastern Tennessee 1100′ thick. In Canada it is 600′ thick at Montreal, 750′ further west, but only 50′ around lake Michigan. In Iowa and Illinois its lower blue division, 120′ thick, is capped by the lead and zinc-bearing dolomitic layers of Galena, 150′ thick. In Missouri it is 400′.

Its wide distribution attests an open and moderately deep sea deposit. Its wealth of life is exceptionally great. Graptolites and Trilobites were on the decline; but Crinoids, Cystideans, Brachiopods, Corals, Gasteropods and Lamellibranchs were on the increase.*

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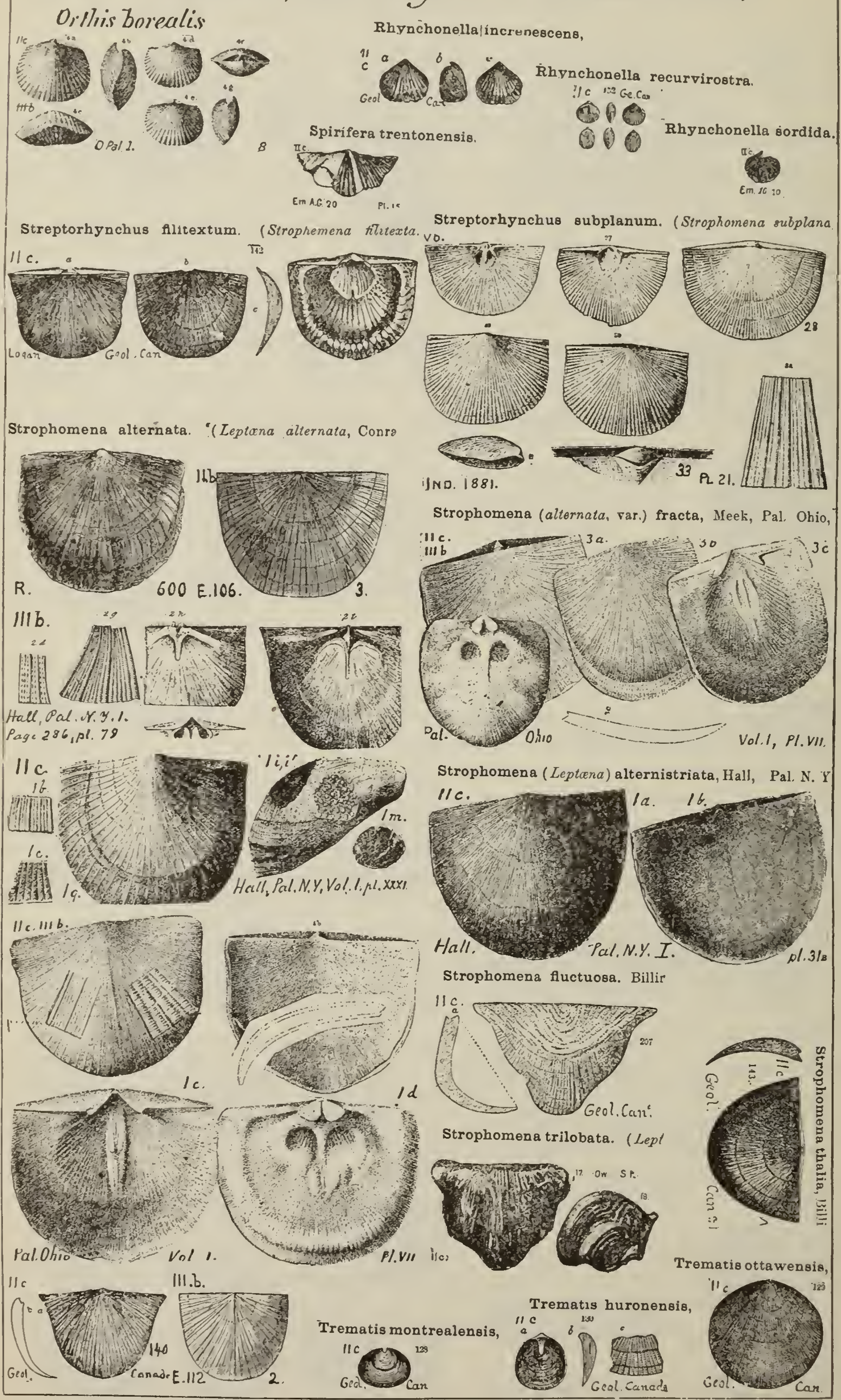
* C. A. Miller's Geol. and Pal. N. Amer. 1889, p. 41. I cannot do better than extract the interesting paragraphs from this indespensable guide to the student of fossils which follow on pages 41, 42:

"*Receptaculites oweni* is peculiar to and characteristic of the Galena division of this Group, and it is usually accompanied with *Lingula quadrata*, *Murchisonia major*, *Fusispira elongata*, and other characteristic species. The species most characteristic of the Trenton Group, and which may be relied upon as determining its age wherever they occur, are *Orthis tricenaria*, found in New York, Canada, Kentucky, Missouri, and Nevada; *Orthi pectinella*, found in New York, Canada and Kentucky; *Cyrtolites compressus*, found in New York, Canada, Wisconsin and Minnesota; *Hybocrinus tumidus*, *H. conicus*, *Amygdalocystites florealis*, *A. radiatus*, *Blastoidocrinus carcharidens*, found at Ottawa, Canada, and High Bridge, Kentucky; *Leperditia fabulites* and *Conularia quadrata*, found in New York, Canada and Kentucky; and *Orthis borealis*, found in Canada, Wisconsin, Minnesota and Kentucky. The genus *Amygdalocystites* has a wide geographical distribution, though a rare fossil in every locality, and, so far as known, is confined to this Group. Other characteristic species are *Bythotrephis succulens*, *Monticulipora lycoperdon*, *Schizocrinus nodosus*, *Stictopora elegantula*, *Orthis bellarugosa*, *O. æquivalvis*, *Trochonema umbilicatum*, *Subulites elongatus*, and *Helicotoma planulata*.

"There are numerous species which continued to live until the Hudson River age, and are, therefore, common to three Groups, as *Strophomena alternata*, *S. rhomboidalis*, *Leptena sericea*, *Zygospira modesta*, *Rynchonella capax*, *Calymene callicephala*, *Asaphus gigas*, and *Ceraurus pleurexanthe-*

XXXIV

No. II c. Trenton, Birdseye and Black River.



The Trenton fossils have been in Pennsylvania best studied at Bellefonte in Centre county. Strata occur "*composed almost entirely of fossil remains*," all of them recognized Trenton forms. Prof. Ewing, late of the State College in Centre county, adds in his report (embodied

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mus. Such species are usually quite variable in form and size, and seem to have changed to suit the conditions of their habitat, and also, in accordance with the theory of evolution, to have reached the climax of development, and subsequently gradually declined. *Strophomena rhomboidalis* occurs in Trenton, Utica Slate, Hudson River, Clinton, Niagara, Lower Helderberg, Upper Helderberg, Hamilton, Chemung, Waverly, Burlington and Keokuk groups. Its vertical range exceeds that of any other species in any of the rocks of the known world, and its geographical distribution is common to every continent where strata of these ages have been studied and described. The varietal forms have been called *S. tenuistriata* from the Lower Silurian, *S. depressa* from the Upper Silurian, and *S. rhomboidalis* from the Devonian and Subcarboniferous. The Lower Silurian specimens are usually smaller, and have fewer concentric wrinkles over the visceral region than those from the Upper Silurian and Devonian, while the length of the front and lateral margins from the geniculation is usually greater in the Upper Silurian than it is in the Lower Silurian, Devonian or Subcarboniferous specimens; but these differences are not so constant as to form inflexible characters, and hence it is that many of the learned and better palæontologists have classed them all together under the first and oldest specific name. The various forms which *Strophomena alternata* assume in the same group of rocks are wonderful; the radiating striæ differ in size and number, the hinge line is sometimes longer and at other times shorter than the greatest width of the shell. The shells are sometimes much longer than wide, and at other times as much shorter. The lateral sides are sometimes straight, and at other times rounded. Some shells are nearly flat, others are deeply concave on the dorsal side and highly convex on the ventral. Age in some specimens appears to have materially thickened the shells, and preserved strong imbricating lines of growth, while in other cases we have much larger shells that are very thin and destitute of imbrications. Like differences may be distinguished in other species having great vertical distribution, as in *Rhynchonella capax* and *Zygospira modesta.*

"The rocks of this Group are composed almost entirely of remains of the hard parts of animals that swarmed in the seas of that age. Some shells are preserved in good condition, but generally the comminuted fragments are held together by lime cement, forming the limestone strata, leaving well-preserved specimens to be found only in the shaly partings. It is common to find that one animal has grown upon another, as a *Lichenocrinus* upon a brachiopod, and a bryozoan upon the former, under such circumstances as to show the shell was at the bottom of the ocean during the growth of the *Lichenocrinus*, and that the latter must have ceased to grow before the bryozoan attached. From this we infer the *clearness of the water*, for otherwise mud would have intervened; and we also infer a slow deposition of materials; for the lives of two animals transpired before the deposit was sufficient to cover a thin shell. There is no evidence of any difference between the temperature of the water then and now, nor between the climate then and now.

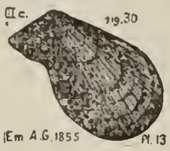
XXXV

No. II c. Trenton, Birdseye and Black River.

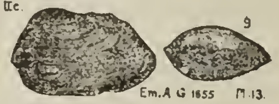
Ambonichya) *bellistriata.*

Avicula elliptica.

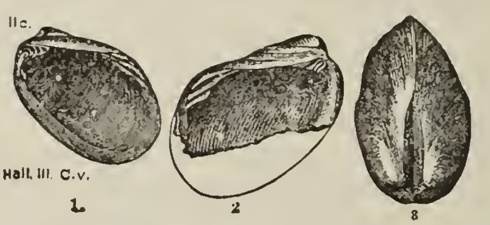
Avicula trentonesnsis,



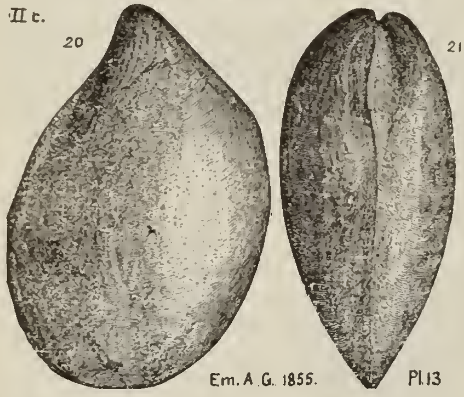
Cardiomorpha vetusta.



Palæarca ventricosa (now **Cypricardites ventricosus.)**

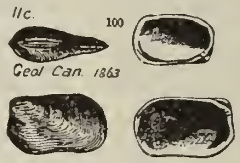


Cypricardites amygdalinus. (*Ambonychia*



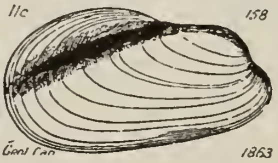
Cypricardites ventricosus.

Matheria tener, Bill

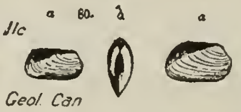


Modiolopsis trentonensis, Hall,

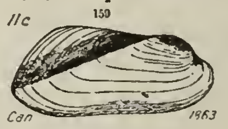
Modiolopsis meyeri, Billi



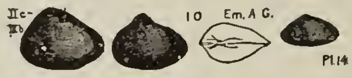
Modiolopsis maia,



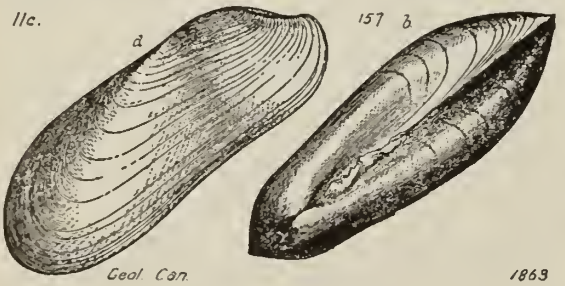
Modiolopsis carinata,



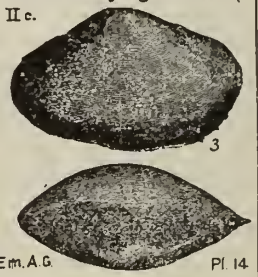
Tellinomya levata. (*Nucula le*



Modiolopsis gesneri, Billings. Geol. Can. 1863, p. 172,



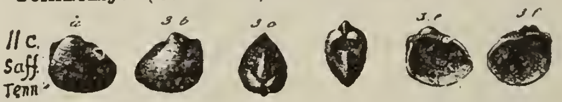
Tellinomya gibbosa. (



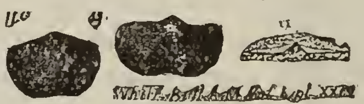
Tellinomya nasuta.

Tellinomya dubia. (Hall, Pal. N. Y., Vol. 1. *Black R,*
TELLI.
166

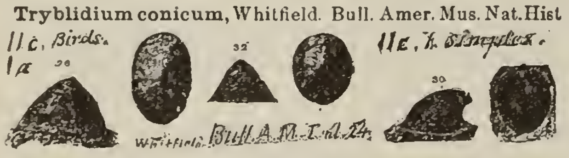
Tellinomya (*Ctenodonta*) **hartsvillensis,** Safford. Geol.



Triplesia lateralis. Whitfield.



Tryblidium conicum, Whitfield. Bull. Amer. Mus. Nat. Hist



Triplesia ambigua. (*Atrypa ambigua*, Hall, Pal. N. Y.

Triplesia extans. (now **Camarella extans.**

in Report T4, p. 424) the following list:—*Schizocrinus nodosus* (stems of this stone lily); *Streptelasma corniculum; Orthis testudinaria* (very common above); *Orthis tricenaria; Orthis pectinalinea?; Orthis lynx; Orthis subequalis; Strophomena alternata* (very common above); *Leptæna sericea* (common above); *Lingula curta* (one); *Pleurotomaria lenticularis*, and another species; *Murchisonia gracilis; Leperditia ——?; Trinucleus concentricus; Calymene ——?; Chætetes lycoperdon.*

Mr. C. E. Hall in his collection lists published in the Catalogue of the Museum of the Survey, O3, 1889, page 177 *et seq.*, adds to the above, numerous *Bryozoa; Stictopora acuta;* fragments of *Tentaculites*; *Ceramopora ——?;* fragments of *Trematopora; Monticulipora pulchella*; *Beyrichia* (numerous); *Zygospira modesta; Calymene beckii;* an *Orthoceras* (encrusted with bryozoans); *Spirorbis* (numerous); a *Bellerophon.* Again on p. 183, *Edmondia subtruncata; Murchisonia gracilis; Cypricardites subtruncatus; Camarella ambigua; Camarella hemiplicata; Palæophycus simplex* (in fair condition); *Buthotrephis succulens; Asaphus obtusus;* a colony of *Leptæna sericea* on one slab; an *Illænus; Cypricardites ventricosus; Plumulites jamesii; Pholidops trentonensis; Ceraurus pleurexanthemus; Atrypa altilis.*

In Fellows' collections for C. E. Hall in Trenton layers on the Little Juniata at Tyrone Forge (List in O3, p. 189), appear, with many of the above, these also: *Rhynchonella capax; Escharopora* (*Philodictya*) *recta; Retepora; Cornulites flexuosus;* and *Stictopora elegantula.*

Reedsville, in Mifflin county, is another excellent collecting ground for Trenton fossils, where many specimens of *Homalonotus trentonensis* were got. (See list in O3, p. 179.) Among other forms are noticed *Orthis costatus; Endoceras proteiforme; Lingula oblonga; Bathyurus extans; Modiolopsis faba;* and *Raphistoma lenticularis.* The two last were collected also near Martinsburg in Morrison's Cove in Blair county. (O3, p. 181.)

Collections were also made at Belleville, in Mifflin county, XXXVI

No. II c. Trenton, Birdseye and Black River.

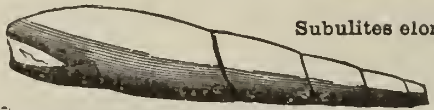
Holopea ventricosa. (Hall, Pal. N. Y. V.

Holopea paludiniformis. (Hall

Macrocheilus subcostatus ? Ow

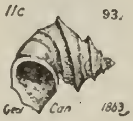
Murchisonia abbreviata,

Subulites elongatus, Em



Murchisonia arachne,

Murchisonia serrulata,

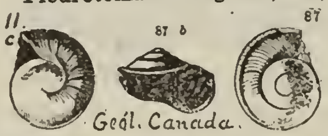


Murchisonia bellicincta.

Pleurotomaria supracingulata,

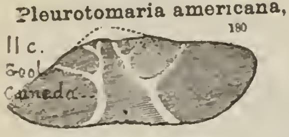
Pleurotomaria

Pleurotomaria eugenia, Bil,

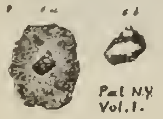


Pleurotomaria progne,

Pleurotomaria americana,



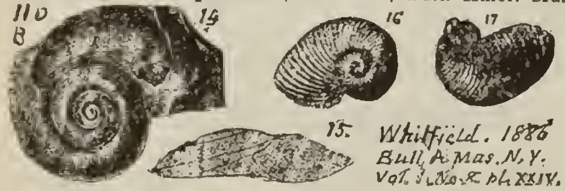
Pleurotomaria ? nucleolata



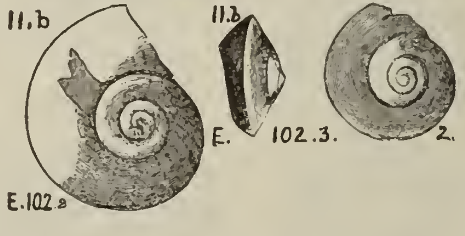
Pleurotomaria rotuloides.

Pleurotomaria subconica, Hall. Pal. N.

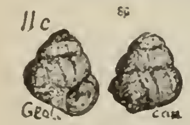
Raphistoma compressum, Whitfield, Bull. Amer. Mu



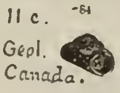
Raphistoma lenticulare. (*Pleurotomaria*



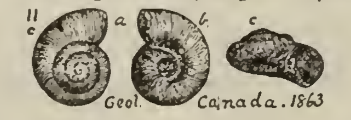
Straparollina (*Straparollus*) **eurydice,**



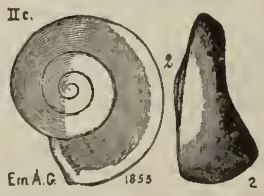
Straparollina (*Straparollus*) **asperostriatus,**



Straparollina (*Straparollus*) **circe,**

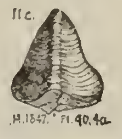


Straparollus labiatus.

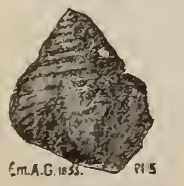


Bellerophon bilobatus, var. **corrugatus.**

Bellerophon bilobatus. var. **acutus.**



Cyclonema percarinatum.



Bucania expansa. (*Bellerophon expansus,*

Bucania bidorsata.

by Mr. Billin, at Campbell's quarry in Trenton limestone top beds. (O3, 190.)

I have found colonies of Trenton brachiopod shells covering slabs of limestone in the Nippenose and Oval Musquito valleys of Lycoming county.

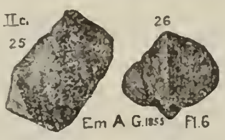
The Trenton belt in Northampton county is rich in crinoidal stems, with *Orthis pectinella*, and *Atrypa recticularis* at Martin's creek on the Delaware, and in the numerous quarries along the line crossing the Bushkill. See Prof. Prime's Report, D3, Vol. 1, already mentioned in a preceding chapter.

I have no doubt that a shrewd and zealous collector would reap a plentiful harvest by traversing the center line of Black Log valley in Huntingdon county. Good collections could be made in Friend's and Milligan's coves in Bedford, and perhaps around the edges of the McConnellsburg cove, and along Path and Horse valleys in Fulton. Trenton fossils have been found at Chambersburg in Franklin.

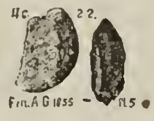
No. II c. Trenton, Birdseye and Black River.

Cyrtolites compressus

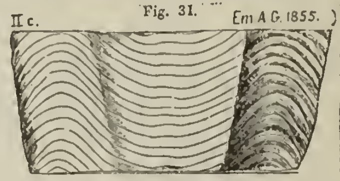
Cyrtolites subcarinatus.



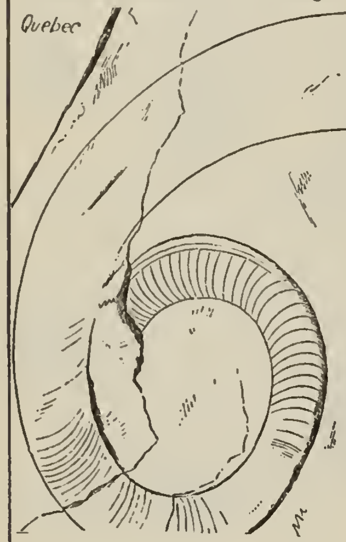
Cyrtolites trentonensis



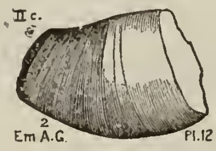
Gonioceras halli. D'Orbigny.



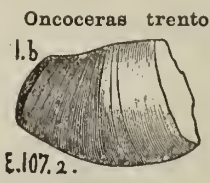
Lituites farnworthi, Billings. Pal. Foss. Vol. 1, 1861



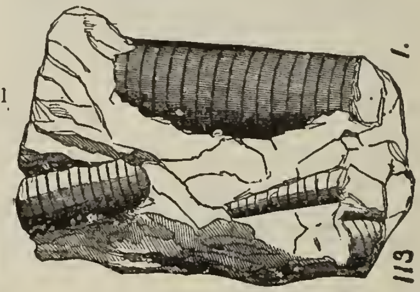
Oncoceras constrictum.



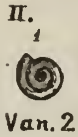
Oncoceras trentonense



rthoceras æquale. Emmons Report on

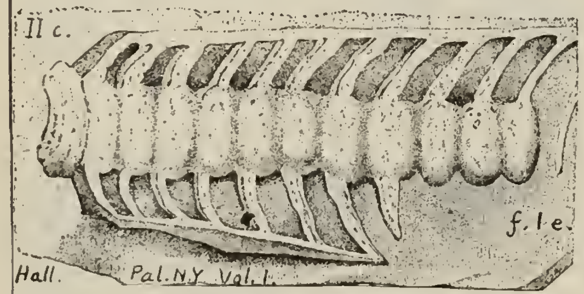


Ophileta levata

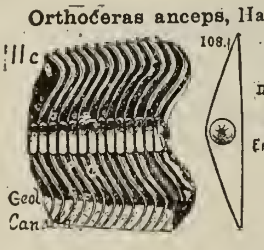


Ophileta ottawaensis, Bill

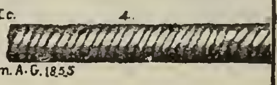
Ormoceras tenuifilum. Hall, Pal. N. Y. Vol. 1, 1849,



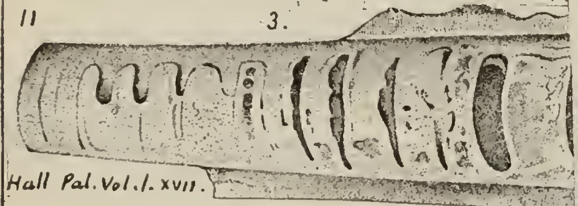
Orthoceras anceps, Hall.



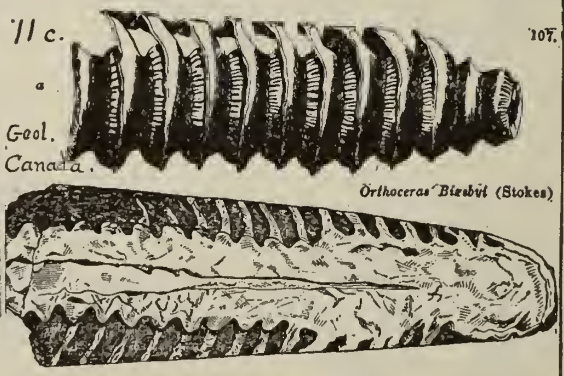
Orthoceras arcuoliratum



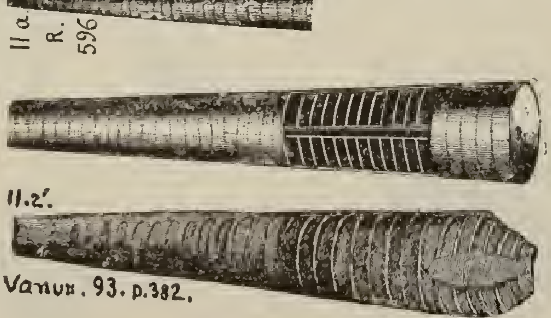
Ormoceras? gracile. Hall, Pal. N. Y. Vol. 1, 1849,



Orthoceras bigsbyi, Stokes. Geology of Canada, 1863



Orthoceras multicameratum.



Endoceras proteiforme, var. tenuistriatum.

CHAPTER XLV.

Formation No. III. Utica and Hudson River slate.

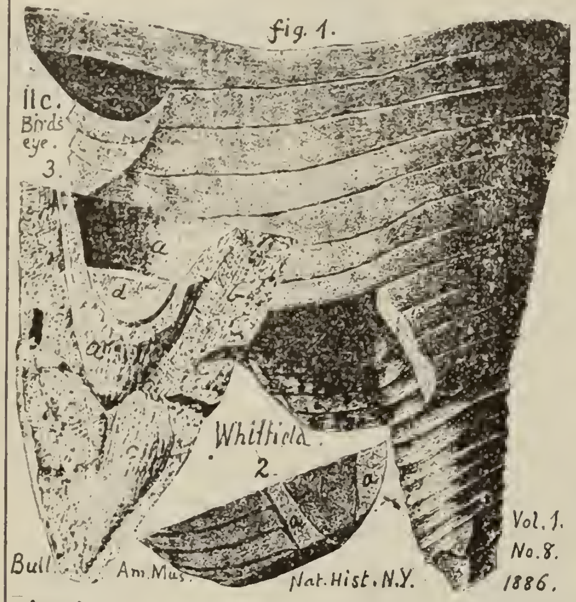
The age of limestone which has been described in the preceding chapters, was followed by an age of slate. Primeval rivers which had been pouring for thousands of years their lime and magnesian waters, nearly pure of mud, into the Appalachian sea, thenceforward for other thousands of years flowed turbid with clays, which settled to the bottom, blackened with the decomposition of innumerable animal remains mostly of microscopic size. At first the layers of clay were not continuous; thin layers of limestone, or rather lime shale were deposited between them; but these gradually became fewer and fewer, and in the end an almost continuous deposit of very slightly calcareous mud went on. At long intervals and apparently only in certain parts of the sea bottom, layers of very muddy limestone, 3 or 4 feet thick, were made. Toward the close of the age another change took place in the character of the stuff brought down by the rivers; their mud became coarser by an admixture of fine sand; the sand increased in size and quantity; and finally became the prevailing sediment.

Knowing so little of the conditions which then prevailed on the globe, so little of the character of that primeval sea, and of the continent whose rivers furnished it with stuff by which it was at last filled up, it seems audacious to attempt to sketch even in general terms the sequence of events, a picture of these operations of Palæozoic history; and every sentence of the sketch is liable to error. For no explanation can be given of the changes by land and sea which produced so radical a change of deposits as that which stares the geologist in the face wherever he crosses the Great Valley. He sees 6000 feet of the slate formation

XXXVIII

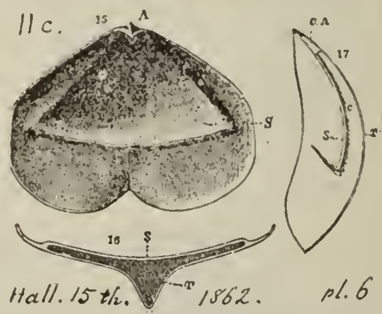
No. II c. Trenton, Birdseye and Black River.

Piloceras amplum.



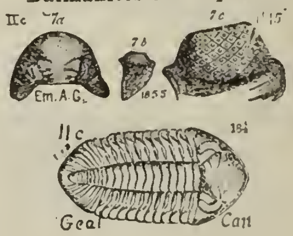
Cytherina crenulata

Pterotheca (*Clioderma*) saffordi,

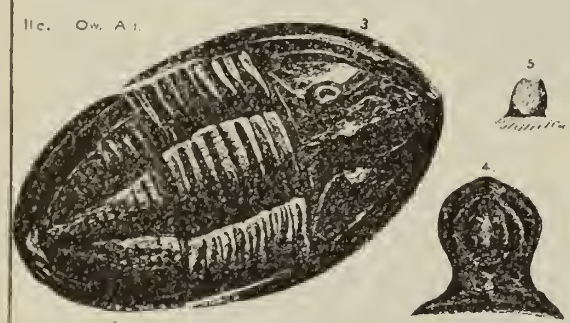


Encrinurus vigilans.

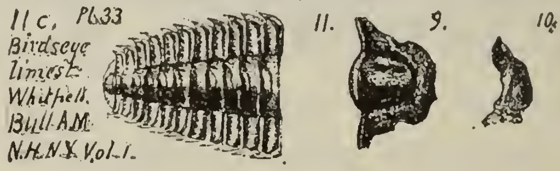
Dalmanites callicephalus.



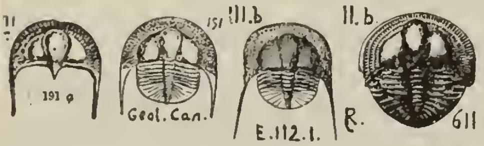
Asaphus (*Isotelus*) iowensis. Owen. Geo. Wis.



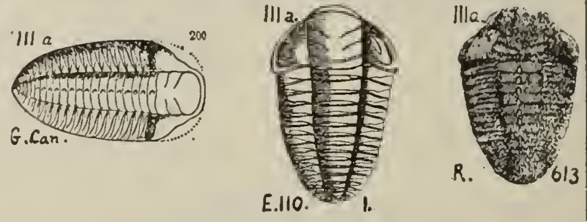
Sao ? lamottensis, Whitfield, Bull. Amer. Mus. Nat. Hist



Trinucleus concentricus (*T. tessellatus*).

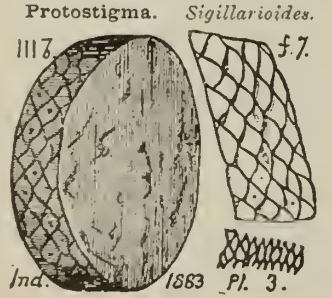


Triarthrus beckii, Green, Mon. Trilobites, 1832. *Trent.*

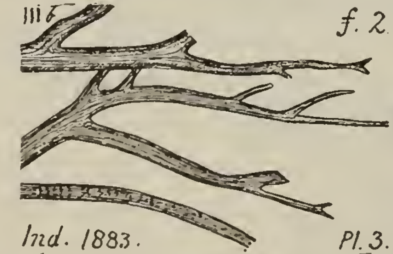


No. III a. Utica and No. III b. Hudson River.

Protostigma. *Sigillarioides.*



Psilophyton cornutum, Lesquereux.



Spirophyton cincinnaticum.

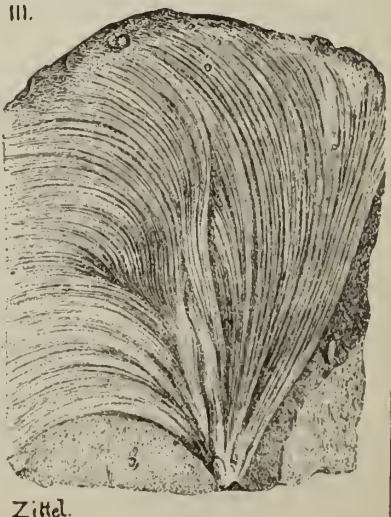
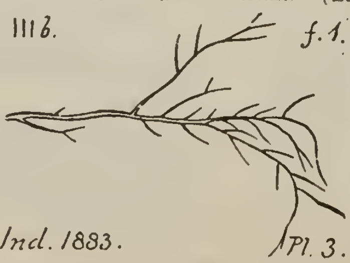


Fig. 43

Alectorurus cincinnaticus Sch. Untersilur v. Cincinnati.

Psilophyton gracillimum. (Les



Sphenophyllum primævum.

No. III, in Northampton and Lehigh counties, piled upon 3000′ of the limestone formation No. II; but it is left to his imagination to conjecture what stopped the deposits of limestone and started the deposits of slate. He knows nothing of the depth of the sea at any stage of that history.* He knows nothing of the evenness or unevenness of its floor. He cannot tell at what distance lay the continental shores from which issued the mighty rivers which furnished the sea with its sediments; nor how the general level of the ocean rose or fell upon those shores, now removing them to a greater distance, or now bringing them nearer. He only sees that the bottom slates of Formation No. III (Utica slate), were precipitated as black mud; and that the rest of the 6000 feet (Hudson River slate) is made up of thin layers of fine shale, of various tints of gray, with a few layers of impure limestone in Dauphin and Cumberland counties, a remarkable set of gravel beds in Lehigh county, and a whole series of roofing slates, with coarser sandy beds, toward the top.

One extraordinary part of this obscure history rivets our attention.

Taking the two formations together, that is, measuring the whole thickness of their sediments from the bottom of the limestone to the top of the slate, on the Lehigh and Delaware rivers, we have between seven and eight thousand feet of strata. Doing the same in Nittany valley on the upper Juniata, we have the same amount. And yet measuring the two formations separately we see that while No. II is say 2000′ on the Lehigh and over 6000′ on the Juniata, No. III is 6000′ on the Lehigh and only 1000 on the Juniata. Incautious geologists would pass lightly over so wonderful a phenomenon by simply pronouncing that talismanic word *non-conformability;* or, perhaps, giving it a little more consideration, would content themselves with

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*The *Cincinnati* (*Hudson river*) shale and limestone beds are supposed to have been deposited in *shallow water*. This is the opinion of Dr. Newberry, Prof. Shaler and Prof. J. F. James. Mr. N. W. Perry's article in the American Naturalist, Dec. 1889, illustrated with phototypes of *rain marks*, *ripple marks* and *mud cracks* of the most characteristic kind, explains them as made over the gradually sinking bottom of a shallow sea.

XXXIX.

No. IIIa, Utica and IIIb, Hudson river, continued.

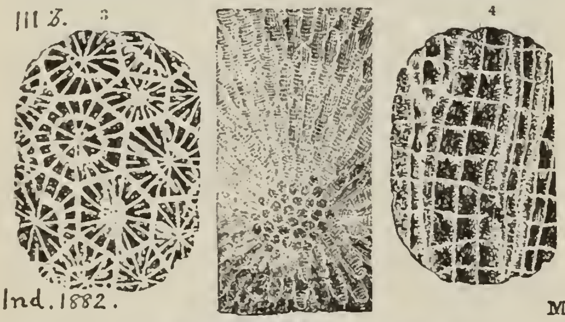
Constellaria (Stellipora) antheloidea.

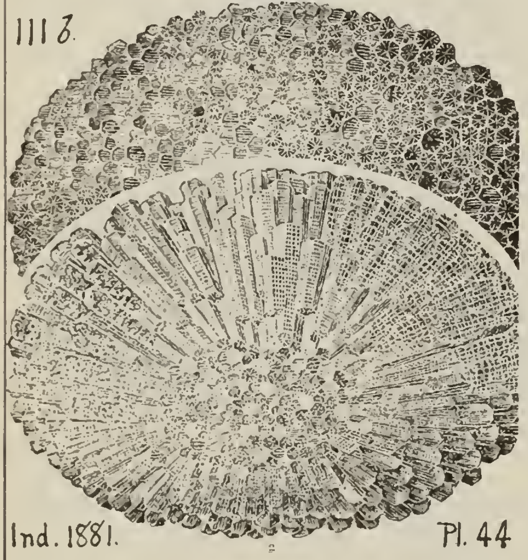
Monticulipora jamesi

Monticulipora approximata.

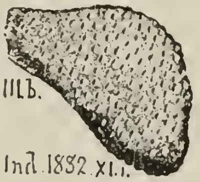
Monticulipora dallii.

Favistella stellata. (Hall, Pal. N. Y., 1847, Vol. 1. Hud

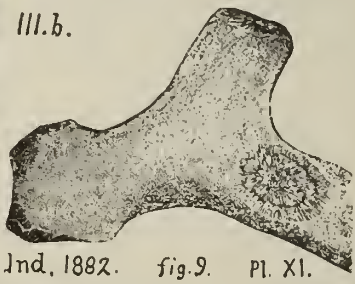




Monticulipora mammillata.

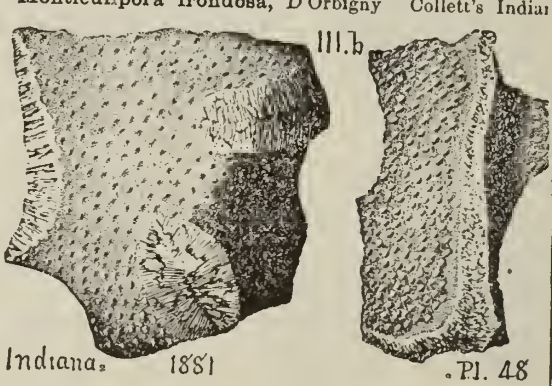


Monticulipora andrewsi. (Nich

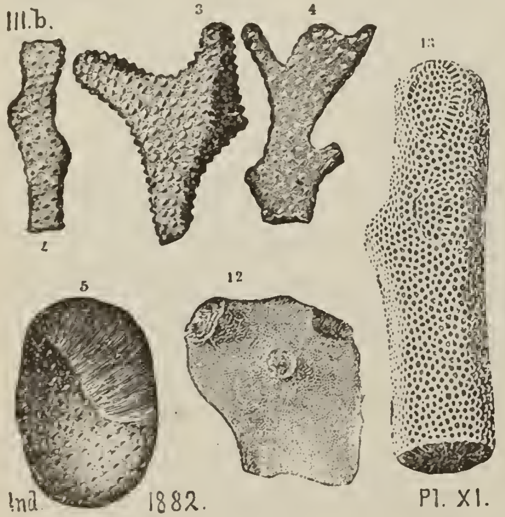


Monticulipora ulrichi.

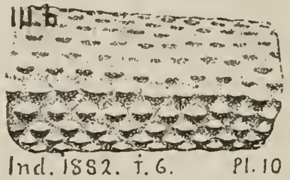
Monticulipora frondosa, D'Orbigny Collett's India



Monticulipora corals of undetermined species fig

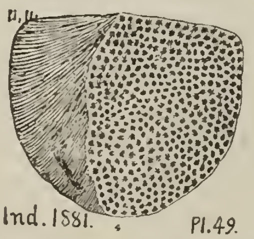


Monticulipora tuberculata,

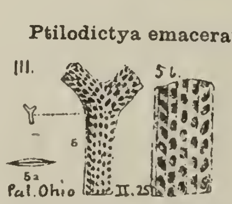


Monticulipora gracilis, (Jan

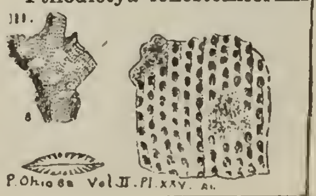
Protarea vetusta, Edw



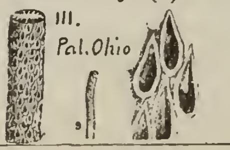
Ptilodictya emacerata,



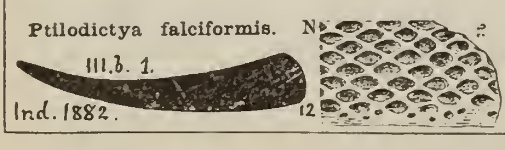
Ptilodictya fenestelliformis



Ptilodictya (?) arctipora.



Ptilodictya falciformis.



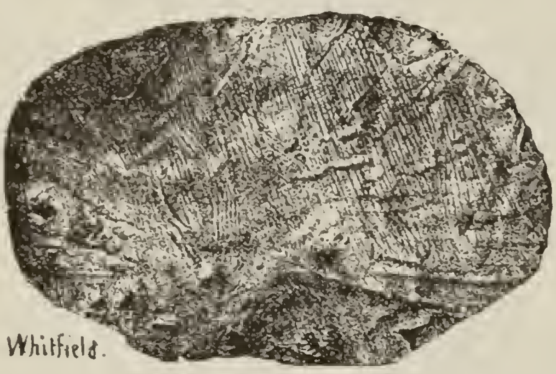
suggesting some oscillation of the sea bottom, without being able to explain how that oscillation could produce the effect. Both formations spread throughout the United States. But their thickness in Pennsylvania is diminished to one-third in the western States. There continental source would therefore seem to have been in the far east. Seeing that mud is the usual contribution of rivers to the sea, and that therefore the slate Formation No. III would probably be thicker at the east than at the west, one might be inclined to regard the limestone formation, which is so much thicker in Middle Pennsylvania than in the Great Valley, as a product of the sea itself, and not of the rivers of a bordering though perhaps distant continent. Such in fact is the conviction of many, some of whom regard all limestone beds as chemical deposits from standing water; while others regard them as made up entirely of the solid parts of animals inhabiting the sea, dying in it and sinking to the bottom. But reasons have been given in a preceding chapter for rejecting both these views; at all events without including the action of inflowing river sediments. The fact is that our science is as yet at fault in its discussion of this and other kindred subjects.

The shape and size of the Appalachian sea at the close of the limestone age were undoubtedly greatly modified by physical movements in the crust of the earth supposed to be then going on in eastern New York along the Hudson and Mohawk valleys. Around the escarpment of the Catskill mountains the slate formation No. III, and the succeeding formations No. IV and No. V are so thin as scarcely to be visible; and this can hardly be explained on any other hypothesis than that of an upward movement of the land, temporary or otherwise, and the contraction of the eastern and northern borders of the sea. Such a movement in that region could hardly have taken place without a more or less general elevation of the sea bottom, and a shallowing of its water-basin, bringing the top of its limestone deposits nearer to the surface of the water. This may perhaps set us on the track of a future satisfactory explanation of the wonderful change from reputed deep-

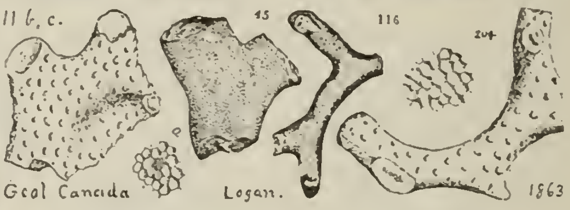
XXXX.

No. III a, Utica and III b, Hudson river, continued.

Rhombodictya discum, Whitfield.

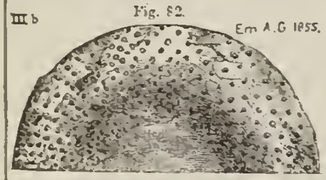


Stenopora (Monticulipora ?) fibrosa, Goldfuss.

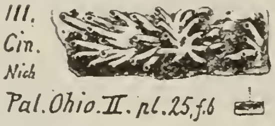


Stictopora shafferi.. (*Ptilodictya shafferi*, Meek.

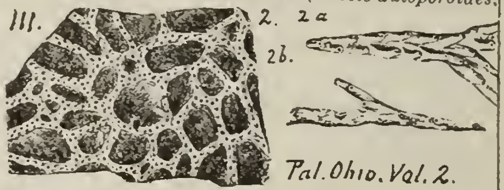
Receptaculites circularis.



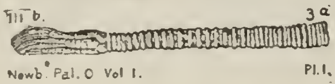
omatopora (*Alecto*) **confusa**,



omatopora auloporoides (*Alecto auloporoides.*



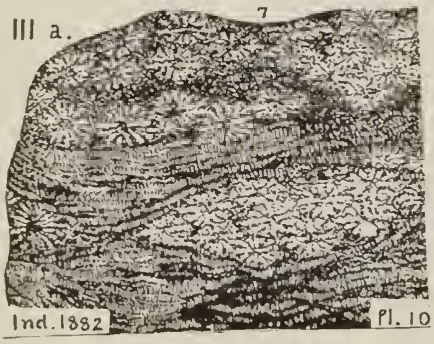
Heterocrinus. juvenis. (Hall



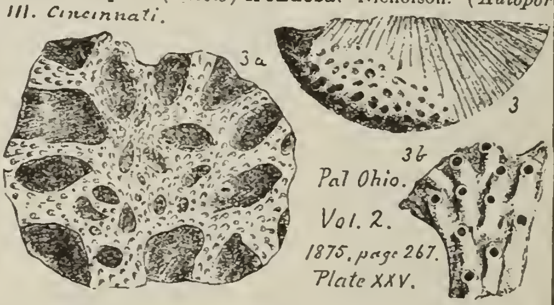
Glyptocrinus decadactylus.

Crinoid]

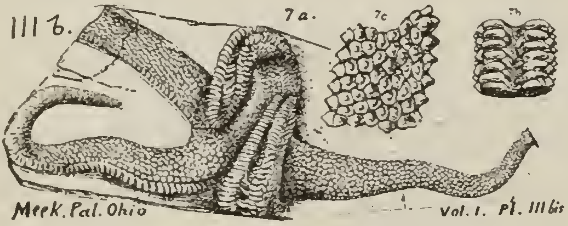
omatopora densum. (*Syringostroma*



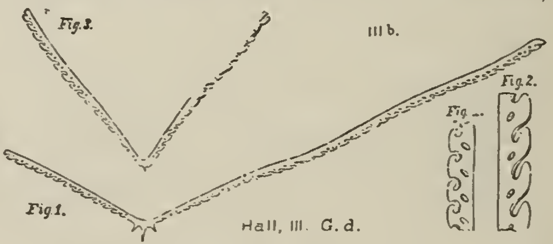
omatopora (*Aleeto*) **frondosa**, Nicholson. (*Aulopor*



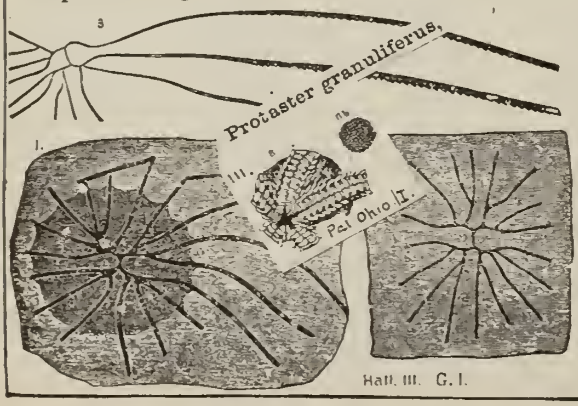
Stenaster grandis, Meek, Amer. Jour. Sc. and Art [3],



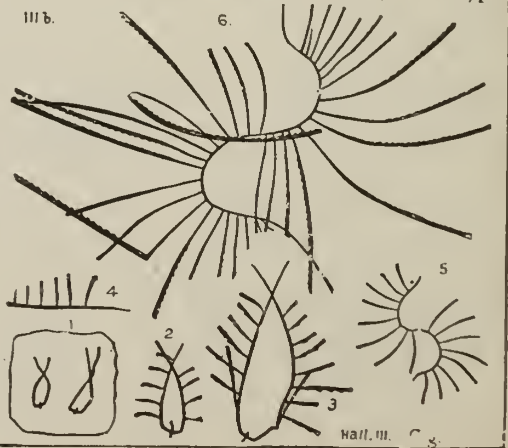
Graptolithus divaricatus. Hall. Pal. N. Y., Vol. III,



Graptolithus logani. Hall, Canada Rt., 1858, Pal., N. Y..

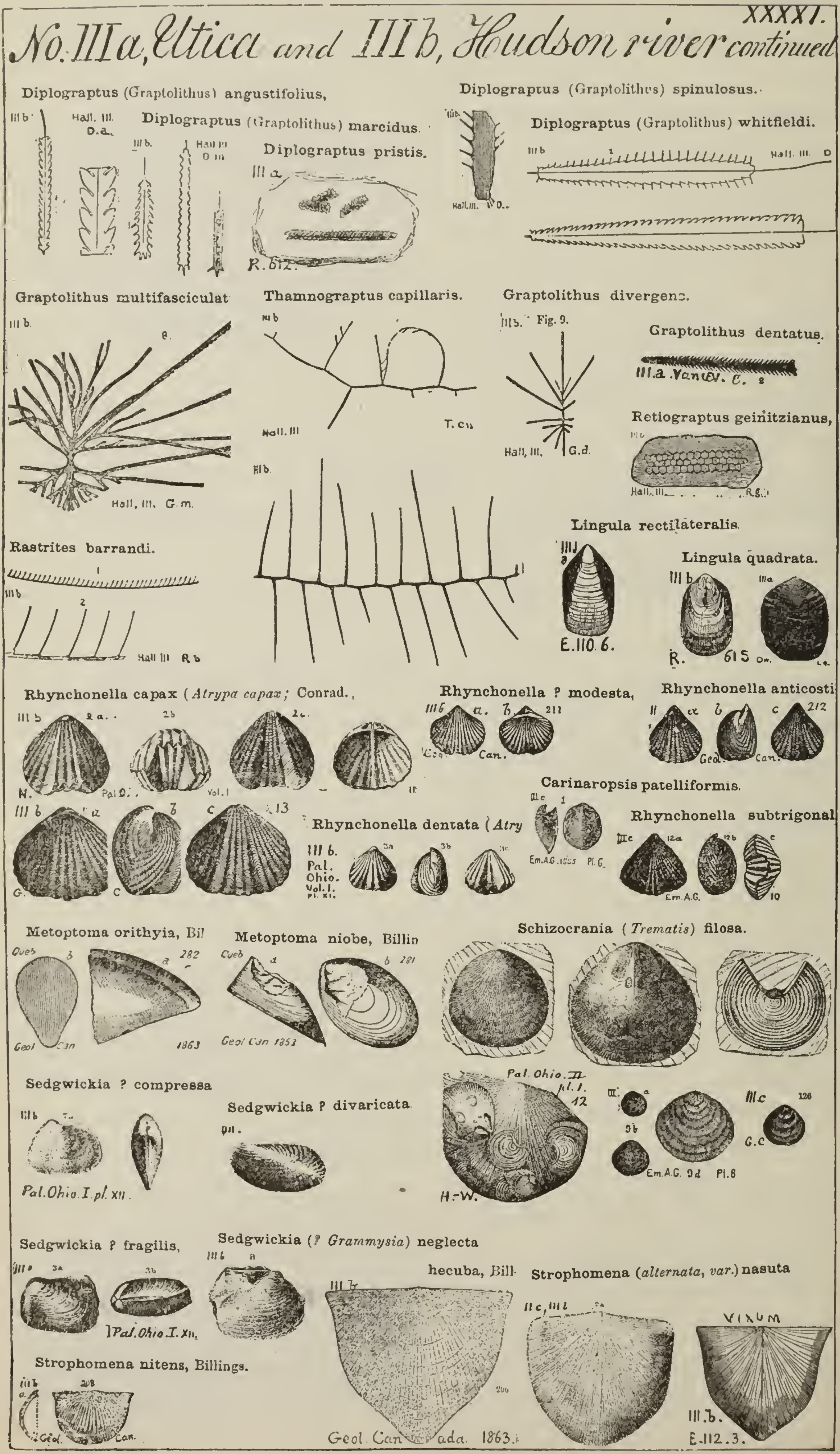


Graptolithus gracilis. Hall. Pal. N. Y., Vol. III, p.



sea limestone deposits to reputed shallow-water shale and slate deposits. But it still leaves to be considered the important fact that 6000 feet of the shale formation No. III was laid down in reputed shallow water. If we adopt that explanation we must conclude either that a shallow sea can be nevertheless as much as 6000 feet deep, and still receive near shore deposits ; or else that any rapid upward movement at the end of the limestone age must have lasted but a comparatively short time, and was followed by a long slow downward movement of the sea bottom to receive the 6000 feet of slate. It will be seen hereafter, in describing the successive formations from No. IV to No. XVII, that such a downward movement did in fact take place, continuously, or by successive instalments, and at varying rates, through the whole series of Palæozoic ages to the end of the Coal age.

The darkness which covers this whole subject is still further increased by our insufficient knowledge of the effects produced long afterwards upon the condition of the Palæozoic formations by the great earth movements in the Mesozoic ages ; for many of the phenomena usually considered as falling under the head of *original non-conformability* have been produced by the crushing and faulting of formations beneath, against and over each other. It has been rather too rashly asserted that the limestone beds of No. II in Pennsylvania along the Great Valley were plicated and lifted out of water, and subjected to the erosion of atmospheric agencies, and then resubmerged and covered over *non-conformably* by the slate beds of No. III. The old and recent surveys of the Great Valley show that there is no sufficient ground for such an assertion. On the contrary, wherever the contact of the upper beds of II with the lower beds of III are exposed to observation they are seen to overlie each other in uninterrupted sequence as if they were beds of one formation. Along the middle line of the Great Valley however, from the Delaware to the Susquehanna, the contact is obscured by the crushed, folded and overturned condition of the rocks. But from the Susquehanna to the Potomac the contact line can be studied with


XXXXI.
No. IIIa, Utica and IIIb, Hudson river continued
Diplograptus (Graptolithus) angustifolius,
IIIb
Hall. III. D.a.
Diplograptus (Graptolithus) marcidus.
IIIb.
Hall III D m
Diplograptus pristis.
III a
R. 612.
Diplograptus (Graptolithus) spinulosus.
IIIb.
Hall. III. D.
Diplograptus (Graptolithus) whitfieldi.
IIIb
1
Hall. III. D
Graptolithus multifasciculat
IIIb.
8.
Hall, III. G.m.
Thamnograptus capillaris.
IIIb
Hall. III
T.c.
IIIb.
Graptolithus divergens.
IIIb. Fig. 9.
Hall, III. G.d.
Graptolithus dentatus.
III.a. Van. Ev. C.
Retiograptus geinitzianus,
IIIc
Hall. III. R.g.
Rastrites barrandi.
IIIb
1
2
Hall III R b
Lingula rectilateralis.
IIIJ a
E.110.6.
Lingula quadrata.
III b
IIIa
R. 615
Rhynchonella capax (Atrypa capax; Conrad.,
III b
2a.
2b
2c
N.
Pal. O.
Vol. I
III b.
a
b
c
13
G.
C
Rhynchonella ? modesta,
IIIb
a.
b
211
Can.
Rhynchonella anticosti
II
a
b
c
212
Geol.
Can.
Carinaropsis patelliformis.
IIIc
1
Em.A.G. 1855
Pl. 6
Rhynchonella dentata (Atry
III b.
Pal. Ohio. Vol. I. Pl. XI.
3a
3b
3c
Rhynchonella subtrigonal
IIIc
12a
12b
c
Em.A.G.
10
Metoptoma orithyia, Bil
Queb
b
a
282
Geol Can
1863
Metoptoma niobe, Billin
Queb
a
b
281
Geol Can 1863
Schizocrania (Trematis) filosa.
Pal. Ohio. II pl. 1. 12
H.-W.
III
a
9b
Em.A.G. 9d
Pl. 8
IIIc
126
G.C
Sedgwickia ? compressa
IIIb
Pal. Ohio. I. pl. XII.
Sedgwickia ? divaricata.
IIIb.
Sedgwickia ? fragilis,
IIIb
3a
3b
Pal. Ohio. I. XII.
Sedgwickia (? Grammysia) neglecta
IIIb
a
hecuba, Bill.
IIIb
206
Geol. Canada. 1863.
Strophomena (alternata, var.) nasuta
IIc, IIIb
2a
VIXUM
III.b.
E.112.3.
Strophomena nitens, Billings.
IIIb
a.
208
Geol. Can.

comparative ease; and in the bends of Conodoguinet creek the upper limestones of No. II are seen changing, by a system of alternations nearly a thousand feet thick, into the lower beds of No. III. These alternations of thin limestones, lime shales and clay shales are called the *passage beds* of No. II and III; and they occupy in that region the place in the series which the *Utica shale* division of No. III occupies elsewhere.

In Franklin county the superposition of No. III on No. II can be studied to great advantage by means of the four anticlinal belts of II sustaining synclinal belts of III, as more fully described in Chapter XXII, page 288, above. In Berks county the same fact is made clear in another way, as the limestone belt west of the Schuylkill is set with parallel synclinal slate ridges lying in long narrow troughs of the limestone. In Lehigh county we have the best of these exhibitions in Huckleberry ridge. Here the front edge of the slate belt at Foglesville runs forward 6 miles to a sharp point within 2 miles of the Lehigh river at Allentown, while a great cove of limestone behind it encloses the Ironton mines.* All these isolated streaks and spurs of the slate No. III in the limestone valley of No. II are so many separate proofs that the slate formation overlies regularly and conformably the limestone formation No. II.

This condition of things becomes still plainer when we leave the Great Valley to study the two formations in the interior valleys of Middle Pennsylvania.

Path valley in Franklin county serves as a link of connection between the interior mountain country and the Great Valley, into which Path valley opens at its southern end. The *McConnellsburg cove* in Fulton county is the first completely isolated uprise of the limestone back of the North mountain and is surrounded by a border of overlying slate. *Horse valley* in Perry county is almost entirely floored with slate. A border of slate entirely surrounds the central limestone floor of *Kishicoquillis* valley with its three parallel slate prongs towards the east. A similar border of No. III slate entirely surrounds the irregular

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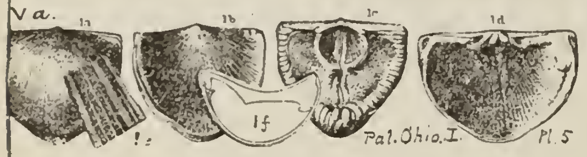
*See description in Chapter XXX, page 347, above.

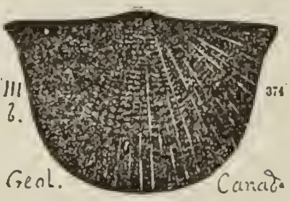
XXXXTI.

No. IIIa, Utica, and IIIb, Hudson river continued.

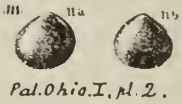
Streptorhynchus (*Strophomena*) **nutans.** (*Hemipronites*



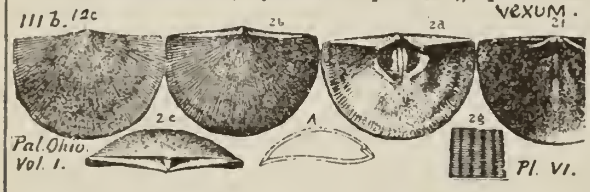
Strophodonta (*Strophomena*) **patersoni.**



Tellinomya ? obliqua ?



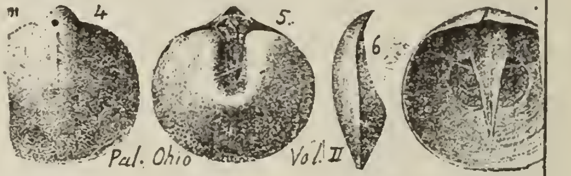
Streptorhynchus (*Leptæna, Strophomena,*) **planocon** vexum.



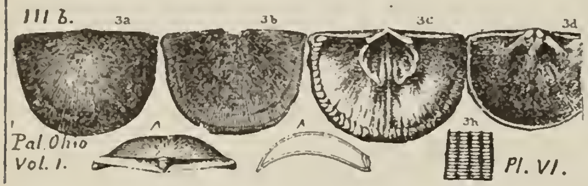
Tellinomya pectunculoides,

Trematis punctostriata,

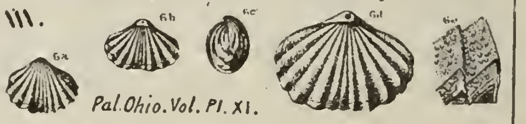
Trematis millepunctata, Hall.



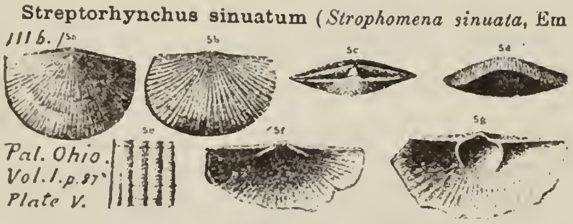
Streptorhynchus planumbonum, Hall.



Trematospira granulifera (*Retiza granulifera.*



Streptorhynchus sinuatum (*Strophomena sinuata,* Em



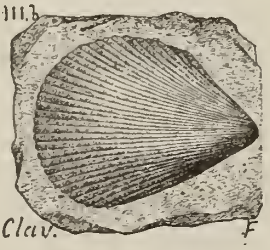
Zygospira cincinnaticesis.

Streptorhynchus sulcatum (*Leptæna sulcata,* De Ver

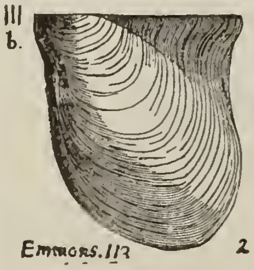
Zygospira headi. (*Athyris headi,* Bill

Ambonychia carinata.

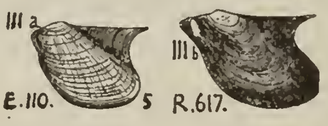
Ambonychia radiata.



Avicula demissa. (Co



Avicula insueta. Rogers, page



Cleidophorus planulatus.

Lyrodesma poststriatum. (*Nuculana postsriata.*)

Modilopsis nasuta. (*Cypri*

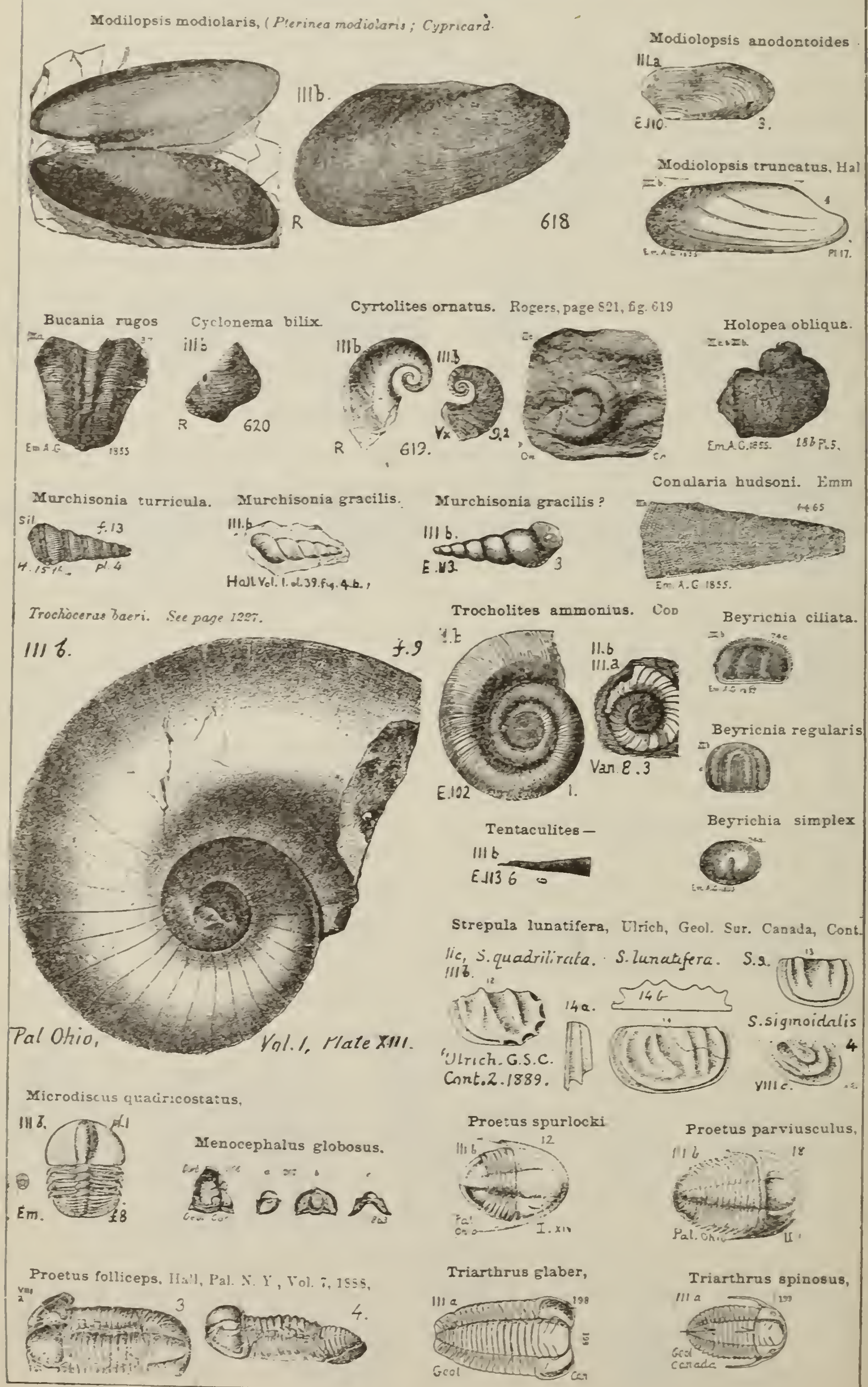
limestone area of *Penn*, *Brush*, *Nittany*, *Sinking Spring*, *Canoe* and *Morrison* valleys. Similar slate rings surround the limestone of *Nippenose* and *Mosquito* valleys in Lycoming, and *Friends* and *Milligan's* coves in Bedford. All these outcrops of No. III show the slate to be about 1000 feet thick, resting *conformably* upon the top beds of Trenton limestone, and descending conformably beneath the surrounding sandstone mountains of No. IV. It may be affirmed with confidence that in no part of the world is there a more satisfactory exhibition of regular conformity in the superposition of one great formation upon another over an extensive region.

The attention of the reader is directed to the fact that all the valleys floored with No. II and surrounded by a continuous outcrop of No. III, as described above, are in counties of middle Pennsylvania lying west of the Susquehanna river; for neither the limestone nor the slate reaches the present surface of the State anywhere east of the Susquehanna river, except in the Great Valley. When No. III goes down for the last time along the south foot of the Bald Eagle mountain in Centre county, and Dunnings mountain in Blair county, it does not rise again until we reach Cincinnati on the Ohio river, where the slate formation has received from the Ohio geologists the name of the *Cincinnati group*. Its northern outcrop, exposed in Canada, but concealed beneath the waters of Lake Ontario, appears at the western foot of the Adirondack mountains in northern New York, and in the lower Mohawk valley, where it received nearly fifty years ago the name *Loraine shales* and *Utica slate*. From Albany south it was named the *Hudson River slate*, a name by which it has been commonly known in American geology, and by which it has been habitually designated in all the reports of the Pennsylvania Geological Survey since 1874. The name of *Nashville group* was given to it by the Geological Survey of Tennessee, around the central area of which its outcrop describes a great ring.

Along the southern extensions of its outcrop No. III exhibits a remarkable change of color soon after passing out of Pennsylvania into Virginia, becoming so red by ex-

XXXXIII.

No. IIIa. Utica, and IIIb, Hudson river; concluded.



posure to the atmosphere as to give the slopes of the mountains into which it sinks a reddish soil; indicating a much larger percentage of disseminated iron pyrites throughout the mass than in Pennsylvania. From the Hudson river northward through Vermont into Canada the slate beds also exhibit an extra percentage of sulphide of iron; but in that region the pyrites instead of being distributed microscopically through the slate is concentrated into millions of separate beautifully perfect individual cubes, of all sizes from a half inch down to the tenth of an inch. Long exposed surfaces of these Vermont slates are pitted with square holes from which the crystals of pyrites have been removed by solution. In the roofing slate belt of eastern Pennsylvania such crystals are frequently seen; and some of the beds are rendered worthless to the quarrymen by the quantity of microscopic pyrites which they contain; others seem to be almost perfectly free from this noxious adulteration.

One of the sources of the pyrites was no doubt an infusion of sulphate of iron poured into the sea by primeval rivers. But we must ascribe the special abundance of pyrites in certain parts of the formation, in certain beds, and at certain localities, to some more restricted cause ; and we know of no other special cause than that of the secretion of sulphur in the tissues of animals and plants, especially of sea weed vegetation. The accumulation of sea weed on a shore will always furnish a considerable amount of iron pyrites to the shore sands ; and consequently to the deposits of the sea bottom in the neighborhood. We have a right to suppose that the general distribution of iron pyrites through the slates of No. III testify to the existence of *marine plants* in great abundance in that age, even were no traces of the existence of such plants preserved as colored impressions on the surface of the slates. We are, however, not left to any vague speculation on this subject. The remains of plants have been collected from the New York outcrop of No. III and described and figured by Professor Hall under the names *Sphenothallus*, *Buthotrephis*, and *Palæophycus*.* It is true that other imprints on the

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*Palæontology of New York, Vol. 1, 1847, pl. 68, 69 and 70.

slates have been described and figured as plants which are now believed with good reason to be merely markings left by wriggling worms, crawling crustaceans, and locomotive shell fish ; yet this does not invalidate the plant character of the remainder ; and we cannot imagine a sea inhabited by animals, even of the lowest grade, without the co-existence of a world of marine plant life on which these animals could feed.

One of the most curious facts connected with the exposures of No. III is the occurrence in some places of streaks and nuts of a sort of *anthracite coal.* Such nuts of coal, as large as a hen's egg, have been picked out from between the slates of No. III on the side of Cove mountain in Franklin county. Their composition will be given in another place. Their origin is quite unknown ; they have no connection whatever with beds of coal ; they have not been transported, but were made in the place where they were found ; they are disconnected also from each other ; they appear to be concretions or small accumulations of nearly pure carbon ; and their genesis is probably connected in some manner with that general distribution of carbon through the slate-mud which has given so many of the beds of the formation a black or blue-black color.

Besides the markings made by animals and the impressions left by plants there is a third kind of fossil forms in No. III of the greatest interest to the geologist. Some of the slate beds are made up of innumerable paper-like layers of slate connected together ; and on the surface of these black films of mud appear millions of markings resembling scattered straw, and bits of black thread. Most of them are fragments of some living organisms which at first sight would be taken for the thin stems of plants. Others are arranged together in regular forms radiating from a center or with a center line forked at both ends, the end-forks forking again. Some of these kinds have all their forks connected by a delicate almost invisible membrane, like an old umbrella with its ribs sticking out beyond the edge of the silk. Others are like oval leaves pointed at both ends and with radiating nerves, the ends of which project all round beyond the edge of the leaf. Most of those which are single fragmentary threads or narrow ribbons have one edge delicately toothed from end to end; some are toothed on one edge toward one end and on the opposite edge toward the other end. Some have both edges set with fine saw teeth; and it becomes evident that many which seem to be toothed only on one edge have been folded along the middle so as to bring all or some of the teeth of both edges to one side. Large collections of these *Graptolites* have been made both in Europe and America, and subjected to the closest examination and comparison. It is quite certain that these little creatures were a peculiar kind of floating animal, but nearly as low in the grades of life as plants; that they grew from living specks, as the leaves of a tree grow from buds; and that they produced at first a foot stalk, which expanded and multiplied itself and became gradually furnished with the necessary organs of nutrition and reproduction. A great number of separate genera and species of these *graptolites* existed in that very early age of the world; some of which continued to exist for two or three ages following, and then this whole family of living creatures disappeared from the waters of the world. In the age of No. III the Appalachian ocean and its extension through northern Europe was alive with them, incredible multitudes floating and feeding on the surface and sinking to the bottom to be fossilized in the slate-mud. It is probable therefore that the prevailing dark color of our roofing slates and other beds of No. III should be ascribed to the vast amount of carbon secreted by the graptolites, and at their death transferred to the slate-mud which was all the time accumulating at the sea bottom. It is barely possible (perhaps if we knew more about it we would say it was quite possible) that colonies and conglomerations of graptolites in some places were dense enough to account satisfactorily for the thin streaks and nuts of coal mentioned above. We may imagine that the graptolites floated mainly at the surface of the water and received the principal part of their sustenance from the carbonic acid which in those early ages loaded the atmosphere more heavily than now;

and that this manner of feeding brings the graptolite life into close analogy with the plant life of all ages, the leaves of trees receiving their sustenance in like manner from the air; but we must not forget that microscopic life has always pervaded the world, furnishing the chief food of all lower orders of creatures.

The relations which existed between these curious animals, the graptolites, and other animated inhabitants of the Appalachian sea the solid shells of which are also abundant at some of the outcrops of Formation No. III is a subject of mere speculation. Whether the graptolites had any intercourse, friendly or hostile, with the multitudes of free-floating crinoids, or with the submarine meadows of stone lilies waving their calcareous heads upon long-jointed stalks rooted in the mud, and spreading their locks of calcareous hair abroad in search of microscopic food, we cannot tell. Nor do we know what intercourse there was between these crinoidal animals and the innumerable shell-fish of various classes, kinds and species which then lived. A great variety of species have been figured and described. Most of them persisted through the whole slate age, then perished to be seen no more in higher formations; so that a collection of fossils of No. III is quite sufficient to distinguish this formation from all preceding it and from all that followed it in geological history; and quite sufficient to identify the outcrops of No. III wherever they may be encountered in Europe or America.

The amount of *coralline life* in the Utica and Hudson River age was very great and a variety of beautiful forms are figured by Hall in plates 75 to 78 of his first New York volume, and by Newberry in plates 1 to 4 of the first volume of the Palæontology of Ohio.

A considerable variety of shells have also been preserved in these two formations. Among BRACHIOPODS were species of *Lingula*, *Leptaena*, *Orthis*, *Atrypa*, *Orbicula*, *Strophomena*, *Zygospira*, *Rhynchonella*, *Retzia*, *Nuculites*, *Cypricardites*, *Megambonia*. Of LAMELLIBRANCHS were species of *Avicula*, *Ambonychia*, *Modiolopsis*, *Orthonota*, *Lyrodesma*. Of GASTEROPODS there were species of *Murchisonia*, *Pleurotomaria*, *Bellerophon*, *Cyrtolites*. Among CEPHALOPODS were species of *Endoceras*, *Orthoceras*, *Ormoceras*. Of TRILOBITES there were various species of *Dalmanites*, *Acidaspis*, *Ceraurus*, *Proetus*, *Asaphus*, *Calymene*.

Previous to Dr. Walcott's publication in 1890 of his discovery of *fish remains* on the Colorado river it has been the opinion of all geologists that no vertebrate animal yet existed. Not a trace of any kind of fish has elsewhere been detected in the first four formations of the Palæozoic series; the earliest known fish-spine was found by Professor Claypole in one of the beds of Formation V, in Perry county (to be noticed hereafter); nor is there any *certain* evidence of the existence of land plants. As the corals of the present day pervade the trophical belt of the earth, and as a change of temperature of a few degrees is known to produce widespread destruction among the finny tribes of our present sea, the abundance of coral life and the absence of fish in the early ages conspire to testify to a high temperature of the ancient ocean water; and this agrees with our supposition of the gradual cooling of the globe.

The black *Utica slate*, and many darker layers of the Hudson River slate, especially in the western States, have been so heavily charged with carbon from the decayed bodies of the creatures which filled the sea, that hand specimens will smoke and flame in a blacksmith's fire. This has given them the mineralogical name of *fire slate* (pyroschists).

Dr. Sterry Hunt in his Tenth Chemical Essay, 1875, page 178, gives analyses of *Utica slate* composed of 53 to 58 per cent of carbonate of lime with a little magnesia and oxide of iron; the insoluble part of the rock lost 12.6 per cent of volatile and combustible matters, leaving a coal black residue. When this was heated in the open air it lost 8.4 per cent additional, making in all 21 per cent of volatile and carbonaceous matter in the rock. Very little of this however was bitumen; the most of it was of the nature of a true coal. Attempts to distill oil on a large scale from this rock resulted in the production of only from 3 to 5 per cent of oily and tarry matter, besides combustible gases and water.

It is not likely that the black slates of any part of this great formation No. III will ever be used by the business world for the distillation of oil, or the production of illuminating gas.

Such *pyroschists* or black slates have been deposited in all ages. It will be shown in a proper place that they are not only sometimes very rich in carbon, but interleaved with thin beds of coal, deceiving people into the belief that they can be profitably mined. Such is the case especially with the black slates near the botton of Formation No. VIII on the Juniata and elsewhere in the State. It will also be seen that such pyroschists usually form the roof of every true coal bed and furnish the material from which the distillation of coal oil was carried on previous to the discovery of petroleum. But in the upper or later formations the carbon distributed through the black shales was certainly derived in large part from water plants growing in pools surrounded by a land vegetation. We may, therefore, take it for granted that the carbon of the black slates of formation No. III was obtained also from the destruction of some kind of water plant vegetation, but mixed with the decayed animal tissues of shell-fish, corals, water-bugs and worms. It will be shown in describing the Oil Measures, that the quality of petroleum obtained from formations of different ages differs greatly, especially in odor; and this is part of the evidence that the older petroleums are of animal origin more than vegetable; and that the newer petroleums (in Pennsylvania) had a vegetable rather than animal origin.

In speaking of worm tracks as abundant in No. III no mention was made of the forms of the worms themselves; for it can be readily understood that such soft creatures, destitute of internal skeletons and external hard coverings would die and vanish without leaving any trace except casts of their barrows, and impressions of their movements. This is true of the whole family of sea slugs. But there were in the Hudson River Age, and also in ages subsequent, vast numbers of leeches, with horny plates in their mouths set with little tooth-like conical projections. Multitudes of the shining little cones (*Conodonts*, see Chapter XLIV, page 507, above) have been found, not only scattered separately, but in small groups, and in some instances attached to fragments of the horny plates on which they were set. What these leeches lived on is an interesting question. They are found scattered over surfaces of slate on which appear worm tracks which were probably made by the animal that owned the teeth. But the size of the animal and the efficient character of its biting apparatus would lead us to suppose that there existed then sea animals of a considerable size clad in succulent flesh ; yet no remains of that kind have been discovered.

The few limestone beds which are locally interstratified with the slates, as in Dauphin county, are too thin and muddy to make them deserving of serious mention in economical geology ; especially seeing that they crop out within two or three miles of the north edge of the limestone belt of the Great Valley. In the outcrops of No. III around the isolated limestone valleys and coves of Middle Pennsylvania also such interstratified thin limestones have been occasionally observed. As for example on the slopes above Spring Mills in Southern Centre county (426, T4). As there are no iron ore beds in No. III, nor any other metalliferous beds, this formation is of no mineral value throughout the greater part of the State. Its soil is disposed to be cold and wet ; but otherwise sufficiently fertile ; so that the No. III slopes of Bald Eagle, Tussey, Shade, Black Log, Tuscarora, North and Blue mountains are farmed by a large number of landholders, the fields extending half way up the mountain side (T4, 425).

The roofing slate belt.

In one part of the State, however, Formation No. III is of great mineral value, furnishing the finest quality of roofing, table, and school slates.

The roofing slate belt of No. III runs from the Delaware to the Schuylkill, through the northern townships of Northampton, Lehigh and Berks, where large settlements of slate workers have opened extensive quarries, and built

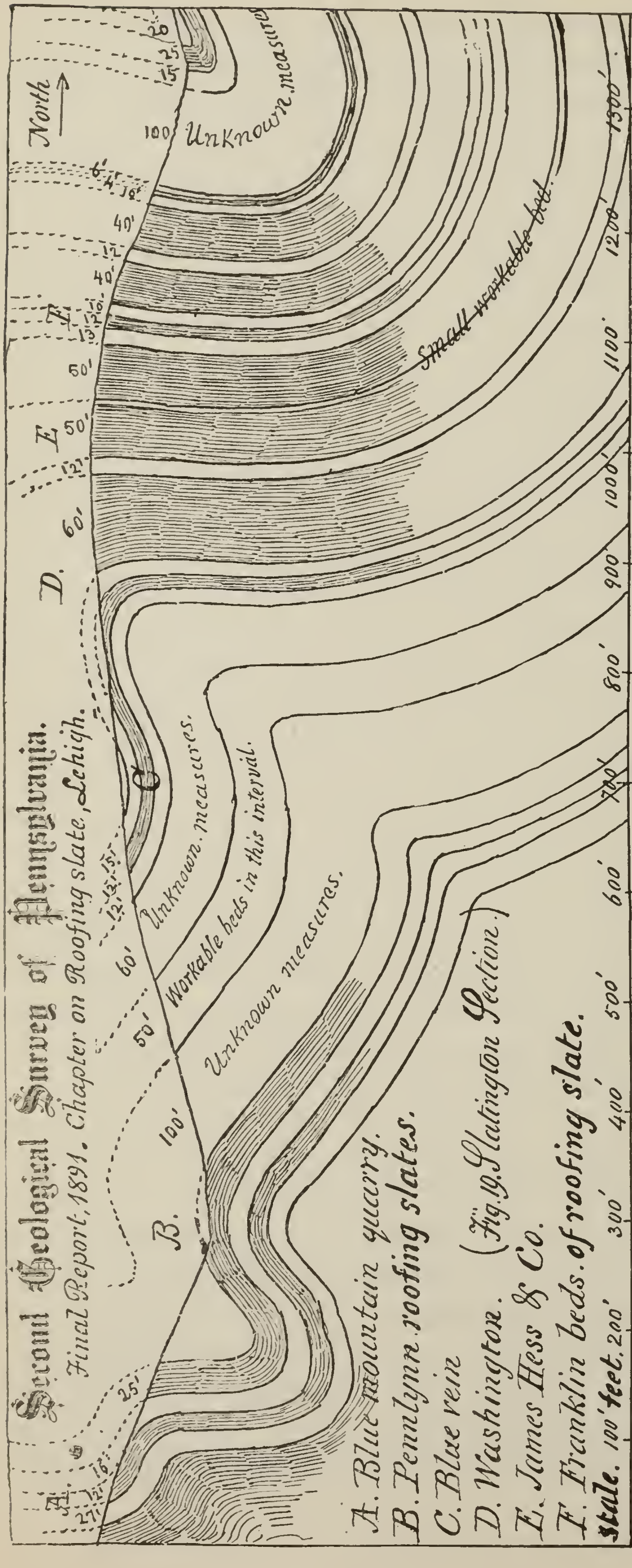
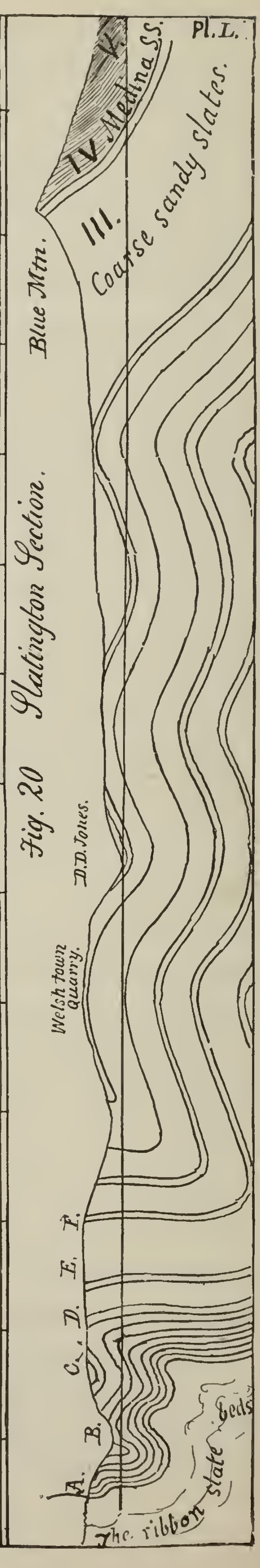


Fig. 20 Slatington Section.

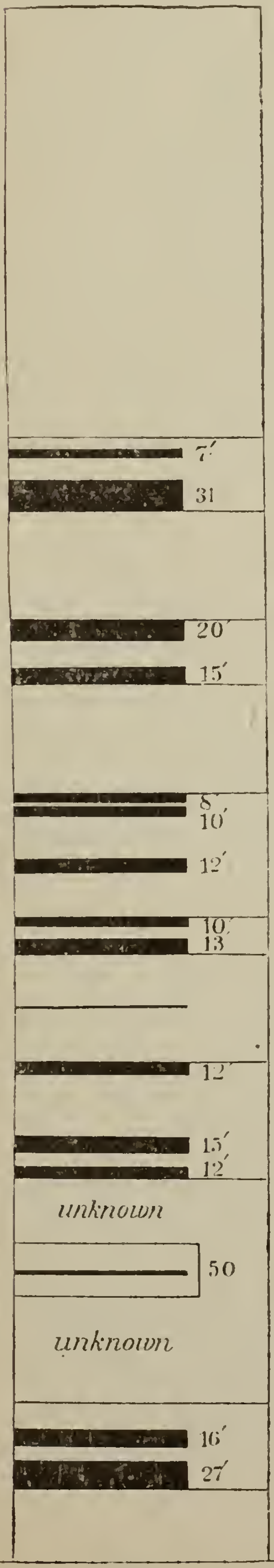


Final Report, Vol. 1, 1891.

Slatington section.

pl. LI.

(D³ page 135.)



400′	Small beds (containing some large beds.) Includes the quarry beds around Heinbacks, and around Slatedale; exact position unknown.
68′	D. D. Jones' roofing slate quarries.
100′	
60′	Welshtown roofing slate quarries.
100′	
114′	Franklin roofing slate quarries.
35½′	
100′	
111½′	James Hess & Co's slate quarries. Blue vein. Washington quarries
210′	
80′	Pennlynn roofing slate quarries. The roofing slate beds of the
150′±	Blue mountain quarry.

D5.

considerable towns connected by railroads. This district is to Pennsylvania what North Wales is to Great Britain; and in the course of time the quarries of Slatington on the Lehigh and Bangor on the Bushkill will become as worthy of the pilgrimage of geologists and tourists as the Welsh slate quarries of Tremadoc. Dr. Chance, in Report of Progress D3, Vol. I, 1883, describes more than a hundred slate quarries, old and new, some abandoned, many vigorously worked, illustrating his descriptions with photographic views of the older and deeper quarries, and giving many sections of the beds in which the workings are carried on. The section along the Lehigh at Slatington (D3, page 147) shows the folded structure of the formation and the order in which the principal valuable beds of slate occur. The measured thickness of the roofing slate part of the formation amounts to 1529 feet, divided up into small and large slate beds, separated by groups of beds which are not fit to quarry (page 135). *See plates L and L1.*

The groups of beds that are worked may be thus described. Group A (at the bottom), 12 feet; Group B, 25 feet; Group C, 12 feet; Group D, 60 feet; Group E, 50 feet; Group F, 12 feet. Groups A and B are only 16 feet apart; C is 222 feet above B, and separated from D by only 15 feet; D from E by 12 feet; E from F by 73 feet. But these only represent beds that have been successfully worked on the Lehigh river. Many others have been opened and tested but not worked.

In a general way it may be said that the upper beds of slate run parallel with the foot of the Blue mountain, at a distance of from half a mile to a mile from it. The outcrop of the lowest beds runs rudely parallel with the other at a distance of from half a mile to a mile further south. These variable distances from the Blue mountain and from each other are in consequence of the folded condition of the formation, bringing up the same beds to the surface in small and large waves again and again. The slate quarries furnish fine opportunities for studying the character and quantity of the earth movement which has thrust the whole country northward. In no other part of the slate belt No.

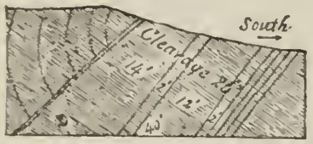
III from the Delaware to the Potomac can the exact quantities of its folding be obtained; but the openings in Lehigh and Northampton are so large and numerous, and so close together, that transverse sections can be constructed without much difficulty, and the shape of the plications can be represented to the eye (as in plate L).

It must not be supposed that the slates sent to market are the original laminæ of the beds deposited one above the other and split asunder. The beds of the formation will not thus split. Although originally deposited in leaves or thin sheets of mud these original layers have been compacted into a solid mass and cannot now be separated by human tools. Even if they could be so separated they would be useless to man, because they are bent into curves. Fortunately for our arts of life the pressure which folded the beds produced another and very remarkable effect upon them. Being a great and uniform pressure from the south toward the north, it subdivided the whole formation into millions of thin plates, perpendicular to the direction of the pressure; and these are the plates which are split asunder by the quarrymen and sold for various purposes. Thus we have *curved planes of original stratification*, and *straight smooth planes of pressure-foliation.* The most striking feature of the slate quarry to the eye of a spectator is this double-banded structure of the rocks. He sees the face of the quarry crossed by the *foliation* in straight lines, seldom vertical, but usually dipping steeply toward the south; and the quarry operations follow these bands and pay no attention whatever to the original stratified *beds* of the formation. Across the *bands of foliation* the curved ribbons of the *folded strata* are seen passing from one side of the quarry to the other in a series of waves, each stratum distinguished from the strata above and below it by either strong or delicate differences of color. Every one must have noticed in roofing slates, and sometimes in writing slates, bands of a lighter or darker tint crossing them; these reveal the original sedimentation. Every one must have noticed on dark writing slates, whitish spots, and that the slate pencil when it leaves the black

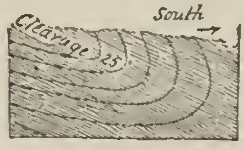
XXXXVIII

No. IIIb, Slate bedding and foliation.

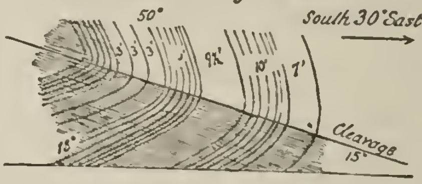
1. Snowdon Quarry. No. 5



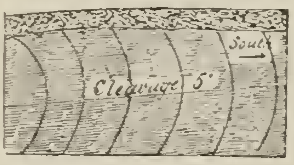
2. W. Mannus' Quarry, No 6.



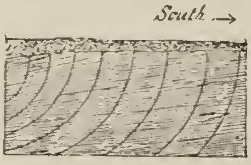
5. North Bangor Quarry, No. 26



3. Bangor Quarry, No. 21.



4. Washington Quarry, No 22.



True Blue Slate Quarry, No. 29.

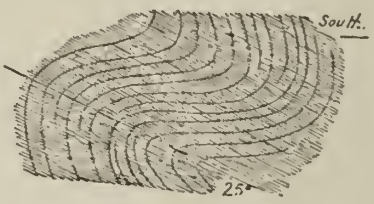
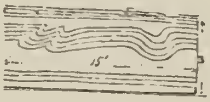


Fig 7 No. 97



8. Outcrop, No 109.

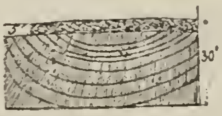


Fig. 11 Old Quarry No 2. No. 155.

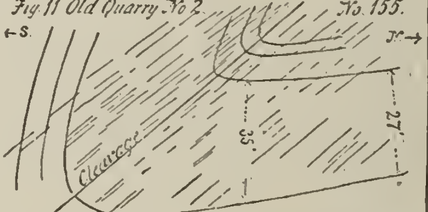


Fig. 9 Uplinger & Griffith's Q. No. 115. Uplinger & Henry's Q.

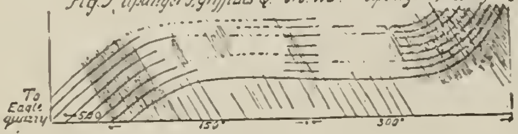


Fig. 10. Heinbach's Quarry.

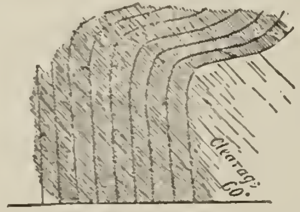
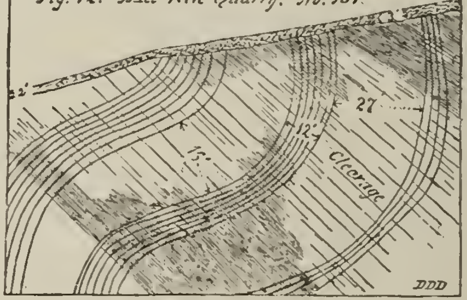


Fig. 12. 'Blue Vein Quarry. No. 157.



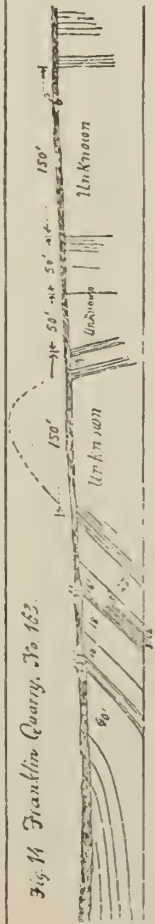


Fig. 14 Franklin Quarry. No. 163.

Fig. 13. American Quarry No. 1. No. 159.

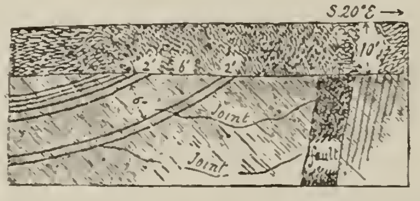


Fig 15 Blue Mountain Slate quarry. No. 169.

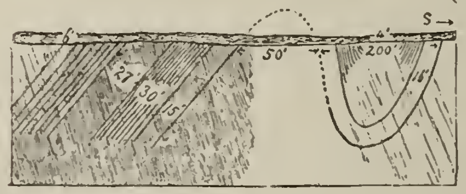
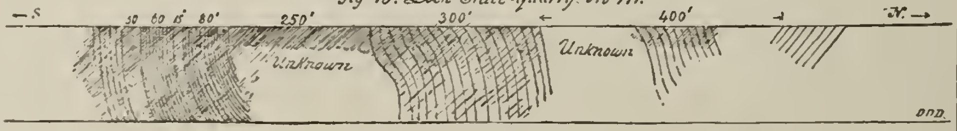


Fig 16. Lock Slate-quarry. No 171.



South.

Fig. 17 Diamond Slate quarry No. 182.

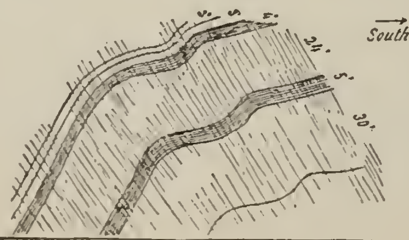
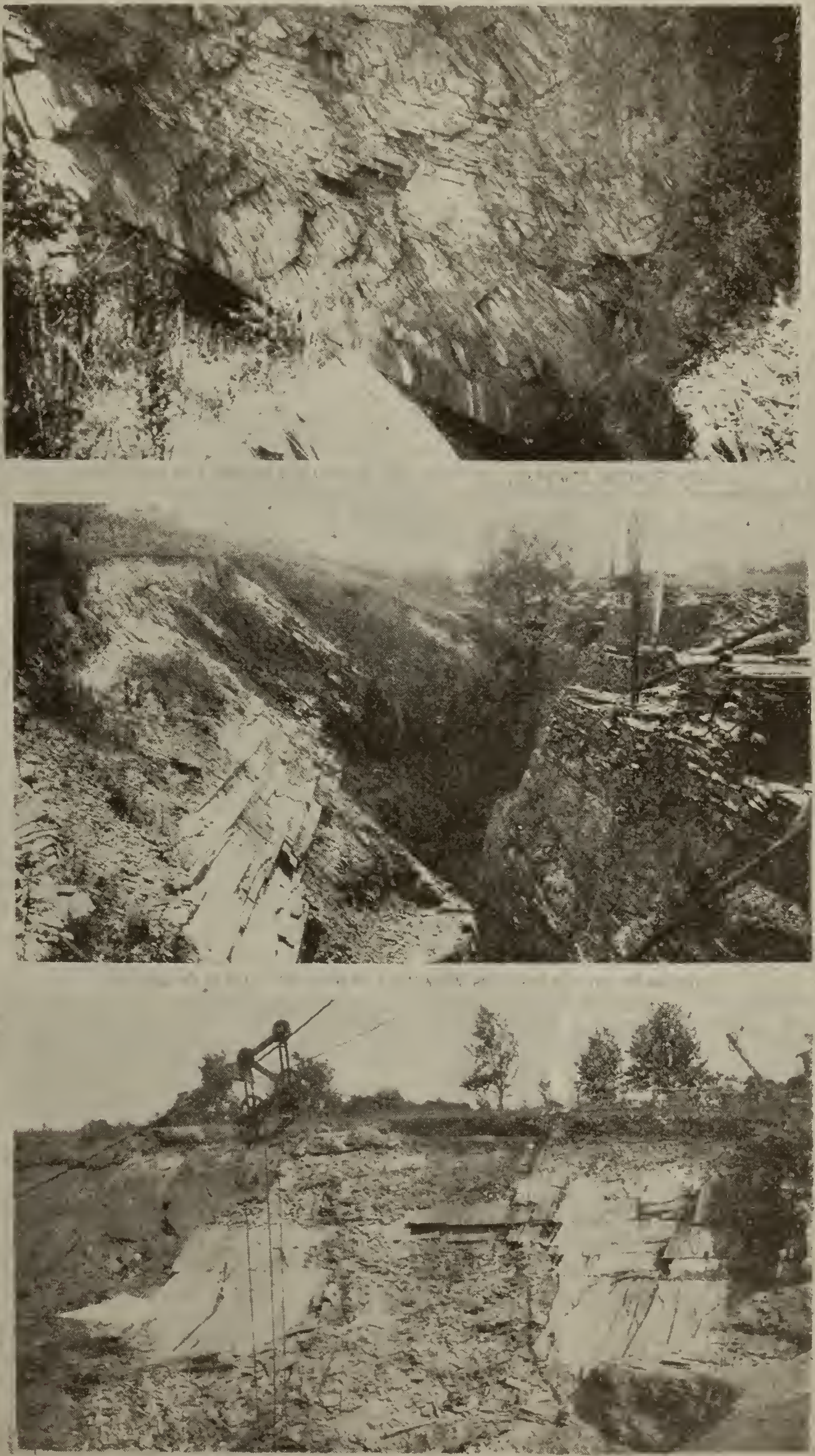


Fig. 18. Star Slate quarry. No. 195.

XXXXIV

No. III b, Slate quarries on the Lehigh.



surface and crosses such a white spot will not bite. These white spots are small pellets of clay in the original sediment mashed flat and enlarged, and reduced to an exceeding thinness by pressure. *See plates XXXVIII, XXXIX.*

Another interesting phenomenon connected with the planes of *foliation* is their frequent fan-shaped structure, especially where the original beds are sharply bent upon themselves; for, since the foliation was produced by pressure, and in planes perpendicular to that pressure, whenever the mass was sharply bent the direction of the pressure was modified on the two sides of the fold, causing the planes of foliation to diverge. This will be sufficiently explained in a more detailed description of the slate region.

As the development of the cleavage planes or slate foliation was produced by the pressure expended by an earth-movement from the south, and as the amount of this movement must have been measured by the number and sharpness of the anticlinal and synclinal rock-folds which resulted from it, we should expect the greatest amount of foliation, that is, the greatest number of workable slate beds to be in districts where folds are most numerous. At the first glance this would seem to explain the fact that there are only two workable slate beds on the Delaware river, for there the whole mass of Formation No. III slopes northward in a very regular way, with dips of 20° increasing to 35° at the top (in the Delaware Water Gap) where the uppermost Hudson River beds are seen going down beneath Formation No. IV.

On the Delaware river there is an almost total absence of the sharp small rolls and basins which are so prominent a feature on the Lehigh river; and this has given an opportunity for a fair measurement of the thickness of the formation north of the great anticlinal which crosses the river about 2 miles south of the Gap. Its *upper series of beds* measured from the base of No. IV down to Williams' old slate quarry count up say 1540 feet; the *lower series* measured from Shocks down to Belvidere counts up say 3700 feet; the total of 5240 feet ought probably to be increased to 6000.

The upper series consists of beds which are commonly more than one foot thick; and the lower series, of beds which are usually less than one foot thick (Sanders' report in D3, page 85). An independent set of measurements along the Delaware river gives an equally large estimate, and places the two slate quarry beds at 1000 feet and 2350 feet respectively beneath the base of No. IV (Chance's report).* These five or six thousand feet of rocks consist of beds of slate varying in thickness from only one hundredth of an inch up to a maximum of at least 30 feet; being nearly all of them of a dark grey bluish black color; some of them of very fine-grain; others coarser; and some coarse enough to be considered sandstone, but not continuous.

It has already been said that No. III in its frequent appearances in Middle Pennsylvania west of the Susquehanna river exhibits nothing like this thickness. At Orbisonia in southern Huntingdon it measures only 1870 feet (Ashburner F, 160). At Logan's gap in Mifflin county it measures 2304 feet.† In Blair county gaps the whole formation was estimated at only 900 feet. In Penns valley, Centre county, it is estimated at 800 feet or upwards (T4, p. 425) without any distinction being made between *Hudson* and *Utica*. In Friends cove and along the Juniata in Bedford county it seems to be about 700 feet.‡

Seeing that the roofing slate beds are confined to the eastern end of the Great Valley in Pennsylvania, it looks as if they constituted a separate formation and were not deposited to the westward; the thinning of No. III toward middle Pennsylvania being possibly explained by that fact. The belt of roofing slate, however, runs on through northern New Jersey and southern New York toward Newburgh on the Hudson; and important quarries have been opened in later years along this line.

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* In Munroe township, Lebanon county, Mr. Sanders got by construction 6000 feet for the probable total thickness of No. III. But in the geological reports of the New Jersey Survey an estimated thickness of only 3000 feet is assigned to the whole Formation No. III along the Delaware river.

† *Hudson River* 937, *Utica Upper Gray* 210, *Utica Middle Black* 302, *Utica Lower Gray* 855 feet (F, p. 55).

‡ Utica being 200 feet.

The continuation of the belt beyond the Hudson along the New York-Massachusetts line through Vermont into Canada, has given rise to the most protracted, the most vehement, and undoubtedly the most important discussion which has ever agitated the American geological world. It is called the discussion of the TACONIC SYSTEM.*

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*It commenced upon the publication in 1844 of the report of the New York geologist, Dr. Emmons, upon the rocks of northern and eastern New York; and it has been participated in by almost every geological field worker in the United States, and by several of the most distinguished geologists of Europe. It has not ceased yet; and in fact the controversial literature on the subject has been largely increased in the last few years. The hinge of the controversy is the question whether the great slate formation of the Taconic mountains in New York and of the plain between the Green mountains of Vermont and Lake Champlain is really Formation No. III of Pennsylvania and the Southern States; or whether it represents the older and underlying Cambrian system of formations.

The place where the most perfect cross-section has been made is in Georgia county, Vermont, where broad outcrops of four formations, two of slate and two of limestone, alternate, and run side by side. Some look upon these two slate belts as repetitions of each other and the two limestone belts as repetitions of each other. If there be no repetition, we have at the bottom 1000 feet of fossiliferous limestones; then 3750 feet of slate (the lowest 200 feet, Georgia shales crowded with fossils and the uppermost 50 feet a quartzite); then 1700 feet of limestone (many of the beds broken into breccia); then from 3500 to 4500 feet of slate. (Bulletin U. S. G. Survey No. 30, C. D. Walcott, 1886). If there be a repetition we have a state of things greatly resembling the geology of Lehigh and Northampton counties in Pennsylvania, namely, a limestone formation measuring 1000 or 2000 feet in thickness like No. II, overlaid by a slate formation between 3000 and 5000 feet thick, No. III. Resemblance is rendered the more striking by the presence of beds of *roofing slate* quarried along the outcrop. Those who claim no repetition, that is, who refuse to believe in the existence of a fault bringing up again the *lower* limestone and slate to the surface to make the *upper* limestone and slate, have constructed the extraordinary theory, that the *upper limestone* is a lenticular or local deposit in the body of the slate formation. A lenticular limestone formation at least 1700 feet thick seems to me a physical impossibility; and it is evident to those who have studied the Appalachian faults that a great fault must run through Georgia county, Vt., which swallows up the upper limestone at its north end, and a large part of the upper slate in the same direction. The discussion is, however, at present in the hands of palæontologists, who are not deterred by structural laws when these present extraordinary obstacles to their classification of the rocks by the fossil forms which they contain.

It is evident that, if the *Cambrian* age of the Vermont limestone and slate be forced upon us as it seems to be; and especially if the two great limestone and two great slate formations of Georgia, Vermont, be insisted upon, then it becomes impossible to explain their absence in New Jersey and Pennsylvania. It throws doubt upon the identification of the Potsdam

As the slates of No. III are seen going down beneath the northern edge of the Mesozoic formations along the Leba-

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sandstone along the foot of the South mountain under the Lehigh valley limestones; and it breaks all connection between the well-established geology of the Great Valley from Alabama to New York with its evident continuation through Massachusetts and Vermont into Canada. If the roofing slates of Georgia county Vt. underlie the Potsdam then they cannot be in the same formation with the roofing slates of No. III; and it becomes necessary to repeat again and again the great fact that at the bottom of our roofing slates of No. III lie the black *Utica* beds, and underneath these lie the uppermost beds of No. II containing *Trenton* fossils.

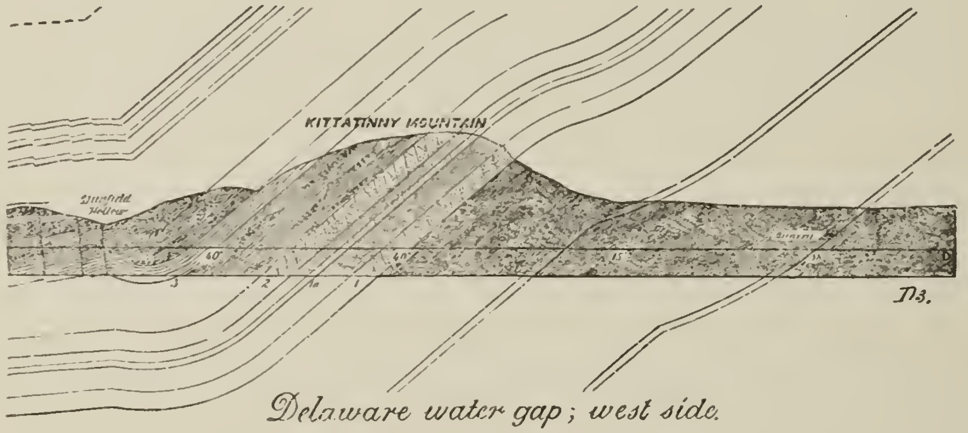
It would be a most astonishing thing if 10,000 feet of slates and limestones in Vermont and eastern New York should be wholly wanting in New Jersey and Pennsylvania; and at the same time at least 8000 feet of slates and limestones on the Delaware river should be entirely absent east of the Hudson.

It may be objected, that the 6000 feet of No. III on the Lehigh and Delaware fades away to 700 or 800 feet on the West Branch Susquehanna and upper Juniata rivers. But we must remember that the direction of this thinning is across the measures northwestward; and that the great thickness of No. III reasonably maintains itself along the line of strike from northeast to southwest. Therefore it is to be expected that No. III will be as thick in Massachusetts and Vermont as it is in the Great valley of New Jersey and Pennsylvania. It is a conclusion of equal validity that if No. III diminishes in thickness from its Great Valley outcrop northwestward toward the Allegheny mountain it must have been of equal or greater thickness in its original area southeastward toward the Atlantic Ocean; and although the destruction of this great formation over all that part of its original area has been almost if not quite complete, yet we ought to find fragments of it in southeastern Pennsylvania which have escaped such destruction. We may not be able to recognize it with absolute certainty in such preserved patches, because of the universal metamorphosis which all the rocks of southern Pennsylvania have evidently undergone. In other words, if the limestones of No. II preserved in Lancaster county, in the Chester county valley, and in similar basins still further and as far south as the Delaware State line, gradually change their aspect and become beds of white crystalline marble, we ought to expect that the slates of No. III if preserved anywhere south of the Great Valley should also present a similar difference of aspect, and show themselves as crystalline slates or schists, perhaps even as chlorite slates, talc slates or mica slates. But it is well known that limestones are always much more changed than mud rocks are; except when the mud contains an unusual percentage of magnesia and iron. Unfortunately too little attention has yet been paid to the chemical analysis of the beds of No. III; and therefore we are not in condition to speculate safely upon the degrees and varieties of crystallization which the slate beds of No. III might assume in the highly metamorphic region of southeastern Pennsylvania. Without this chemical knowledge we cannot argue to conclusion the moot question whether the South Valley Hill slate belt in Chester and Lancaster counties is a preserved part of No. III, or whether it is an older (*Cambrian*) formation brought to the surface by a great fault running along the southern edge of the Chester county valley.

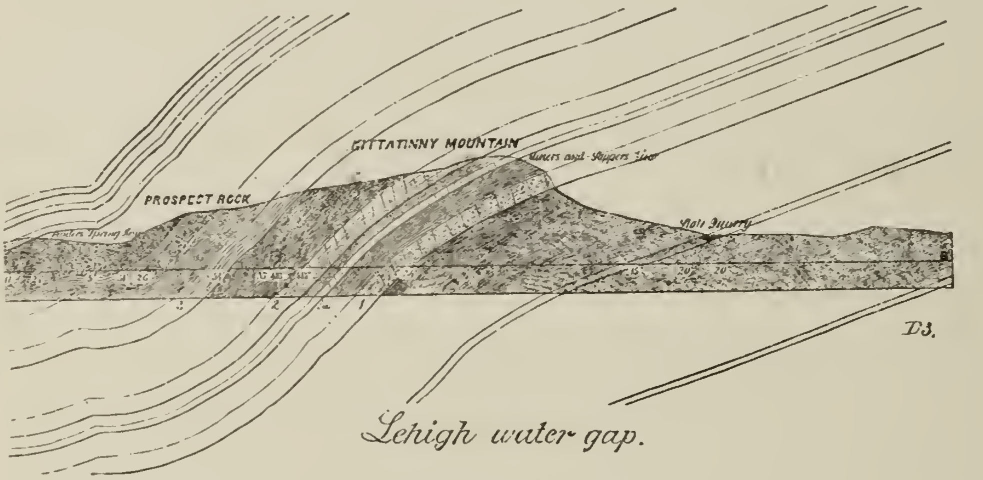
LII

No. IVa, Oneida and No. IVb, c, Medina.

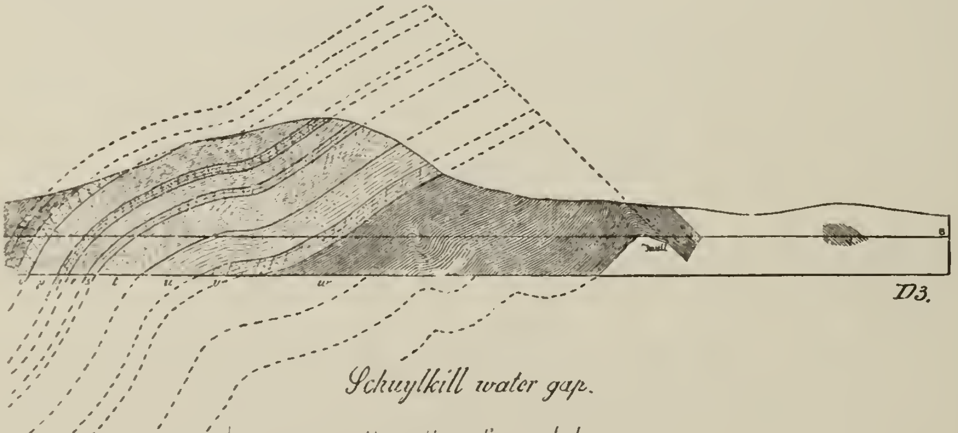
Delaware water gap; east side.



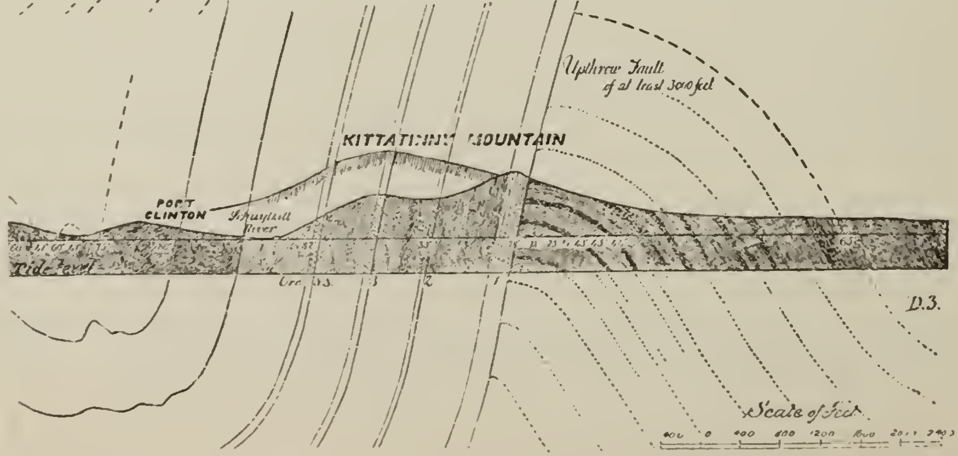
Delaware water gap; west side.



Lehigh water gap.



Schuylkill water gap.



non county southern line, and at the south foot of the South mountains between the Schuylkill and the Delaware; and as slates, apparently No. III, are brought up to the surface through the Mesozoic by the Doylestown fault, we have a right to suppose that the slates of No. III form, at least in some places, the floor of the Mesozoic belt along parts of its range; although there are good reasons for believing that the principal part of that floor consists of the eroded outcrops of the limestones of No. II, which are seen rising from beneath it, *without any slate*, at Norristown.

It is not surprising, therefore, that Dr. Frazer, in his survey of Lancaster county, observed at several places, a slate formation, very black and lustrous, which may be inferred to be *Utica slate*, because overlying the limestone formation No. II. This is rendered the more probable when, as at Brickerville, in Elizabeth twp, the black slates appear emerging from beneath the south edge of the Mesozoic, as if they were connected underground with the No. III slates of Lebanon county. They are so black that excavations have been made in them in the hope of finding coal; but their principal interest to the geologist arises from their resemblance to the Peach Bottom roofing slates which have already been mentioned as crossing the Susquehanna river at the Maryland line.

The Peach Bottom roofing slate belt projects northeastward into Lancaster county and southwestward through the corner of York county into the State of Maryland. It appears to be a closely folded basin about 9 miles long, the beds dipping nearly vertical. Eight principal quarries have been worked, some of them for many years, to a maximum depth of 200 feet. As in the Slatington region, so here, the quarries are not continuous, the roofing slate quality varying lengthwise of the basin.

It is described in more detail in Chapter XIII, page 141 above, but it requires mention here because it has been supposed to be a far south outlier of III, and its quarries have been compared with those on the Lehigh, on the strength of numerous undescribed seaweed-like fossil markings on the faces of some of the slates, which our great master in

Palæontology, James Hall, pronounced to be *possibly* a species of *Buthotrephis*, a genus of Hudson River age.*

This is a slender support for so important a theory. The fact of a roofing slate foliation of some of the beds goes for nothing; or rather is in favor of a Cambrian age, when the great slate quarries of Wales, and Vermont, and the quarries now being opened in the South Mountains of York and Adams counties are considered. It is hard to imagine the Peach Bottom slates to be III, and the great limestone formation II to be wholly absent from the district; and in its place the Chiques quartzite (see page 183 above); while the surrounding region consists of mica and chlorite schists. It hardly seems worth while to conjecture that the Peach Bottom slates represent the upper member of No. III, and the mica schist country the lower division metamorphosed regionally. It is still less worthy a conjecture that the Lehigh slate belt is a separate formation deposited where the rest of III and the whole of II were not deposited. In Pennsylvania such non-conformability of deposition is scarcely possible, however probable it may be elsewhere, in Canada for instance.†

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* Prof. John S. Stohr, of Franklin and Marshall College, Lancaster, Pa., read a paper before the Linnæan Society, in 1886, to draw public attention to the Peach Bottom fossils. Subsequently, in a letter to me dated May 20, 1886, he says that one of the specimens in his possession "seems to have a woody stalk, with pinnæ extending from both sides, but not distinct enough to determine their character. What seems to be *pinnæ* are probably lobes or branches of some fucoid like *Buthotrephis;* and what seems to be the stalk or axis is partly mineral incrustation. When I first showed a specimen to Prof. Porter, of Lafayette College, he exclaimed, "Oh, that is dendritic;" but when I showed him another he said, "No, that is evidently the impression of a plant, and it looks very much like a fern." "So far as ferns are concerned I have never yet been able to convince myself that any of the impressions I have seen are really those of ferns, although some of them strongly resemble ferns."

† Mr. Alex. Murray reported in 1879 that in all places where fossils could be obtained the Hudson river formation (No. III) overlaid *unconformably* the serpentine beds which overlie the Levis beds of the Quebec group, and that the nonconformity becomes so great in part of the islands, that the whole Hudson river formation and all the Silurian formations are wanting, and Devonian rocks lie upon the serpentine beds, which he suggests may represent the *Chazy* beds of No. II. Intrusive masses mark the break (Geol. Mag. Notice, March, 1879, p. 139).

CHAPTER XLVI.

The thickness of No. III.

The original thickness of the combined Hudson River and Utica slate formations in the region of the Great Valley cannot now be measured by reason of the excessive crumpling to which the whole deposit has been subjected, by a side pressure from the direction of the South mountains.

It is easy to see that oceanic deposits of gravel, sand and mud, when pressed sideways (by the shrinking of the size of the globe, or any other cause), and lifted thousands of feet into the air, along certain lines, while in their wet state, charged with ocean water, and therefore as plastic as putty or wax—it is easy to see that they would have their solid shapes changed in various ways.

The thick deposits of gravel and coarse sand would be folded, but not crimped ; and their original thickness would be somewhat swollen everywhere ; in some parts much more than in others ; and it is even possible that where they were originally thickest they would be artificially swollen most.

The thinner layers of finer sand would be also folded, but the folds would be smaller and more numerous. And as the finer sand deposits are always in company with mud deposits, their smaller foldings would be made to some extent at the expense of the mud layers ; and this would save the sand layers from being thickened.

The deposits of fine mud, whether the common feldspar-quartz mud of No. III, or the lime-mud of No. II—would be crushed out of all recognizable original shape ; would be swollen in whole and in parts, and distorted by myriads of folds, crimps or creases in every direction.

We have any number of illustrations of the above mentioned three modes in which the various great deposits have actually had their bulk enlarged and their shapes distorted in all parts of Middle Pennsylvania, but especially in southeastern Pennsylvania. It is only necessary to follow the banks of the river channels cut across the outcropping formations to see how the great sandrock and conglomerate formations No. IV, No. X and No. XII are grandly curved—how the smaller and finer sands and shales of Nos. V, VII, VIII, IX and XII are thrown into series of smaller folds—how the great soft mud formation of No. XI is closely complicated—and how the slates and limestones of the Great Valley (Nos. III and II) are crumpled and mashed together in thousands of pleats, which crowd each other out of line, so that in many of the outcrops the strata seem to run more *across the valley* than lengthwise of it.*

Illustrations of this condition of things in the limestone belt have been already given in this report; but here it is only needful to state the fact, which has no doubt arrested the attention of most of the inhabitants of the Valley without their assigning any geological importance to it. Geologists however have observed it with special interest because it is calculated to raise a doubt concerning the age of the formation, and its true relationship to the overlying formations, because it creates the impression that the limestone formation was crumpled and uplifted from the ocean and worn away to a level surface, and submerged again, to be covered by the slate formation. In other words, geologists have found it hard to harmonize the irregular detailed stratification of the limestone with the *conformity* of the whole underlying limestone formation to the whole overlying slate formation.

And the same apparent difficulty is reported in the case of the *irregular local dips and strikes of the slate belts*, especially along the northern or upper edge of the belt,

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*See the illustrations of folded beds in the slate quarries in Report D3. See especially Fig. II, page 119, D3, where a bed of slate is thickened in the fold. See also the numerous sections of thickened folds in the Anthracite Reports AA.

where the top slate strata are overlaid by the very regular sandstone formation of the North mountain. This has bred a suspicion that the two formations (III and IV) are *unconformable*—did not follow each other immediately in time—but that the slate formation was elevated and eroded and resubmerged to receive the long subsequent sand deposits.

But let it be once understood that if a very thick fine shaly, slaty or muddy formation lies between two very massive, coarse, sandy or gravelly formations, and all three are subjected to a great side pressure, the sands will be merely thrown into great waves, but the mud will be badly crumpled together in thousands of closely compressed small local folds—the idea of *non-conformability* at the contact of the limestone and slate belts of the Valley, and at the contact of the slate belt and the North mountain sandstone, will no longer impose upon the imagination.*

The thickness of Formation No. III.

To return then to the starting point of this chapter, it is quite impossible to measure the thickness of the slate formation No. III along the Great Valley on account of its closely folded, swollen and distorted condition. All that we can say is, that in Middle Pennsylvania, where it is not in that condition, where it is merely upturned, it has been measured pretty accurately; and while it is in some places only 1000, in other places it is 1600 feet; being thinner towards the Allegheny mountain and thicker towards the South Mountan.* How much of this difference is due to the *original* thinning of the deposit northward, and how much of it is to be set down to the diminished intensity of the side pressure as we recede from the South mountain range, cannot be known.

That it increases in thickness *eastward* is indicated by the fact that the measurable thickness increased from 700'?

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*For further remarks upon this subject see foregoing chapters on the limestone belt, and a following chapter on the non-conformity of IV upon III.

at Bedford* (Stevenson), and 900′ ? at Tyrone city (Platt and Sanders), to 1000′ at Bellefonte (H. D. Rogers),† and 1600′ at Logan Gap (H. D. Rogers).‡

As Prof. Stevenson says that it is decidedly thicker at McConnellsburg than at Bedford, and as Messrs. Ashburner and Billin got a measurement of 1870′ at Orbisonia, we must suppose it to increase also in a *southerly direction.* Taken together these data lead us to expect a great thickness in the Chambersburg valley ; and an increasing thickness from Chambersburg towards Harrisburg, Reading and Easton.

It is not so astonishing then as it otherwise would be that both Mr. Sanders and Dr. Chance gives it a thickness of 6000′ at the Schuylkill, Lehigh and Delaware water gaps.§

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* In Bedford county Prof. Stevenson estimates the total thickness of both III*a* and III*b* at 700′ ; for an outcrop 1040′ wide with dips of 30° to 60° follows Tussey mountain across the Juniata below Bedford ; and the same estimate is made along Evitt's mountain on the west side of Friend's cave. But in Fulton county, around the edge of the McConnellsburg cove, he says, the thickness is evidently greater. The Utica (III*a*) on the Bedford pike near Williams Grove is about 200′. (T2, p. 93).

† Mr. D'Invilliers calls it at Bellefonte 1011′, in Report T4, p. 304.

‡ Billin and Ashburner's measurement make it here 1632′.

§ Prof. Cook says that in New Jersey it cannot be accurately measured, but calculates from steep N. W. dips across a 2 mile belt from the Delaware water gap south to Columbia it is probably 3000′. But 2 miles at only 15° would make 3000′, and the dips are much steeper than that; see sections in Reports G6, and D3.

The latest precise thickness of the formation was got (in 1886) by my lamented assistant, Mr. C. E. Ashburner, from a study of the Knowersville gas well in Albany county, N. Y., 25 miles west of Albany. It struck the top of the Trenton limestone (II) at 2880′, and went 112 into that formation ; mouth of well about 500′ above tide ; top of Hudson river slate (III) 550′ above well mouth ; therefore total thickness of III, 3430′.—The lower part of the formation is calcareous. Specimens from 2500′ downward were analysed and yielded 25 per cent of carbonates, lower down 10 per cent; at the top of the Trenton the percentage suddenly rose to 60 per cent and soon to 80 per cent; continuing at that to the bottom of the boring.—The dark Utica formation (III*a*) was plainly distinguishable, lying on the Trenton, and calcareous, as stated above.—The bottom of the Lower Helderberg limestone (VI) rests directly upon the top of the Hudson river states (III*b*) *Clinton and Medina* (V, IV) being entirely absent in this part of New York. The *Cauda-Galli* (VII*b*) makes a bold cap to the mountain, and is probably the cause of the cliff which runs along the escarpment for many miles westward towards Utica.

The Clyde well in Wayne county, central New York, is said by Prof. C. S. Prosser of Cornell University to have gone through Oswego sandstone, 210′ ; shale and sandstone, 170′ ; Hudson river and Utica 650′ ; total 1030′, to top of Trenton limestone. (American Geologist, Oct. 1890, page 204.)

Whether the formation be 3000′ or 6000′ thick along the Susquehanna above Harrisburg cannot be discovered; but that it is several thousand feet thick is certain, from the fact that, although the belt is about 4 miles wide, occupying the river banks all the way from the upper part of the city to the Penn. RR. bridge in the gap, yet the underlying limestone formation is never once brought to the surface by any of the folds.

And this is the case eastward through Dauphin county, and westward through Cumberland county. Not until we go six miles into Franklin county, to within 2 miles of Strasburg, does the underlying limestone begin to appear on the sharp top of the Strasburg anticlinal, which keeps it at the surface from here on into Maryland.

The point near Strasburg where the limestone appears is about a mile from the crest of the North Mountain. Two separate exposures of slate a mile southwest of Strasburg show each a dip of 60°; and this may be taken as the dip of the whole formation from Strasburg to the mountain; which would give it a total thickness of something over 4000′.

Proceeding further west to the Bedford pike at Mercersburg, the slate belt is there only about a third of a mile wide, which, on a dip of 70° (in the limestone), would reduce the thickness to 1500′; but there is some reason to think that part of the slate formation is here overlapped by a fault at the contact of the limestone.

CHAPTER XLVII.

Character of Formation No. III.

The slate formation consists of dark mud-rocks (slate) more or less sandy; many interpolated layers of fine sandstone; a few layers of poor limestone, or limy mudstone, not to be compared in quality with the limestone beds of the southern side of the valley; and here and there, at distant points in the length of the valley, beds of sandstone so coarse as to deserve the name of conglomerate.

The slates are softer and darker in the lower part of the formation; and are sometimes quite black at the very bottom of the formation, just over the limestone No. II.*

They are harder and more sandy (and the beds thicker and more massive) towards the upper part of the formation; and here we find most of the sandstones, some of which can furnish good flag-stones, and are in fact quarried in Berks county.

These sandstone beds are mostly grey, sometimes olive, sometimes greenish in hue. The intervening slates are mostly dark grey, sometimes olive or greenish and sometimes a pronounced *red.* These colors are given to the rocks by small percentages of carbonate and oxide of iron distributed through the mass ; but nowhere concentrated into iron ore beds.

It is remarkable that the *red color* is not noticeable along the Great Valley in New York, New Jersey,† and eastern Pennsylvania until one approaches the Schuylkill river. As soon as Berks county is entered outcrops of *red slate*

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* This is the *Utica slate formation* of the New York geologists. The main bulk of No. III is understood to be the *Hudson River formation.*

† Prof. Cook speaks in one place of slates exposed in a railway cut being *reddish-yellow*, fragile and earthy, contrasting strongly with the dark blue-black solid roofing-slate variety. Geol. N. J., 1868, p. 138.

become numerous; increase in number through Lebanon county; and can be seen traversing Dauphin, Cumberland and Franklin into Maryland. In Virginia and Tennessee the whole formation gradually takes on a reddish color, and is quite red in many places.*

The place of the *red slate belt* in the formation is a matter of some moment and will be discussed after and in connection with a description of the *roofing slate belt* further on.

It is possible that the red color is one of the consequences of the decomposition of iron pyrites finely disseminated through the original mud, because *iron pyrites* itself is one of the commonest ingredients of the slate formation as a whole, and is abundant enough at some of the slate quarries to oblige their owners to reject the beds which are most infested with it. Several instances are mentioned by Mr. Sanders in report D3. Prof. Cook speaks of several localities where pyrites is disseminated through the rock mass.

But it is much more likely that the red slate beds were originally deposited as red clay, and that the presence of pyrites is merely a coincidence; for pyrites is perhaps more abundant in the roofing-slate part of the valley east of where the red rocks begin to make a show; and moreover, the sulphur of the pyrites unites with the alumina of the slate rock to produce the white efflorescence which is so often to be seen, while the iron set free is carried off by the waters. At all events there is no apparent precipitation of limonite.†

The amount of *iron* in the rocks of the slate belt must

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*This is very surprising to a geologist fresh from Pennsylvania, accustomed as he is to see the *red* formation always lying *back* of the mountain and not in front of it; and the change in III *from gray to red* going south is still further accentuated by a corresponding change in V *from red to gray.*

†To show that the amount of iron in slates and shales is not *necessarily* influential in reddening them it is only needful to compare the following analysis by Mr. McCreath:

1. Yellowish white damourite slate of Lehigh county, from the bottom of No. II, two specimens. (Report M, page 92.)

2. Red shale from the Catskill No. IX of Tioga county. (Report MM, page 372.)

3. Catskill red shale from Wayne county. (M3, page 108.)

vary within a small and narrow range. Prof. Cook gives the following analysis:

A. Ordinary bluish black Delaware Gap roofing slate.
B. Sandy massive Deckertown-pike slate.

	A.		B.	
Silica,	56.60	77.60	68.00	82.40
Alumina,	21.00		14.40	
Protoxide of iron,	*5.65*		*5.40*	
Lime,	3.42	7.32	2.68	6.06
Magnesia,	2.30		1.51	
Potash,	1.10		1.76	
Soda,	0.50		0.11	
Carbonic acid,	2.20		2.30	
Carbon [graphite ?],	2.69		—	
Sulphur,	0.57		—	
Water,	3.00		2.70	
	99.03		99.10	

The *pyrites* (sulphide of iron) so universally disseminated through the slate formation must have been one of the original constituents of the oceanic mud; for there are no traces anywhere to be found of either ancient or modern volcanic action in the Great Valley, to supply sulphur.* The amount of sulphur also, in any specimen of slate is so small that we must suppose it derived from the sea water

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	1.		*2.*	*3.*
Silica,	55.880	60.530	59.630	59.260
Alumina,	19.400	17.400	18.560	19.877
Oxide of iron,	*10.570*	*9.290*	*8.571* (*a*)	10.071 (*b*)
Lime,	.080	.080	.672	.250
Magnesia,	1.710	1.920	2.252	1.917
Water,	8.170	5.510	4.560	3.600
Alkalies,	3.760	5.270	5.109	4.855
Sesquiox. manganese,	—	—	.290	—
Sulphuric acid,	—	—	.123	.012
Phosphoric acid,	—	—	.279	.058
	99.570	100.000	100.046	

(*a*) and (*b*) are sesquioxide of iron.

Dr. Genth's analysis of the blackish Peach Bottom roofing slate, the reddish white and the greyish white damourite slates of Lehigh county (Report B, page 126) show that the green specimens had more iron than the reddish.

* The two trap dykes which cross the valley, one in Cumberland county and one in Berks county, are of so local a character that they need not be considered.

above, rather than from the earth-crust beneath the oceanic mud. But if it came from the sea waters it must be ascribed to sea vegetation; about which however we know very little, because the marks which that vegetation has left on the slate rocks are few and indistinct, especially so along the slate belt of the Great Valley. In New York state however great numbers of what seem to be sea-weed forms are found in the Hudson river slate formation No. III. At all events, we know that the ocean waters in that age swarmed with innumerable living things called *graptolites*; and if these were more animal than vegetable, still it is not to be supposed that the waters were not quite as prolific of other kinds of more strictly vegetable life, and in sufficient quantity to furnish all the sulphur required to explain the analyses. Much of this vegetation was probably of microscopic size and infinite fecundity. We cannot otherwise account for the sustenance of the innumerable swarms of animals which then populated the sea; especially the free-swimming *trilobites*, of all sizes from an inch to a foot in length. But besides *trilobites* there was the greatest abundance of other kinds of animals—chain corals, star fish, shell fish of many kinds as well as flesh-eating cuttle fish *—in other regions of the ocean, if not in the part of it which is now Pennsylvania. And a few fragments of land plants have been found, which compels us to believe that rivers brought plenty of decayed vegetation into ths sea, and therefore a percentage of sulphur. And of course the same rivers must have brought down to the sea the mud out of which our great slate formation was made. The continent must have been large from which so much mud was manufactured; and the rivers must have been huge which brought so much stuff to the sea. Its fineness shows that the mouths of these rivers were at a great distance; and probably there were vast deltas, mud-flats. If so, it is impossible not to imagine them covered with some sort of salt water vegetation, and that will help to account for the abundance of such shell fish as liked the shallows.

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* A rather dangerous term for popularizing the designation *Cephalopod*; but one can do no better.

That the deltas and shallows must have been at a great distance from the present site of our Great Valley is evident; for it is impossible to suppose 5000 or 6000 feet of mud to have been deposited in any but a deep sea basin; for if the shores had been near, some of the earlier and middle beds would have been of coarse sand and gravel; but none such were deposited until the basin had become well filled and the shores approached nearer by some change of the world's ocean level; then indeed, the upper flagstones of No. III were deposited over the older fine muds; and finally the off-shore shingle of No. IV (Oneida conglomerate and Medina sandstone) was spread over all.

These considerations are offered here not for the purpose of settling scientific questions still under discussion among geologists; but to familiarize the minds of readers of this report with the extent and complexity of our geological phenomena; and to illustrate the value of the practical rule to keep all the facts in view for explaining each one.

Quartz veins are very numerous in many parts of the slate belt. They are seldom more than an inch or so thick and usually cut across the beds, but often insert themselves between the slates.

The substance matter of these veins, which is now so glassy and brittle, was originally fluid, and deposited itself in any open crack or fissure in the rocks, however small. This fact was practically discovered by Dr. Graham of London about 20 years ago, when he succeeded in separating *silica* in a jelly-like state from other elements with which it is commonly combined as a hard rock. Graham's *gelatinous silica* (or *fluid quartz*) can now be made by any chemist and kept in bottles for a long time before it will harden into *quartz*. Nature has been manufacturing it in all ages and in immense quantities, and has put it to several particular uses, one of which is to make gems like the *precious opal*, etc.;* but chiefly to heal the wounds of the

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*A beautiful example of the use which Nature makes of gelatinous silica is the production of a kind of opal above a bamboo joint. These lens-shaped stones, called *tabasheer*, are sold for "madstones" or "snakestones" in India. See G. F. Kunz's paper on "Madstones and their Magic" in Science, Vol. XVIII, No. 459, Nov. 20, 1891, page 286.

rock formations after earthquakes, to fill up all the cracks opened in the strata (when compressed and folded and foliated like those of the slate belt) with *vein quartz.*

The material out of which nature manufactured the fluid quartz is indicated by the analyses on page 564 above.

The specimen of Delaware gap roofing slate (A), when analyzed, was found to be more than one-half *silica.* The other specimen (B) was about two-thirds *silica.* In fact, taking the whole slate belt of the great valley together, if we could analyze it as a single specimen, we should probably get from it about 60 PER CENT of *silica*, 20 PER CENT of *alumina* and the remaining 10 PER CENT would be lime, magnesia, soda, potash, iron, carbon, sulphur, oxygen, hydrogen, with traces of other rarer elements.

Thus we see that the original mud deposit was mainly *silicate of alumina* derived from the wear and tear of *feldspar* rocks on some distant continent. But a certain extra amount of *silica* came from the wear and tear of silicate rocks not feldspar ; and this extra amount was an available reserve for the natural manufacture of *vein quartz* after a long lapse of time.* For the veins had to be opened before they could be filled. The original mud had no fissures in it. When the bed of the sea was lifted into the air, dried, hardened, folded and fissured, the deposit of vein quartz took place. The whole mass was still warm as well as wet, not merely warm but hot,† and must have remained so for an indefinite number of ages since the cooling could take place only at the surface of the whole mass, now elevated 30,000 feet above its former level. The sea water still resident throughout the mass shared the high temperature of the mud deposits, dissolved a portion of their silica, and filled the cracks with vein quartz.

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*Of course the above statement is too short and simple to be in any sense complete. Chemists and geologists will fill it out for themselves. But some true and easily-seized notion of the genesis of quartz veins ought to be given to the uninitiated.

†The law of increase of heat downwards from the surface, at the rate of 1° F. per 60′ depth (added to the local invariable annual mean temperature ten feet beneath the surface) would give the rocks of No. III before elevation a temperature of melting lead, 635° F.

This operation, taking place throughout the whole 3000 feet of uplifted deposits. would have different results in the different formations. In the sand and gravel deposits (Potsdam, Medina, Oneida, Oriskany, Pocono, Pottsville) the silica would be deposited between the grains and pebbles, cementing them into a solid sheet or stratum of quartzite, sandrock, or conglomerate.* The mud deposits would not only be cemented, but cut with transverse and longitudinal quartz veins. The lime muds would receive quartz veins in abundance (as we see in the present surface sections), but an infinitely greater number of *calcite veins*—the supply of silica being limited, and the supply of carbonate of lime unlimited.

Meanwhile the tearing down of the elevated mass in the regions of eternal frost went on, and formation after formation was washed away, continually producing a lower and lower upper surface, until the present surface level has been reached; and still the waste goes on, and still the surface gets nearer and nearer to sea level.

The quartz veins of the swept away upper portions of the mass, have been carried off with the rest, into the Atlantic. But the tops of the quartz veins which are at the present surface strew the ground with fragments underneath where they once existed as solid veins. This accounts for the quantities of quartz fragments which are found lying on the present surface in many places along the slate belt. For example, on the Jordan in Low Hill township Lehigh county the ground is covered with pieces of quartz (See D3, p. 124, No. 187). A few miles south of this the veins of quartz show in the slates (No. 190, p. 124). In most of the slate of that region, quartz veins are abundantly numerous, and some of them are quite large, like the one noted in D3, page 105, No. 96, at the Northampton Slate Quarry. The insertion of the quartz between the laminæ of a slate beds, that is, following its lines of cleavage, is noted in D3, p. 122, No. 175, at the North Peach Bottom Company's quarry.

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* This is a fair way of accounting for the general quartzite aspect of the lowest, hottest and most compressed formation No. I, as compared with the higher, cooler and less compressed coarse strata of the Coal measures, No. XIII.

Flag stone layers occur in the Slate formation No. III, and many small quarries have been opened along the slate belt both in New Jersey and Pennsylvania; some of them in connection with the *roofing slate* quarries (to be described further on)—some of them having apparently nothing to do with the roofing slate strata.

The sand deposits which made these flagstone layers, were in some few places so coarse as to deserve the name of gravel beds, or conglomerate rocks, although the pebbles in them are all small. For instance, there is a pretty high ridge of land two miles long south of Slatington in Lehigh county, made rocky by loose fragments of a conglomerate.* But where the rocks are exposed on the Lehigh river, they consist of fine-grained sandstone, in a series of beds, none of them more than four feet thick, 40 feet of them being visible and the rest concealed (See D3, p. 114, No. 142).

As a rule the sandstone beds in the slate belt are fine-grained and thin-bedded. That they are very numerous, and are separated by slate beds can be seen wherever the belt is not too much folded. A very good exhibition the purpose is made in Berks county, Albany township, where the rocks are vertical. Here 500 feet of fine sandstones and dark gray slates can be measured (see D3, p. 126).†

Sometimes both the sandstone and the slate beds all have a greenish hue. Such a belt crosses the Schuylkill river at Hamburg (D3, p. 128 to 133).‡ Sometimes the slates are olive colored or red, as already mentioned. Red slates at various places along the Hamburg belt strike so as to come between the sandstone outcrops.‖ The flagstone strata quarried in the northeast corner of Perry township, Berks county, roll so as to connect them with the red slate exposures (No. 244). On the other hand the quarries about

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* Dr. T. Sterry Hunt was so much impressed by this exhibition of coarse and massive strata in the midst of the slate belt, as to imagine it a proof of the far greater age of the formation, on grounds which it is not necessary here to discuss.

† See also p. 113, No. 133, on the Lehigh; also, the Emanuel Church hill in Northampton county covered with thin sandstones, p. 105 D3.

‡ See also north of Seeberlingville, page 126, No. 198.

‖ No. 236.

Shoemakersville do not seem to have a connection with the red slate belt (No. 250, 251).

It looks as if the upper part of the slate formation No. III furnishes most of the flaggy sandstone strata. There are quarries in Berks county where the strata dip 65° towards the south, in a line which would carry them west into the spur of the North mountain. It is hardly possible therefore to assign them a position more than 1000 feet or so below the top of No. III. The flags taken out here (at J. Gilt's, D3, No. 205) have rough faces, but dress up well.

It is not safe to conclude however that the flagstone strata are confined to the upper part of the formation. They may probably be found in all parts of it. The massive flaggy sandstone outcrops south of Smithsville in Berks county are in the line of the red slate belt; and yet there are argillaceous limestone beds near them (No. 222, 223).

The mineralogical poverty of No. III.

The mineral wealth of the Great Valley is concentrated in its southern or *limestone belt.* The northern or *slate belt* is a farming district, of a fertility varying with the more or less sandy quality of the different layers of slate which come to the surface along narrow lines parallel to the sides of the valley.

As the slate formation is several thousand feet thick everywhere along the Great Valley; it might be expected that at least some of this huge series of layers would be valuable to the mining interests of the country. Not so, however. A few thin layers of poor limestone, or limy slate alone appear to attract attention. Not a single mineral ore is to be found in the whole extent of slate belt of the valley. Not even a bed of iron ore of any kind whatever worth shafting on has ever been seen or is likely to be ever seen. The whole formation seems to have been deposited in deep oceanic waters, and what metallic salts were deposited with the mud and fine sand remain disseminated through the whole so as to be practically worthless in a strictly mineral sense.

Neither Oil nor Gas in No. III.

Of late it has become necessary to give warning that neither oil nor gas is to be found by any amount of boring anywhere in the Great Valley.

Since the wonderful development of gas and oil at Lima and other towns of Western Ohio and Indiana from the Trenton limestone a thousand projects have been formed to exploit the Trenton in Middle Pennsylvania by boring down to it through the overlying slates. Some of these vain projects have disregarded the commonest rules of prospecting. For example, a well was bored north of Harrisburg where the slates stand vertical! No attention was paid to the fact that the bore hole if vertical itself must necessarily keep down always in the same rocks in which it started, at least until they turned to take a north dip. It would probably require a depth of between 10,000 and 20,000 feet for that well to strike the Trenton limestone which crops out at Harrisburg; where moreover it raises no suspicion of oil or gas.

A little science is a dangerous thing. It usually resides in words and names. The *Trenton limestone* has yielded vast quantities of gas and some oil in Ohio and Indiana; why not in Pennsylvania? Simply because the Trenton in Ohio and Indiana lies on almost a dead level, and far enough under ground (1000–2000 feet) to preserve its gas from escaping until bore-holes are provided. In the Great Valley, on the contrary, as every farmer must know who opens a quarry on his farm, the limestone beds have been upturned, even overthrown, crushed, crumpled and broken into fragments, and in that condition they reach the surface. Why is the limestone belt scarce of water? Because the upturned and broken beds easily permit the rainwater to *descend* to caverns which ramify beneath the valley in all directions. Of course the *ascent* of oil, and still more of gas, must be equally easy. If the Trenton in our State ever had any store of the precious mineral it has lost that whole store long ago. There can be none left. We have no evidence that it ever had any.

No one but an expert geologist can compare two fields so as to say that they are alike, or if they differ how they differ? Twin sons of one father may resemble each other so closely that they pass for one another in common society; yet one may be ignorant and the other learned; the one a poor man and the other a millionaire. These are matters of original constitution, and still more of circumstance. Just so with rocks of the same name, age and character, but either deposited under different conditions, or subsequently subjected to different adventures. The flat lying Trenton of the west is like the titled nobleman heir to princely estate which has remained unspoiled and still abounds for him. The Chambersburg Trenton is like a younger son who has spent his patrimony, whatever that was, in riotous living, and there is no more of it.*

Iron ore in the body of the *Hudson river formation No. III*, in its 500 miles extent of outcrop in Pennsylvania, is almost unknown. The great limonite deposits of Ironton, Moselem, and Leathercracker Cove are below the base of the formation. And yet in Eastern New York beds of carbonate of iron, partly crystallized into spathic iron ore, partly weathered into limonite, are extensively mined.†

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* "CHAMBERSBURG, PA., *July 25, 1887.*—An effort is now being made in this place to secure subscriptions for boring for natural gas. A number of Chambersburg people who have visited the gas-producing districts of Ohio believe that gas can be found underneath the surface here, because of the marked similarity of some sections of this county to the gas fields in Ohio. Subscription books are now being circulated over the town, and it is thought the necessary amount needed for the experiment, about three thousand dollars, can be obtained. Much interest is displayed in the project, for if gas should be found manufactories would undoubtedly spring up in large numbers, and the future of Chambersburg would be almost beyond estimate."

†See Siderite basins of the Hudson River Epoch, by James P. Kimball, in Amer. Jour. Science, August, 1890, p. 155. They lie about a mile east of the Hudson river, between Catskill and Germantown RR. stations, west of Copake, in a range parallel with Taconic hills, and are plicated, some of the anticlinals being overthrown and compressed westward (giving E. dips). One section reads: Dense fissile slate, weathering white, 200′+; brecciated sandstone (ferro-calcareons) 161′; sandstone passing into conglomerate (ferro-calcareous) 120′; black slate and sandy shale (interbedded) 50′; grits (ferro-calcareous, seamed with calcite) 48′; carbonate of iron (clay iron-

stone, siderite, sometimes spathic) 44′; grey slate (weathering into drab shale in the river bluffs) 662, to the bottom of boring No. 1; 1300 in all. These lower slates, which, as Hall and Mather maintained (against Emmons) are Hudson river slates, have afforded *Hudson river fossils* to Mr. T. Nelson Dale near Poughkeepsie. (Am. Jour. Sci. XVII, 1979, page 377.) The ore body is a group of clay iron stone layers separated by more or less ferruginous and calcareous shaly layers, the whole group varying from 8 to 60 feet, and evidently deposited in separate sea side lagoons, into which rivulets from the hornblende gneiss country brought magnesian deposits.

CHAPTER XLVIII.

The roofing slate beds of No. III.

These are what give an economical value to the formation, and redeem the slate belt of the Great Valley (geologically speaking) from almost utter barrenness. Were it not for its roofing slate quarries, one-half of the Great Valley would be merely farming land, without mineral wealth of any kind beneath the soil.

At present, however, there are no roofing slate quarries in the Great Valley except at its eastern end in Lehigh and Northampton counties, and in New Jersey. It is even doubtful whether or not the beds of roofing slate continue to range through the formation west of the Schuylkill river. The signs of their existence in Lebanon, Dauphin, Cumberland and Fayette counties are very scanty, although, here and there, what look like well laminated slate beds do crop out; as for example on Conodoguinit creek; where, however, the slate is spoiled with pyrites.*

It is, therefore, of considerable importance to ascertain all the geological facts which bear upon the place of the roofing slate beds in the formation where we know them to exist, in order that their outcrops may be traced along the valley where their existence has not yet been certified.

On the Delaware river Formation No. III appears divisible into two series: an upper, and a lower.

The upper series, mostly consisting of thicker beds (from one foot to many feet thick each) may be considered as occupying say 1540 feet of the whole thickness of the formation.†

The lower series, mostly consisting of thin beds (less than

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*At Alton's mill. See Rogers, Geol. Pa., 1858, Vol. 1.

† Measured by Dr. Chance, and Mr. Sanders, from the base of No. IV in the Delaware water gap down to Williams' old slate quarry.

one foot in thickness) occupies the remaining say 3700 feet, down to the limestone of No. II.*

But this subdivision of the formation is not founded upon any other distinction than the one apparent fact that there is a general tendency to heavy beds in the upper, and thin beds in the lower parts of the formation. As for the material itself there seems to be no good ground for the distinction. The whole mass, 5240 feet (and probably more) in thickness, consists of beds infinitely various in thickness, from 30 feet down to the hundredth of an inch—beds of slate, nearly all of the same uniform dark grey or bluish-black color, both coarse-grained and fine-grained—with occasional beds of sandstone, which are not persistent but either run out in a short distance or change into ordinary slate beds.†

In the section along the eastern bank of the Delaware river (see page 554) two slate quarries are shown, one on beds which come 1000 feet below the bottom sandstone of No. IV; the other 2350 feet below it.‡

The interval of 1350′ would represent the extreme thickness of the roofing-slate zone in the formation if no other quarry beds exists still lower, that is in the remaining 3000 feet of the formation down to the limestone. But of this we cannot be sure, and in fact have reason to doubt, as will presently appear.

On the Lehigh river the section is not so simple, and measurements are not so easy.‖ Here a broken arch in the slates has given rise to a fault, of unknown upthrow, half a mile in front of the center of the gap, which cuts off all

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* Measured from opposite Belvidere, up the west bank of the Delaware to R. Shock's. See Report D3, Vol. I, p. 85.

† Dr. Chance remarks (D3, p. 150) that the foreman of the quarry on the New Jersey side informed him that the *diamond saw* used there for sawing out slabs showed that the diamonds were more rapidly worn away by the fine-grained than by the coarse-grained slate. These saws cut through the slate at the rate of 1 inch in 5 minutes, 50 strokes forward per minute (D3, p. 103).

‡ This section, constructed by Dr. Chance from data obtained by him in making his contour map of the Water Gap, will be found on page 159 of Report D3; the section along the west bank of the river on page 157; the map in Report G6.

‖ See Dr. Chance's section on page 554 above, and map in G6.

measurements down from No. IV after the first 1000 to 1500 feet.* Other rolls of considerable magnitude traverse the slate belt between the fault and the Slatington quarries, which are between 2 and 2½ miles from the center of the gap.† Then we get the crumpled roofing slate belt 810 feet thick; which, although crumpled, can be measured with much certainty.‡ But the country south of Slatington, between the quarries and the limestone is so full of folds that no measurement of strata is possible; therefore the real height of the lowest Slatington quarry-bed above the limestone, cannot be made out.§

All that we can say then is (1) that the uppermost part of the great slate formation at the Lehigh water gap consists of hard sandy slate beds, alternating with steel colored fine-grained sandstones, beneath which come soft, shaly, bluish-black slates; (2) that more than 1000′ down from the top of the formation lies a zone of roofing slates at least 1500′ thick; and (3) that underneath this comes a vast ribbon-slate series.

The Slatington roofing slate zone is itself made up of groups of beds of very various qualities, each group consisting of irregularly arranged thick and thin beds, some of which (both of the thick and thin beds) have the roofing-slate character.

This section could never have been made out but for the extensive exploitation of many of the beds, several of which are brought to the surface again and again by the rolling

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* Even the thickness of the slate between No. IV and the fault is uncertain owing to small rolls at the base of the mountain; but it cannot be less than 1000′, nor more than 1500′.

† Mr. Sanders has endeavored to adjust these rolls in his long section, underneath the Slatington section.

‡ See the Slatington section on plates L and LI, p. 554 above.

§ Dr. Chance expresses the opinion that between the fault at Slatington the crumpling is so great as to suggest a possibility that the roofing slate belt may be near the bottom of the formation (No. III) and therefore not far above the limestone (No. II). But the continuation of the Slatington belt westward near the foot of the mountain to be described directly, and the measurements at the Delaware water gap already given, seem to make it quite necessary to place the Slatington beds in the upper half of the formation (D3, Vol. I, p. 151).

of the measures, as shown in plate L, on p. 544 above, the most important consecutive section in the Great valley.*

Its great value consists in its proving conclusively, (1) that the roofing-slate zone of the formation is (here at least) 1500 feet thick; (2) that in this zone lie many different beds of workable slate, some small, others of great size; (3) that although the zone is crumpled the roofing-slate beds hold their special character over a space sufficient to allow them to appear again and again at the present surface; (4) that the top of the zone is more than 1000′ down from the top of the slate formation No. III; and therefore (5) that the bottom of the zone must be a long way up from the top of the limestone formation No. II.

The section has moreover a peculiar value for geologists since (6) it shows what a small percentage of the whole thickness of No. III its roofing-slate beds make, even where those peculiar deposits make their best show. But to the business world this is an unimportant consideration. Just as a few five and ten foot coal beds in 3000 feet of coal measures, if accessible over an extensive region, can make the fortune of a whole commonwealth, so a few ten and twenty foot roofing-slate beds in 5000 feet of slate formation may suffice to supply an extensive commerce; although all comparisons between the two cases in the matter of supply and demand must necessarily be omitted.†

The roofing slate beds differ from the slate strata among which they lie (1) by the special fineness of mud out of which they were made; and (2) by the special closeness and evenness of the cross cleavage. All the slates of No. III are more or less foliated; but the roofing slates are so delicately and evenly foliated (not parallel to the bed planes, but across them at various angles) that they can be split apart into school-slates, roof-slates, billiard-table slabs, mantle pieces, and fine flags of various market values.‡

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*And yet it is imperfect, inasmuch as its continuity is broken by three concealed intervals of 100′, 60′ and 100′; besides the indefiniteness of its uppermost 400′ "which includes large known workable beds."

†30,000 tons of slates is a fair annual shipment from the Slatington district; 50,000,000 tons of coal from the anthracite region.

‡See the commercial tables in D3, p. 144 to 146.

The belt of quarries extends 30 miles across Northampton and Lehigh counties. Numerous towns and villages have sprung up along the belt—between East Bangor within 5 miles of the Delaware river, and Slatedale 3 miles west of the Lehigh river. Branch railroads have been made for their service; and new localities are being all the time explored. The belt is wide and the outcrops numerous. Some of the quarries are within a mile of the North mountain; others (Chapman's for instance) are five miles from the mountain, and two miles from the edge of the limestone of No. II. Isolated quarries have even been opened within a mile from the edge of the limestone belt. But all the successful quarries seem to belong to the Slatington zone, the outcrops of which repeat themselves in parallel lines, with alternate north and south dips, over a geographical belt of surface varying in width from one to three miles according to the number of the rolls and the flatness or steepness of the dips.

But as yet there is no proof that any one of the quarry beds extends for 30 miles or for 10 miles along the zone. The continuance for any distance of the special roofing slate quality of any layer or group of layers in the slate formation is only determined for the individual quarries, or immediately adjoining quarries. It is not certain therefore that a fine quarry bed may not exist along a line of ordinary and worthless layers. Every exposure should therefore be tested for itself. The place of a coal bed in the coal measures is a good guide for the coal prospector; but there is as yet no satisfactory proof of the fact that the place of a slate bed in the section (if discoverable) is a sure guide for the slate prospector.

Even the continuance of the Slatington zone as a whole along the Great Valley westward beyond the Schuylkill is a matter of doubt. Roofing slate quarries have been opened in the northeastern part of Berks county which undoubtedly belong to the Slatington zone; but no roofing slate quarries have been opened in western Berks, in Lebanon, Dauphin, Cumberland or Franklin counties. The explanation of the fact may be a geological one, viz: that the

Slatington zone thins away and vanishes in Berks county, going west. Or the explanation may be a financial one, viz: that exploration confines itself to the neighborhoods in which capital has been planted along the lines of already constructed railroads, etc., within near and easy reach of the principal markets. Thus far, no inducement for exploring the slate belt of the valley has been sufficiently strong to divert capital invested in the roofing slate manufacture into new channels and to distant districts. The cost of testing the value of a new coal opening is inconsiderable. The cost of testing the real value of a slate outcrop for roofing slate quarry purposes is a serious consideration. It requires the eye of an experienced slate miner to pass judgment upon a slate outcrop as to whether there is a likelihood that the bed will furnish roofing slate at a considerable depth underground ; and the actual profitableness of a slate quarry is never known until extensive quarrying has been done. This the great number of abandoned quarries sufficiently demonstrates.

Even where the qualities of fineness and foliation (splitability) is possessed by a roofing slate bed, it is sometimes made worthless by a want of evenness. The excessive crumpling of the slate belt applies sometimes to the minutest details of a quarry, and quarries have been abandoned because the slates are *twisted* or *warped*, and therefore worthless.*

The *ribbon structure* of the roofing slate beds is their most striking peculiarity. The *ribbon pattern* seems to cross the beds ; but in fact it shows the real bedding of the original deposits, and has been itself subsequently crossed by the cross-cleavage, or slaty foliation, produced by the tremendous side pressure at the time of the folding of the formation.†

The ribbon pattern is made by the different colors of

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* The Flynn quarry is said to have been abandoned for this reason (see D3, p. 104, 109). See also the *bent* slates in the Blue Vein quarry, p. 117, No. 156*b*. On the Jordan the cleavage is described as *curly* (p. 124, No. 184).

† See D3, p. 85; and Rogers' Geol. Pa. 1858, Vol. I, p. 248.

the original muddy deposits, some gray, some black.* The ribbons at the Newville slate company's quarry are "tight and some of them jet black" (D3, No. 119). Those at the Blue Vein quarry when they get under 30′ or 40′ of cover become tight (No. 156*b*). An expert slate miner judges of the value of slates partly by its *ring*.†

Westward extension of the roofing slates.

West of the Lehigh river the Slatington roofing slate beds run on towards the Schuylkill. The old Diamond slate quarry 4 miles west of Slatington (3 miles from the North mountain) was worked to a depth of 250 feet and abandoned. A quarry near Pleasant Corner (7 miles) is abandoned. The Laurel hill quarry and Lynnport quarry (11 miles) are each 60′ deep.‡

Near the Berks county line (15 miles) are the New Slateville quarries, on the two sides of a roll, both on a bed 4′ thick and both abandoned.§ On the other side of the county line in Berks county the Centennial quarry is 80′ deep; and near it an abandoned quarry on a 20′ bed. West of this no roofing slates have been found, but flagstone quarries have been opened. ‖

There arises then a practical question:—how is the roofing slate sub-division of the slate belt to be recognized along the valley?

(1) First, by its distance from the top or bottom of ths formation, as described above, *i. e.* 1000′ to 2000′ beneath the sandstone No. IV of the mountain crest,—2000′ or 3000′ above the limestone. As the latter measurement is almost

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*The best at the West Washington quarry is called "the grey bed" (D3, 98).

†Thin-bedded slates, dark blue, with a good ring (p. 113, No. 135).—The slates have a good ring, dark color and even cleavage (p. 114, No. 146).—The slates left on the pile are thick and have a poor ring (p. 109, No. 114) etc.

‡ The one lies one mile from the mountain the other two miles; at the first the dip is vertical which if it lasted all the way to the mountain would make the bed 5000′ below the sandstone; in fact the distance is much less.

§ These are 6000′ from the sandstone outcrop.

‖ In Albany township west of Kempdon; in Perry township (half-way between Leonhartsville and Virginsville) where 3′ flags 10 feet long are obtained; and near Shoemakersville.

an impossibility on account of the folds in the middle slate limestone zone of the valley the former measurement (*i. e.* from the sandstone No. IV down) is the only one available. When the dips in the foot hills of the mountain are 10° to 20°, the roofing slate belt must be looked for a mile or so from the mountain ; when the dips are 50° to 60°, it must be looked for close to the foot of the mountain slope.

But it must be remembered that the whole breadth of the slate belt is so folded, that the roofing slate zone (if it exists) will come to the surface several (or even many) times between the mountains and the edge of the limestone.

To show how important this consideration is we must go back for a moment to Lehigh county. There are three places west of the Lehigh river where roofing slate quarries have been worked nearer the edge of the limestone than the Slatington quarries are to the mountains;—thus, in N. Whitehall township (2 m. S. W. of Laury's, P. O.) the North Peach Bottom quarry (250×200′ long and 90′ deep) is only $\frac{5}{8}$ mile from the edge of the slate. Here the beds are flat, but in a downfold, and therefore cannot lie *more* than 2000′ above the limestone.

Again in S. Whitehall township between Orefield and Crackenport is an abandoned quarry on Huckleberry ridge, a long downfold (synclinal) of slate between two areas of limestone and only $\frac{3}{8}$ mile wide. Although the slates are here vertical, there is only room for 1320′ on both dips or 760′ on each dip. It seems as if we must insert a roofing slate zone near the lower limit of the foundation.

Again, east of Seipstown, and 4 miles west of the last, there is an old quarry not far back of the limestone edge, dip 70°. But here there is room enough for perhaps 2000′ of distance from the limestone up to the slate,

The truth seems to be that the main belt of roofing slate runs along more than half-way up in the formation ; but that there exists beds of roofing slate in the lower half of the formation, some of which, in some neighborhoods, may possess commercial] value. And this explains a fact first noticed by the First Geological Survey of Pennsylvania, and published by Prof. Rogers in his final report, Vol. 1, page 260:—After saying that "in no part of the slate formation" from the Susquehanna to Maryland "have the strata the structure and cleavage to produce *roofing slate*, he adds: "The nearest approximation to that useful variety yet seen occurs in the bed of the Conedoguinit, above Alter's Mill, where the rock is traversed by cleavage-planes of tolerable regularity, but its usefulness is destroyed by its containing *sulphuret of iron*." As the Conedoguinit runs along the southern edge of the slate belt, and sometimes cuts a little into the limestone belt, these *cleaved slates* must belong to the lower part of the slate formation No. III.

So in Franklin county 1½ miles southeast of Orrstown on the road from Orrstown to the railroad, there is a fine road-cutting 30 feet long by 15 feet high which showed the folded slates with a roofing slate cleavage at right angles to the folds and the accompanying local map shows how close the locality is to the southern border of the slate belt, and therefore in the lower part of the formation.

Red slate, which is *not* roofing slate, has not been observed in Northampton county; nor in Lehigh county except within a few miles of the Berks county line 1½ m. N. E. of Seiberlingsville in Weisenburg township No. 197, D3, p. 155); but in Berks county it is frequently noticed by Mr. Sanders, *e. g.* in Albany township, west of Kempdon (No. 206) red slate spotted with green; half a mile S. of Kempdon (No. 208).

Notes on the Bangor slate belt.

By R. M. Jones.

At my request Mr. Jones addressed me the following letter, embodying in his own way valuable information, which it is natural that he the pioneer of this important industry alone knows, or knows better than any one else.

Bangor, *October 10, 1883.*

"According to my promise, I write to you concerning the slate interests of our country, and particularly of Northampton county. . . . .

"The slate belt of Fairhaven and Paultney, Vermont, runs through Middle Granville and Granville Corners in Washington county, N. Y. to Pawlet Wagen. In all the above named places there are large and extensive quarries in full operation. In this part of the belt the slates are of various colors, viz: purple, green and red. This belt thence runs through North Hoosick and Hoosick Falls in Rensselaer county into Columbia county, N. Y. In this county the stratum makes a large dip which runs under the bluestone of the Hudson river division below Kingston, N. Y. This dip is over sixty miles in extent. The slates are nothing in all this distance but a conglomerate slate of no value whatever as slates. The finest slate of any value we will meet in this stratum is in Sussex county, N. J., which is of an inferior quality, properly belonging to the Chapman division, what is called the wavy or ribbon slate adapted only for local trade. In the north part of the stratum what are called the Bangor slates are considered in England and the Continent (where they know what to look for in slates) the trade mark of America, so much so that all slates shipped from this country are called Bangor slates to gain credit and reputation. The slates of Sussex and Warren counties N. J. do not amount to much. We have made a close examination of the strata between the Delaware Water Gap on the Jersey side through Warren and Sussex counties, N. J., into Orange county, N. Y., and we find the article of poor quality, more of the earthenware nature than slates, lacking the principal quality of the right kind of slates for roofing or school slates, which is toughness. There is an old quarry at the Delaware Water Gap, one on the Jersey side of the river, opened over sixty years ago by a gentleman named O. Evans, a native of Carnarvonshire, North Wales. He worked the quarry successfully for a number of years until his death, and accumulated considerable property and money through the working of this quarry. On the west side of the Delaware river near the gap, nearly opposite the Evans property, is another slate quarry near the village of Slateford, in Northampton county, Pa. This is supposed to be the *oldest* slate quarry in America, the quality of the slate is the same as in the Jersey part of the stratum; the stratum makes a southwest dip here of over five miles in length, appearing and outcropping at the Boyer farm and other places in that locality in that neighborhood. The quality of the article in those places for roofing or school slate is only ordinary. This stratum runs southwest through the Brushy Meadows Valley, East Bangor, Bangor, Penargyle and the Wind Gap. And right here I would say that the great slate center of our state is destined to be between East Bangor and about one mile southwest of the Wind Gap; a belt of slates near ten miles in length from northeast to southwest, and about one mile in width or thickness from north to south. We have a number of quarries opened and in course of opening in this section. The principal quarries are the following: First, in East Bangor the celebrated Seek-no-further property, the old Delp property the Meyers, Bray and Short property, the Star slate quarry, the Standard slate property, the Bangor Central, the Howell property, the New Bangor quarries, the Old Bangor quarries, the Bangor Royal, the Bangor Unison, the North Bangor and the Washington slate property. All of these quarries except the little Washington are in full operation; and there is more slate made in this section of the country than in any other one part of the United States. And then we must take into consideration that all these improvements are of a very recent date. R. M. Jones started nearly all these quarries since July, A. D. 1865. When he started the Old Bangor quarry on the first of August, 1866, Bangor under the name of the New Village contained less than twenty inhabitants. Now it is made into a borough of near three thousand souls; and if all who work in the borough of Bangor would live in it we would have a population of over nine thousand inhabitants. Bangor was named after old Bangor in Wales, and is considered by all the finest mining town in the State of Pennsylvania.

"Two miles and half northwest of Bangor on this slate belt is the town of Penargyl; there is a very geart body of large beds of slate in this locality. The cleavage in this place is mostly horizontal, the ribbons pitching from 35 to 45 degrees southeast. When we talk about a bed of slates we mean that portion of the rock that lays between ribbons or black streaks that run across the cleavage and grain of the slates. These streaks only occur in this stratum in the slates of New Jersey and Pennsylvania; there are no rubbons or black streaks in this stratum in the States of New York, Vermont or New Hampshire, nor Virginia; but we find the ribbon in part of the State of Maryland near the Point of Rocks. There is much difference in the quality of these ribbon slates. In some parts of the belt, especially in the north part of this stratum the ribbon slates will not do for roofing slate; but the south part of the belt is well adapted for roofing as a second quality of slates; and the fact of the matter is that all ribbons or wavy slates are nothing more than second grade of roofing materials. Still there is a large quantity of this kind of slate recommended by architects in your city and some parts of the adjoining counties. Some do it from ignorance of the true quality of slates; but the most of our architects specify this article of roofing because it pays them to do it; and the only way a second quality of slates of this kind has succeeded so well is by having percentage paid to that class of men who specify what material shall be used for the buildings. When such stuff is sent to England where they want first quality of slates they are not accepted.

"At Pen Argyl two and one-half miles from Bangor there are some very fine slate quarries opened by Jung & Co., John & Rich, Jackson & Co., Stean, Jackson & Co. and the Albion Slate Company, and Henry Fulmer. All these quarries contain large beds of slates; and slates can be produced in this section of the slate belt at from thirty to forty per centum cheaper than at other localities on this stratum; because from a large bed of slate we can make large sizes of slates. For instance, it only takes 98 slates of 24×14 to make a square of slates (that covers 100 feet of roofing); while it will take 533 slates of 12 inch by 6 inch slates to make a square (or 100 feet); and while the mechanics are making one square of 12×6 they will make five and one-half squares of 24×14 inch slates. Hence the importance of selecting slate properties containing large beds of slate. In this part of the stratum the slates are not adapted for school slates; but in the south part of this the mountain strata is where the school slates can be procured. About one-half a mile south of Pen Argyl on the Bangor and Portland Railroad a large deposit of a very fine quality of school and roofing slates was discovered by R. M. Jones of Bangor, Pa. at a place called the Grand Central quarry which are of a fine texture and very dark color. Also Mr. Jones has discovered a large plant in the north part of the slate stratum of the Pen Argyl division, which is about three miles southwest from Pen Argyl. This is a large field for enterprise. The slate stratum pitches like the waves of the sea. The general dips are about three miles. And right here I would like to draw your special attention to the fact that the same bed of slate loses its strength and toughness in its outcropping. On the down dip the article will split from the side across the grain or cleavage readily, but on the outcropping it will not split across the grain or cleavage at all. About one mile from the Wind Gap southwest, the position of the ribbon changes to nearly a vertical position, and keeps on that way principally all through Northampton county to the Lehigh river at Walnutport; and the cleavage dipping about seventy-five degrees southeast. The stratum is much conglomerated from the first mentioned points to the Lehigh river. There are a few places in and between the aforesaid points where good quarries are and may be opened. At the Little Gap Hower & Son have a good slate property. About one and a half mile southwest of the Howard quarry a good quarry may be opened on the same beds. At Berlinsville there are several quarries opened and in course of being opened. At a place called Himbach several good quarries within about two miles from Walnut Port are well adapted for both school and roofing slates, but there is considerable conglomeration in the slate belt from the Wind Gap to Walnutport, and investments should be made with great care and close examination of the premises.

"The whole width of the slate belt from about one mile above Siegfried's bridge on the Lehigh river to the Lehigh

Gap is near nine miles, but in all that distance there is not over three quarters of a mile of what might be termed a No. 1 article of slates adapted for school and roofing slates. This commences about a quarter of a mile below the Queens hotel at Walnutport and runs up the river towards the Lehigh Gap less than half a mile north of Walnutport as we proceed northeast from Walnutport. Beyond Berlinsville the good stratum is about a quarter of a mile wider. From the Little Gap to the Wind Gap the belt is much conglomerated and full of posts and crystals, which makes it a very dangerous field to operate in."*

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*Mr. Jones' letter is brought to a close with a beautiful verse of poetry in the Lower Silurian language of Wales, the age of which is not quite so remote as that of the slate belt, but nevertheless has this in common with it, that the vowel foliation crosses and obscures the original consonantal stratification. I would gladly give it here had I any friend at hand learned enough to verify the orthography.

CHAPTER XLIX.

The slate quarries of Northampton and Lehigh counties in 1882.

In 1883, Mr. Sanders' notes on the quarries of the slate belt were published in report D3, Vol. I, pages 86 to 133. No subsequent resurvey of the belt could be made, as the corps were fully occupied in other counties. New operations, especially upon the Lehigh river above Slatington, deserve description for which I have no data. The following list and short mention of the quarries as they were before 1883 will suffice to show the character of the belt.*

In Northampton Co., Upper Mount Bethel township.

1. Washington Brown's Quarries, on the slope of the mountain overlooking the Delaware, recently opened; 75×75×40 feet; 600′ below the Oneida sandstone; dip 25° N. 40° W. cleavage flat. The slates have a good color and are smooth.

2. John Morrison's Quarry, at the foot of the steep slope of the mountain, 800 to 900 feet below the Oneida; opened in 1877; 150×100 feet; five to fifteen of *Drift* on top of the slates, which are decomposed under the drift; dip 20°, N. 40° W., cleavage flat. The beds are four feet and under in thickness.

3. J. W. Williams' Quarry, half a mile northwest of Slateford; 150×150×100; 30 to 50 feet of *Drift* on top, with boulders 2 feet in diameter; thickest bed 4 feet; dip 20°, N. 10° W.; cleavage 2°, S. 10° E. At the factory the *ribbon slate* is seen in the bed at the creek fifty feet below the quarry.†

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*The numbers are those in D3, and are found on the county maps of the D3 atlas. They begin at the Delaware river and run in a general westward order across Lehigh county into Berks.

†This was the first slate quarry opened in Pennsylvania viz: by Mr. Williams about the year 1812. It is described in Prof. H. D. Rogers' Geology of Pennsylvania, Vol. I, p. 248 as follows; but the *fault* is not now visible, being buried under water and debris.

4. Emory Pipher quarry, a few hundred yards west and slightly below Morrison's quarry; abandoned; 200×100 feet; beds seen small; dip in the south and central part of the quarry flat; at the north edge 20°, N. 40° W.; cleavage 20° south.

5. Snowden quarry. (Fig. 1 p. 548)—This quarry owned by H. P. Jones is 500 yards northwest of Williams quarry; 150×150×40; 15′ of drift on top. Two of the largest beds are 14 and 12 feet thick; cleavage 26° south. At the north side of the quarry there is a fault showing, probably the same fault as described by Prof. Rogers in the Williams quarry; beds south of the fault dip 40° north. Product in 1882 about 150 squares a month. Started in 1870.

6. The quarry (Fig. 2) worked by William Manus of Scranton, on Peter Fry's farm; 300×100 feet and full of water; no large beds to be seen.

7. L. Grone's farm, 1½ miles north-east of East Bangor, a small abandoned quarry, 50×50×15; dip 20° N. 40° W., with flat cleavage; largest bed 2 feet thick; cleavage twisted.

8. J. Oyer's farm, 1½ miles north of East Bangor; 100×100 feet, full of water; beds 3 feet thick and less; 10 feet of *Drift;* dip 10°. N. 40° W.; cleavage 20°, S. 20° W.

9. Opposite Belvedere. The contact of the slates and limestones on the Delaware river shows by a high ridge. The dip is 70°, S. 20° E. and the cleavage 25°, S. 20° E. The same dip shows for three quarters a mile up the river. The slates are thin bedded, compacted together, making solid beds, in some cases 10 feet thick, between loose ribbons. From the river road up north until the road leading from Centreville to Porterville is reached, nothing but ribbon slates show.

11. C. Wolf's farm on Martin's creek half a mile east of the township line, a small excavation; dip 15°, N. 40° E.; cleavage 60°, S. 40° E.; ribbon slates.

12. East Bangor quarry No. 3, Bry & Short; north side of the railroad, east of the wagon road leading north from East Bangor; 150×50×50; dip 5°, S. 40° W.; cleavage 20°, S. 10° W.; beds rather small.

13. Old East Bangor quarry. Fisler & McKean; across the road from East Bangor No. 1; 250×150×50, with water in the bottom; dip flat; cleavage 20°, S. 10° W.; largest bed 3 feet thick.

14. East Bangor No. 2. Bry & Short, 300 yards west of the old East Bangor quarry; 200×150×60; dip 10°, N.; cleavage 20°, south; largest bed four feet.

15. East Bangor No. 1. Bry & Short, between East Bangor No. 2 and the railroad; 250×200×100; dip 20°, N. 20° W.; cleavage 20°, S. 20° E.; beds 16, 10 and 11 feet in length along the cleavage.

16. Star quarry. Major Aims, 500 feet west of the East Bangor No. 2; 200×200×50; cleavage 20°, south. There is an old quarry (not being worked) just south of this, on the same beds as the East Bangor No. 1.

Washington township.

Coton Aims' quarry, close to the township line, on the north side of the creek; 100×50×40; with 10 to 20 feet of *Drift* on top; dip 25°, N. 40° W.; cleavage 20°, S. 4° E.; beds all small. Some of the slates are made from single beds, while others have two or more beds in them. The slates made from the ribbon slate are mostly bent; others are good except a few which are slightly bent.

17. Bangor Central quarry, ¼ mile west of the township line on north side of creek; 200×100×40 feet deep; dip 25°, N. 40° W.; cleavage 10,° S. 40 E.; make slate out of single beds, and from two or more beds; some of them slightly bent; beds all small.

18. Bangor Old quarry, 500 feet west of the Bangor Central; side hill cut, 50 feet deep at the face, with from 15 to 30 feet of *gravel* on top; dip 25°, N. 40° E.; cleavage 15°, S. 40° W.; slates made from single beds and from two or more beds; some much bent.

19. Powell's quarry, on south side of railroad, ¾ mile east of Bangor; side hill cut, 300 feet long, by from 50 to 100 feet broad, and 80 feet deep; dip 25°, N. 40° W.; cleavage 15°, S. 40° E.; 5 to 15 feet of *Drift* on top; largest bed 4 feet. The slates on the dumps are made from one or more beds; all of these with two beds in them were bent, some few of the others were also bent.

20. Bangor Valley quarry, a few hundred feet west of Powell's quarry; 200×150×50 feet; dip 20°, N. 50° W.; cleavage 10°, S. 50° E.; 5 to 10 feet of *Drift* on top; largest bed 3 feet; quarry on top of the *Bangor axis;* slates above the Bangor slates.

21. Bangor quarry (Fig. 3), ¼ mile east of Bangor; 600×400×130. A *synclinal axis* passing through the center of it, about 70 feet below the surface; the plane of the axis dips 5° to the north, the cleavage also dips 5° north. There is 30 feet of *Drift* on top of the south side of the quarry; largest bed 9′ 6″; *synclinal axis* pitches to the west, being the same synclinal that shows in the Washington quarry and the Bangor Union. The slate in the north end of the quarry would come to the surface at the railroad, on a line between the Washington and Bangor Union quarries. The slate on the south side of the quarry probably shows in the Washington quarry. There are 60 men engaged in quarrying, besides the drivers, engineers and splitters. The quarry is worked by horses and carts and also by three cable derricks run by separate engines. There are 42 shanties in operation. (1882.)

22. Washington quarry (Fig. 4), Fulmer & Wagner, just west of the Bangor quarry; 150×100; reported 70 feet deep; 20 feet of *Drift* on top; cleavage 12°, N. 30° W.

23. Bangor Union quarry is some 250×250×130 feet deep at the deepest place, with from 11 to 20 feet of *Drift* on the surface; largest bed 4 feet thick. The *synclinal axis* which shows in the Bangor quarry also shows in this one, but the plane of the axis dips slightly to the south instead of to the north as in the Bangor. The quarry is worked by 5 cable derricks, which supply material to 20 shanties. The derricks are run by one engine, which, working a line of shafting, connects with the cable derricks by conical friction wheels. The quarry is running on roofing and school slates. Those slates made just below the turn of the axis are bent; the others are good. The beds in the quarry are tight and some of the slates are made across the beds. (1882.)

24. North Bangor No. 1; south-east corner 200 feet west of the north-west corner of the Bangor Union; 200×200×40; 20 feet of *Drift*, and they make slate one foot below it; cleavage 10°, S. 30° E; dip 45°, S. 30° E.; two largest beds 4 feet; there is a bed measuring 10 feet along the cleavage; at the south end of the quarry this 10 foot bed has two feet of rock on the top of it, making only 8 feet of it workable. The beds show all the way across the floor of the quarry; all of them are under 4 feet in thickness.

25. North Bangor No. 2, a few hundred feet north of No. 1; 150×100, 40 feet deep; dip 35°, S. 30° E.; cleavage 15°, S. 30° E.; beds under 4 feet; I was told there were two measuring 12 feet in the quarry, but could not see them as it was full of water.

26. North Bangor No. 3 (Fig. 5 p. 548 above), 200′ north of No. 2; side hill cut 150×200×100; of irregular shape and worked at the centre of the *synclinal axis;* plane of axis dips 15°, S. 30° E.; cleavage dips the same.

27. Jacob G. Pyster's quarry, one and a half miles S. E. of Bangor, 50×50×20 feet; cleavage 30°, S. 30° E.

28. Two miles S. E. of Bangor, on the east side of Martin's creek, on P. Pysher's farm, is a small cut 50×30×30; dip 10° N, ; cleavage 30° S. ; slates all thin bedded ribbon slates.

29. True Blue slate quarry (Fig. 6, p. 548), on Martin's creek 1 m. E. of Factoryville; irregular, averaging about 150×150×80; at the face the structure is shown as in the figure; in the cut the cleavage is 25° S. parallel to the plane of the two axes. At the bottom of the cut *a quartz vein* shows one foot thick dipping 25° S., spoiling the cleavage for a short distance on each side of it. On the south-east corner of the quarry a few small *quartz veins* show. The slates are all thin bedded; have a good metallic ring, but those that have been exposed on the dump show signs of bleaching. The quarry not being worked in 1882.

Lower Mt. Bethel township.

30. On Little Martin's Creek, half a mile above the school-house, ribbon slates show dipping 70° N., with a cleavage of 25° south. A quarter of a mile below the schoolhouse ribbon slates show with a flat dip and cleavage of 25°, S. 10° E.

32. In the bottom of a small hollow half a mile northwest of Martin's Creek Post Office, there is a small abandoned quarry of ribbon slate ; dip 45°, N. 20° W. ; cleavage S. 20° E.*

Plainfield township.

37. *Hull's quarry*, A. & O. T. Hull, 1 m. N.E. of Pen Argyl ; 250×150×80 ; 15′ loose slate on top ; dip at surface 68°, S. 10° E. but steeper in the lower part of the quarry ; cleavage 15°, S. 10° E. ; two largest beds 10 and 7 feet thick ; blocks come out even and split and sculp well ; not as much waste as in the average run of quarries.

38 *Pennsylvania quarry*, at north end of Pen Argyl ; 250 ×200 feet ; dip at N. end 55°, N. 30° W., gradually flattening southward ; cleavage 25°, S. 30° E. Seventy feet from the north end is a 20 foot bed ; some distance below this a 6 foot bed ; rest of the beds smaller ; most of the ribbons tight.

39. *Jory quarry*, N. A. Jory & Co., 400×200×80 ; worked in the center of a *synclinal ;* dip slight in center of axis ; plane of axis *vertical ;* cleavage *horizontal.*†

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*Just above the mouth of Martin's creek the contact of the slates and limestones shows. The slates for half a mile up the creek are seen dipping slightly towards the north, and are very much contorted. The cleavage is flat, the beds are small but not ribbon slate. Just east of where the road from Martin's creek crosses Mud run, vertical black slates show with a *horizontal cleavage.* The largest bed is two feet thick. On the road leading down Mud run between Hutchinson & Kahler's an *anticlinal* shows in the slates. The slates are ribbon slates. In the same cut two *veins of quartz* show dipping steeply to the south. Just west of Hutchinson's ribbon slates show dipping N. 20° W. Cleavage 40°, S. 20° E.

The contact of II and III enters *Forks township* a few hundred yards south of its north-east corner, and passes through the township in a south-westerly direction, crossing Bushkill creek into *Palmer township* west of the Lutheran church at Churchville. In Palmer township the junction line is not well shown. The area covered by slates is a strip across the northern portion of the township half a mile wide.

*This is the only quarry in which the cleavage can be seen at right angles, or any considerable angle to the plane of the axis. The beds worked are not large, but the cleavage making such a large angle with the bedding, large blocks can be taken out. They were making about 25 squares a day with 4 shanties at the time of visiting the quarry. There are two spar derricks worked by horse power.

40. Jackson's quarry; 300×200 by about 100 feet deep; two cable derricks, run by two double-cylinder engines; 4 shanties averaging about 4 squares a day to a shanty; slates come out in good sized blocks, some of them 20 feet long; split and sculp well and fracture rather well.

41. Robinson quarry, Stephen & Jackson, 400×200×80; dip 28° south; cleavage flat; beds 25, 16 and 12 feet long along the cleavage; one cable derrick and several spar derricks, run by horse power; 16 shanties in operation (1882).

42. West Washington quarry, Fulmer and Jackson, 150×75 feet and 50 feet deep; 25 feet of loose material on top; same bed as at the Robinson and Jackson quarries; best bed is *the gray bed*, which is also worked in the Jackson; dip 48° south; *cleavage flat.*[*]

43. H. Young's farm, 1¼ miles west of Blue Mountain Post Office; a small cut in the hill side showing slate beds, the largest of which is 2 feet thick; dip 15°, N. 20° W. cleavage 15°, S. 20° E.

44. Delabole quarry, of Factoryville; 150×100; dip 80°, S. 30° E.; cleavage 25°, S. 30° E.; all thin bedded slates; beds large between the loose ribbons.

46. Pine Grove quarry, Edleman & Co., 200×150×130; dip 60° N.; cleavage flat; slates all thin bedded; make besides roofing slate, flagging and fence posts.

47. White Oak quarry, T. Reed & Co., 150×100×100; dip 20° N.; cleavage 10°, S. 45° W.; joints vertical, and in one part of the quarry 80 feet from joint to joint; slates all thin bedded; average about 3,000 squares of slate a year.

48. Samuel Seams' quarry, 1 m. N. by E. of Belfast; 200×200×80 feet; dip 20° to the north; cleavage *flat* or slightly to the west; slates all thin bedded; largest bed 30 feet between loose ribbons; other beds worked are 16, 12 and 4 feet between loose ribbons; make about 4,800 squares

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[*] At S. end the top bed is 10' thick, then follow downward 6 beds in 2 feet, there is a 2 , 3'', and a 7'' bed and 1 8'', 2', 3'', 1' 6'', 1' 3'', 7'', 1' 6'', 10'', 9'', 1' 7'', 2'', 1' 10'', 9'', 15' 6'', 6', 3', 3 beds in 6'', 3', 7'', 6'', 2', 9'', 1' 3'', 4'', 1' 2'', 11'', 3'', 1' 1'', 1' 5'', 6'', 10' 2'' *the gray bed*, 30 feet of beds 2 feet and under in thickness, 4'. The 10 foot bed, at the top of the quarry has 2 feet of rock on top, a dark fine-grained sandstone. The gray bed has also rock on top.

a year; also flagging and fence posts; worked by two cable derricks run by one engine.

49. Young, Duck & Co.'s quarry, 1 mile W. of Kessler's Post Office; full of water; dip 20° north; cleavage *flat;* slates all thin bedded.*

50. James Deck's quarry, 100×100 feet, full of water; dip 15° north; cleavage *flat*; slates all thin bedded.

52 Davidson's quarry, 1 m. S. W. of Kessler's Post Office, 150×100, full of water; abandoned; dip 60°, N. 20° W.; cleavage 20°, S. 20° E.; slates all thin bedded.

53. Belfast quarry, ½ m. S. of Davidson's quarry, 150×75; full of water; 10′ stripping; slates thin bedded; dip 20°, N. 20° W.; cleavage 20°, S. 20° E.

Bushkill township.

60. Hughes Bros. quarry, ¾ m. S. E. of Jacobsburg; 100×150×60; average dip 70°; cleavage 20° S.; slates all thin bedded; longest distance between loose ribbons 25 feet; makes about 1,500 squares a year, and have made as high as 8 squares a day to a splitter, but 4 a day is a good average; 25 feet from the top of the quarry a *fault* shows dipping 20° to the south; it has moved the slate on top 3 feet to the south.†

62 Henry's quarry; 150×200×70; dip 20°, S. 50° E.; cleavage 13°, S. 40° E.; slates thin bedded; joints vertical and in different directions; main joints parallel to strike; some few *quartz veins;* color of the different beds of slate almost identical; planes of loose cleavage from 5 to 7 to 12 feet apart; two cable derricks, run by one engine; make about 1,800 squares a year.

65. St. Nicholas quarry, James Titas, township line 1½

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*Two miles northeast of Kessler's Post Office, thin bedded slates show dipping 20° north; cleavage 40° south.

†On M. Train's farm south of his house there is a shaft sunk for slates, 15 feet deep. The dip is doubtful but looks 50° S. Cleavage is 50°. The shaft just enters the solid slate. Just west of Jacobsburg a thin bedded slate shows with a *flat* dip, and cleavage 30° south. One quarter of a mile south of Jacobsburg the cleavage is 10° south. Where the Bushkill creek leaves the township the thin bedded slates show with a *vertical* dip and *flat* cleavage.

miles west of Clearfield ; 100×100×30 feet ; dip 15°, S. 40° E. ; cleavage 55°, S. 40° E. ; full of water in 1882.

66. Douglass slate quarry, on north side of Bushkill creek, west of Douglasville ; 300×150 ; full of water.

69. 1½ miles west of Cherry Hill in front of J. Heyer's house two small openings 50×75 and 20×20 ; slates thin bedded and on the dump have bleached and rusted badly. A few hundred yards further down the run there is an abandoned quarry 150×100 feet full of water ; dip 35°, S. 40° E. ; cleavage 15°, S. 40° E. ; slates thin bedded.

71. Daniel's quarry, full of water, 250×150 feet ; slates thin bedded ; dip flat ; cleavage 20° S. Some of the *slates on the pile have about 10 beds in them.*[*]

Upper Nazareth township.

At the end of the borough of Nazareth the slates are flat and rolling. One mile west of Nazareth, on the Bath road, black slates show with a horizontal dip. A high slate ridge rises 1,000 feet north of the road, but the slates extend half a mile south. This is a good place to study the *Utica black slate formation III a*, and its passage upward into the *Hudson River formation III b.*

Moore township.

76. Daniel Beer's quarry, on the east side of the township, half a mile south of the railroad ; 150×100 ; full of water ; on the same beds as the St. Nicholas ; dip 10° S. 40° E. ; cleavage 65°, S. 40° E.

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[*] There are about 50 squares on the pile, most of them have iron pyrites in them at the junction of the ribbons ; the slates on the end of the pile have changed color. Some of them also have thin veins of quartz in them. On the east side of the creek 100 feet north of the Daniel's quarry, the thin bedded slates are seen turning to the north, the dip being 20° north. The cleavage is 20° south. 500 feet further north the dip is 20° to the east ; 50 feet further north it is 10° north. 800 feet north of this there is a small abandoned cut 60×60 feet showing the slates flat. Half a mile north of Daniel's quarry a small opening 10 feet deep in thin bedded slate shows, with a dip of 10° to the south and a cleavage of 15° south. Half a mile north of the above there is another abandoned quarry 50×75 feet, full of water. The slates are all thin bedded, bleached and iron stained. The dip is flat and cleavage 20° south.

79. Chapman quarry; 500×300×139; has 6 cable derricks run by independent engines; 30 shanties in operation; splitters make from 2 to 6 squares a day, averaging about 4; hoisting apparatus very complete; can hoist a stone of two tons 150′ vertical and 300′ horizontal in about 2 minutes; large factory for making and planing slabs and other sawed material; with 3 diamond saws, 4 planers, 1 jig saw and 1 smoothing table; diamond saws cut by reciprocating motion, at the rate of an inch in 5 minutes, 50 stroke a minute. The slates are all thin bedded, split well and are tough; the blocks come out of the quarry in large even pieces, some of them 20 feet long; sculp and fracture well.*

82. Empire quarry, on the Manocacy creek, 1 m. E. of Chapman's; 100×100; full of water; cleavage 10° south; slates thin bedded; iron pyrites in some of them; also a few small quartz veins running through the slates.

83. Richard Moser's quarry, 300 yards up the creek from the Empire; full of water; cleavage 20° south; slates thin bedded; weather to a slightly different color; some show iron pyrites.

84. Mauch Chunk quarry, at Chapman's Station; 200×150, full of water; dip vertical; cleavage 22°, S. 40° E.; slates thin bedded.

85. Bethlehem quarry; 200×150×80; dip on the surface vertical, then south a short distance and again vertical; cleavage 10° south; slates all thin bedded; distances between the loose ribbons along the cleavage of the workable beds are 7′, 7′, 3½′, 9′, 3′ and 3′; one cable derrick run by a 15 horse-power oscillating engine; six shanties in operation (1882). On the south side of the quarry they had to go down 60 feet before getting to good slate. On the north they went down only 20 feet. There is a *quartz vein* dipping to the south through the quarry 20 feet from the sur-

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* A few hundred yards east of Chapman's there is an abandoned quarry 250×250. East of Chapman's, across the creek, another 50×50 full of water; cleavage 20° E.; slates thin bedded.

face on the north side and 60 feet on the south. The slate above the vein has not a good cleavage.*

88. Thomas Ryan's quarry, 100×50×40; slates thin bedded; joints vertical; cleavage horizontal; dip towards the south averaging about 60°. Some few slates have iron pyrites in them.

89. Jacob Flinn's abandoned quarry, 1,000 feet northwest of Ryan's quarry; 100×40×30; dip 30°, N.; cleavage flat. Quarry said to have been abandoned because the slates were twisted.

90. Abandoned quarry, 1,000 feet north of Chapman's, 60×60, full of water; dip vertical; cleavage S. 10° E.; slates all thin bedded.—400 feet west of this another quarry 100×40 full of water, with vertical dip and cleavage of 10°, S. 20° E.

91. Abandoned quarry, 1 m. W. of Chapman's, 100×50, full of water; slates thin bedded.

92. Helman's quarry, 1½ miles S. W. of Chapman's; 100×100 feet, full of water; dip 45° south; cleavage flat; joints vertical; slates thin bedded; those on the dump bleached and iron stained.

93. McKee's quarry, 600 feet north of Helman's; 100×100, full of water; dip 22°, S. 25° E.; cleavage 15°, S. 25° E.; joints vertical, running east and west and north and south; slates thin bedded.†

96. Northampton quarry, 1 m. S. W. of Chapman's; two, both full of water; the southern one 150×150, the other about the same size; separated by about 25 feet of slate; 15 feet from the top a heavy *vein of quartz* dipping slightly to the south; cleavage 20°, S. 40° E.; slates all thin bedded; those left on the dump appear very rough and thick; some of them have iron pyrites in them, and they have changed color. (See page 548 above.)

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* *Abandoned quarry* west of the last and 300 feet on the strike from it; 200′×200′; cleavage 10°, S. 10° E.; joint vertical. A *quartz vein* shows in this quarry as in the Bethlehem. 200 feet north of this there is another abandoned quarry 100×100 full of water.

† On the ridge a mile east of the Emanuel church, loose thin bedded *sandstone* covers the surface of the ground. 300 yards north of Emanuel church slate dips 90° to the north with a cleavage of 45° south.

97. Abandoned quarry (Fig. 7), ½ m. S. of Chapman's, 150×150, full of water; slates thin bedded; vertical dip. *The horizontal section in the figure shows the contortions in the strike of the rock at the northwest corner of the quarry.*

East Allen township.

98. Chester county quarry is 200×250×130 feet deep. The slates dip 20°, S. 40° W, *Cleavage horizontal.* At 10 to 40 feet from the top of the cut, *veins of quartz* show parallel to the bed plates. The slates are all thin bedded and the beds differ slightly in color. Some few of the slates have a small amount of iron pyrites in them. The blocks coming out of the quarry are large and even in size. Some of them are 20 feet long, 4 feet wide and 2 feet thick, but do not seem to split well. There is a little water in the quarry. It is worked by two cable derricks, run by one forty-horse power engine. At the corner of the road, just north of the quarry, there is an abandoned quarry full of water.*

100. A. Koch's quarry, on Catasauqua creek, 3 miles W. of Bath; 200×100; full of water; dip 15° to N.; cleavage 5° to S.; slates thin bedded; some iron pyrites.

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* The contact of slate and limestone enters the township from Upper Nazareth east of Bath, takes a westerly direction, crossing the railroad half a mile south of Bath, continues on to the south-west for a mile, turns to the south for ¾ of a mile, then turning to the west passes through Jacksonville and then along to the west, keeping south of the road leading west from Jacksonville. There are three outlying patches of limestone in the north-western part of the township shown on the map. They are probably brought to the surface by the *anticlinal* which enters the slate south-west of Bath. Their shape cannot be accurately defined owing to the surface being covered with loose slate. *A limestone quarry*, 1,000 feet west of the Chester slate quarry. The dip of the limestone is 20° to the west. On top of the quarry there is a body of *slate* which is *non-conformable to the limestone.* The slate is somewhat broken and has probably fallen down on the eroded limestone. One quarter of a mile S. of Koch's quarry the limestone crops out, *dip flat*, with loose slate on top of it. 1,000 feet south of this more limestone outcrops, and about 50 feet lower the slates show. There is a small cut in the bottom of the hollow at this place, but it is full of water, and nothing could be seen. At the saw mill dark blue, thin-bedded limestone crops out with a dip of 30° to the S. 30° E. There is a small amount of *graphite* on the bed plates. Just south of this outcrop of limestone, gray slates show, dipping 30° to the north, and at the road leading west from Jacksonville is gray *cement stone* dipping 35° to the south.

Allen township.

106. Abandoned quarry, lies a few hundred yards east of the railroad near S. B. Hoffman's house, having about 5,000 cubic yards taken out of it; dip 10°, S. 10° E.; cleavage parallel to bedding; a few *quartz veins.*

107. Abandoned quarry, 1¾ miles north of Siegfried's bridge, on the Central Railroad of New Jersey, 75×50, full of water; dip flat; thin bedded slates.*

Lehigh township.

108. S. Reple's quarry, across the road from the hotel at Rockville, 100×200, full of water. For 500 feet north along the foot of the hill there are several small openings showing the slates flat and dipping 20°, S. 10° E.; cleavage 65°, S. 10° E.; main opening, slates flat; one bed 7 feet thick.†

111. Old Harper's now *Henry's quarry*, ½ m. S. E. of Danielsville; dip steep N. 45° W.; cleavage 45°, S. 10° E.; beds small, with small tight ribbons.‡

112. J. Henry's quarry (Fig. 8), ¼ m. S. of Harper's quarry; 200×150×30; *regular synclinal axis;* cleavage at center and north side vertical, but on south side about 60° south.

113. Eagle slate quarry, F. M. Hower, ¼ m. S. of Harper's; two openings in a line 100×200×60, separated by 50 feet of rock; dip 80°, S. 10° E.; cleavage 60°, S. 10° E.;

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*South of Kreidersville the slates dip 20° S. and the cleavage 20° S. On R. R. at N. W. corner of the township the slates have a slight dip to the south, averaging about 5° with rolls and twists and a few small vertical *faults*; cleavage indistinct, about 40° to the south; at center and north end of cut slates flat with rolls and twists; everything contorted.

†Three quarters of a mile south of Rockville outcrop of large bed of apparently good roofing slate; cleavage 60° south. East of Harper's gristmill outcrop of small slate beds; dip 20°, S. 50° W.; cleavage 60° S.

‡*The cleavage in this quarry is not parallel to the strike*, but the strike of the rocks is not parallel to the mountain; if it were continued it would strike the mountain at from a mile to two miles and a half. The slates look good, some of them are of a different color, separated by a wavy line but no ribbon.—200′ S. of the quarry is an old opening now being filled up.

no large beds; cleavage nearly parallel with bedding; blocks of 20 to 30 feet in length sometimes obtained. They make about 80 squares a day and also a few school slates.

114. McChunk and National quarries, $\frac{1}{3}$ m. E. of the Eagle quarry and close together; one 100×150, the other 250×250, both full of water. In the southern one the rocks appear to dip 80° S., the cleavage 40° S.; largest bed not over 5 feet, but only 50 of the 250 feet in the quarry is exposed; slates left on the pile thick and have a poor ring.

115. Uplinger & Griffith's quarry and Uplinger & Henry's quarry (Fig. 9); two quarries 150 feet apart; 500 feet south of the Eagle quarry is Uplinger & Harper's quarry; dip 80° N.; quarry full of water. 150 feet south, at the north end of Uplinger & Griffiths' quarry, slates lie flat; for 300 feet more an occasional outcrop shows a flat dip; at the south end of the quarry (where they were working in 1882) a *synclinal axis.* None of the beds large; slates look good and are darker than at most of the other quarries.

116. Continental quarry, 1¼ miles S. of Danielsville; full of water; 200′ square; dip 80° S.; cleavage 45° S.; one bed 10 feet thick.*

118. Col. B. Maurer's slate factory is one mile north of Poplar Grove, where they make about 2,000 school slates a day.

119. Newville Slate Co.'s quarry, 1 m. N. of Poplar Grove on the south bank of Bertsch creek; 75×125×90 deep; dip 42°, S. 10° E.; cleavage 75°, S. 10° E.; ribbons tight; *some jet black;* bottom bed 15 feet; then 4 feet of small beds; one bed 15 feet thick; 25 feet of small beds, and on top one bed 10 feet thick.

120. New York and Pennsylvania quarry, 1¼ m. N. of Poplar Grove; full of water; *reported* cleavage imperfect and slate rocky.

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* An abandoned quarry, ¼ of a mile east of Danielsville and 200 feet north of the strike of the Continental quarry, shows a flat *synclinal*, with the cleavage dipping 60° to the south.

121. Kester's Meadow quarry, leased by John Pauls and Peters; 150×100×60; 10 to 15 feet loose slate on top; largest bed 24 feet; blocks come out in large, even pieces; split well and the slate looks good. In 1882, working on the large bed, on the south side of the *synclinal axis;* cleavage about 45° S.

122. Doddridge quarry, leased by Joseph Roberts; 500 yards north of the Kester Meadow quarry; just (1882) started; cut down 30 feet, showing one bed 11 feet thick, with a few small beds on top; dip 70°, S. 10° E.; cleavage 55°, S. 10° E.

123. J. Remley's quarry, 1 m. E. of Walnut Port, small, 15 feet deep, full of water; dip 60°, S. 10° E.; cleavage 50°, S. 10° E; two large beds reported in this quarry, the largest one 10 feet thick (probably 10 feet along the cleavage); slates on the dump look good.

124. Heinbach's quarry (Fig. 10), 1¼ m. N. E. of Walnut Port, leased by Caskie & Emack. The section of the eastern face of the quarry shown in Fig. 10, gives the structure. The quarry is 100×200×60; main cut originally 150 feet deep, now partially filled by waste. It is now (1882) worked by two tunnels, one driven east and the other west. The main opening shows the rock about vertical, but Mr. Caskie says that in the bottom they bent towards the north. Joints mostly horizontal and quite persistent, but some distance apart, allowing large blocks to be taken out. In each of the tunnels there is a joint at the roof. The largest beds are from 10 to 15 feet thick, making a total (along the cleavage) of about 25 feet. The whole 150 feet of the breadth of the quarry is used for making roofing slate. There is a factory at the quarry for making school slate with a capacity of 10,000 cases a year.

126. Owen Williams & Co.'s quarry, ¼ m. W. of Heinbacks; 200×100×80; 60 feet of slate, used for roofing and school slates; largest bed 8 feet thick; other beds 6′, 3′ and 4′. The note (1882) adds: 100 feet west of this quarry Mr. David Williams has opened a quarry. He has only the *gravel* stripped off, which is about 20 feet deep. The beds he expects to strike are the same as in Owen Williams & Co.'s quarry.

127. Williams & Jones' quarry, just west of Owen Williams' quarry; 200×100×90; dip in the bottom vertical; at the south side near the surface a roll in the rocks; cleavage 60°, 15 S. E. *In this quarry there is a bed of slate from which they make slate pencils.*

128. Abandoned quarry just N. of Walnut Port, 200×200 feet, full of water.*

135. Beach, Barge & Co.'s quarry, 1 m. below Treichler's, in the hill side east of the railroad, is 50 feet deep at its face; dip 15°, S. 10° E.; cleavage the same; slates thin bedded, dark blue with a good ring.†

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*On the railroad above the dam, the dip of the slates is 30°, S. 10° E.; cleavage 60°, S. 10° E. 100 feet further north the dip is 25°, N. 20° W.; cleavage 60°, S. 10° E. Just above this an *anticlinal* shows *with a flat cleavage;* then 100 feet further north the slates dip vertically. A few hundred yards south of the wagon bridge the slates dip 50° to the south. A short distance from where the wagon road goes under the railroad a massive gray *conglomerate* (dipping 30°, N, 30° W.) is made up of white and black pebbles averaging one inch in diameter; also fine grained gray *sandstones. The junction of III and IV* is not visible; but the slates 50 feet below are seen gradually turning into sandstone. A hundred feet N. of the road crossing is the last place the slates are seen, 50 feet below the sandstone of IV. Further south, 250 feet, *an anticlinal in the slates* appears in the side of the road. The axis of the anticlinal is about vertical, and the cleavage is parallel to it. Two-thirds of a mile south of Walnut Port the slates dip 75° south. There are some small beds of interbedded *sandstone* at the same place.

†On the railroad, at the township line there are three peculiar curves showing in the slates. The cleavage is parallel to the axis of these curves. In the first one the axis dips 5° to the south. 500 feet north and under the above there is another flat turn with the axis horizontal, then 300 feet further north there is a flat turn with the axis dipping 10° to the south.

Quarries in Lehigh county.

Washington township.

140. Abandoned quarry, 1 m. N. of Slatington 25×100, a side hill cut 25 feet deep; dip 25° to the north; cleavage 60° to the south.*

146. Captain D. D. Jones' new quarry, on Welch run ½ m. N. of Slatington; (1882); dip 10° S. and pitch 12° W. with cleavage vertical; big bed of slate outcrops several hundred feet to the east, 30′ thick; twenty feet above big bed another 7½′; good ring, dark color, even cleavage.

147. Welchtown quarry, John T. Robinson & Co.; opened in 1844; two large beds, one 27 feet along the cleavage, and another on top 18 feet, separated by 25 feet of smaller beds; in 1882 making 8 squares a day; worked by a tunnel on the 27 foot bed.

148. Williams' railroad quarry, a few hundred yards north of the Slatington depot, 100×100×100 feet deep.

149. Old Keystone quarry, 200′ N. of the Williams RR. quarry; side hill cut 200 feet square, 60 to 80 feet deep at the face; one large bed 16 feet, then 10 feet of small beds, then a bed underneath 25 feet; dip 30° to the S. 10° E. cleavage vertical; dip the same all the way to the Williams quarry; 150 feet south of the Williams quarry slates dip 70° south, cleavage 30° south.

150. Tunnel quarry, on Trout run, 300 yards from river; one large bed back of the tunnel; two smaller cuts along side the tunnel had fallen in.

152. Abandoned quarry, just above the borough bridge on the south side of Trout run; side hill cut 100×50×40 feet at the face; dip 32° S.; cleavage 64° S.; five to twenty

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*At the southern end of Slatington the slates in the river are vertical.—200 yards S. of C. Zellman's on the railroad fine-grained *sandstone* outcrops; dip 20° to S.; largest layers 4 feet thick; *40 feet of sandstone* shows. 50 feet further south a *synclinal* shows with the sandstone on the south side of it *vertical*.—300 yards N. of Rockdale slates dip 45° to the south; cleavage parallel.—At the water station slates are flat. Just south of the run the dip is 25° N.; rocks *slaty sandstone* and slate. Then for over a quarter a mile southward the slates are flat. They then change gradually to a dip of 25° to S. In the next 200 yards the dip changes gradually to 15°, N. 45° W., making a *synclinal axis* between these two points. 500 yards further down the railroad the dip is 20°, S. 45° W.

feet of loose slate at the surface; beds showing all under four feet thick.

153. Penlynn quarry, 150×150×100 feet deep; dip 60, S. 10° E; cleavage 40°, S. 10° E. There is a 20 foot bed in the quarry. The other beds are smaller and most of them workable. North of the quarry 100 feet dip 90°; 200 feet further north flat.

154. Old quarry No. 1, 500′ N. 40° E. from the Penlynn quarry, on the north bank of Trout run, E. of Washington quarry; slates vertical; cleavage 60° south; two 10 foot beds with smaller beds between.

155. Old quarry No. 2 (Fig. 11), around the curve in the hill from quarry No. 1. It shows a *synclinal axis* with the plane of the axis dipping 70° to the south. The cleavage also dips 70° to the south parallel to the plane of the axis. *It also shows the bed thickening as it curves around the axis from 27 feet thick to 35 feet. Just after the curve the distance from where it is 27 to where it is 35 feet is 50 feet.**

156. Old quarry No. 3, a short distance down the creek from No. 2; one bed 20 feet thick dipping 28° S.; cleavage 75° S. The quarry not worked in 1882. All three quarries belong to James Hess & Co.

156a. Washington quarry, James Hess & Co., 300×200×75 deep; at the south side the slates, flat at the middle of the quarry, turn sharply downwards, the dip becoming vertical; cleavage 60° S.; upper bed 15′; then twelve feet of small beds; lower bed 12′.

156b. Blue Vein quarry, 200 feet south of the Washington quarry; on the same beds; 200×150×75; a *synclinal*, its axis dipping 60° S.; an *anticlinal* between this quarry and the Washington.† Under the twelve foot bed there is a *school-slate bed.* The lower four feet of the big bed has rock in it. The ribbons when they get under thirty or

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*This is a flagrant proof of the effect of the earth movement on the whole formation No. III, in changing its thickness.

† This *synclinal* axis passes north of the Penlynn quarry through Slatington, and shows in the Tunnel quarry. It does not show at the river, probably owing to a want of exposure,

forty feet of cover become tight. In the south wall the slates are bent.

157. Blue Mountain quarry (Fig. 12), 600′ long east to west, 250′ at its widest part, 120′ deep; surface loose for 10 to 15 feet down; two beds 16 and 27, separated by 12 feet of smaller beds; started 35 to 40 years ago; originally worked by Williams & Moser; 4 spar derricks and 1 large cable derrick. They are making 55 squares a day (1882).

158. Columbia quarry, N. side of Trout run N. of the Blue Mountain quarry; 300 feet long; dip vertical; cleavage 20°, S. 20° E.; 10 to 30 feet of loose rock on top.*

159. American quarry, No. 1 and 2 (Fig. 13), W. of Columbia. Quarry No. 1, 250×100 feet; beds 30′, separated by 6 feet of small beds, one being 2 feet thick. No. 2 shows the section Fig. 13.

160. Girard quarry, ½ m. W. of Columbia on the N. side of Trout run; 250×100×50; full of water; one bed 15 feet thick.

161. Star Slate quarry, 300×100×60; dip 70°, S. 10° E.; cleavage 50°, S. 10° E.; two beds 27′ and 18′; 10′ of clay on top, and 4′ of blue slate underneath the clay.

162. Williams, Owen & Jones' quarry, 40 feet deep, 100 feet square, in line with Star quarry; shows the slate turning over towards the south; one derrick, working on the 27-foot bed.

163. Franklin quarry (Fig. 14), 1½ m. W. of Slatington depot and N. of Trout Run. (There are several old openings south of it towards the Star quarry.) *On a flat synclinal;* 4 spar derricks and one cable derrick; greatest deph 150′.

165. Junction quarry, opposite the junction of the Slatedale branch railroad, full of water, 200×100′ feet square; one bed 15′; the rest all small; dip steep S.; cleavage about 50° S. 200 feet north of it a small quarry 50×50, full of water. On the Lehigh and Berks RR. S. E. of the junction quarry *a flat synclinal* shows vertical cleavage.

166. Industrial slate quarry, 300 N. of the Junction

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*500 feet south of the Columbia is an old abandoned quarry; the dip of the slate is 70°, N. 20°. The cleavage 50°, S. 20° E.—150′ S. E. of this the dip is 10° N.

quarry ; working on the 20 foot bed ; (1882) making about 15 squares per day ; dip vertical at the surface, curving towards the south at the bottom of the quarry ; cleavage about 45°, S. 10° E.

167. Abandoned quarry 1000′ W. of the Industrial, full of water, 200×290×40. There are three other openings besides this, the largest 300×100, all full of water ; one large bed 15 feet thick.

168. Abandoned quarry 1500′ from the end of Slatington. Its section is shown in the section of the Blue mountain quarry.

169. Blue Mountain slate quarry (Fig. 15), 250′ N. of east ; 200×40×60 ; largest bed 27′ ; dip 60° N. ; cleavage about 60° S. ; at bottom of large bed cleavage slightly curved ; section of the two quarries shown in Fig. 15.

170. Monarch quarry, owned by Mr. Hersh, on the south side the creek from the Blue Mountain quarry shows the same beds with a dip of 15° N. ; not worked (1882). Across the road another abandoned quarry ; dip 70° N. ; beds apparently the same. Two other quarries in the same field, the largest 150×150×50′ deep.

171. Lock slate quarry (Fig. 16), ¼ m. W. of Slatedale. At the southeast end of the quarry there is a small opening 50×50×50 feet showing a bed 15 feet thick, dipping 85°, N. 10° W., with a cleavage dipping 70°, S. 10° E. The main quarry is 400′ long. In 1882 the work was under ground by means of two slopes going down on the large bed ; cable derricks worked by one engine ; inclines three feet apart ; structure shown in Fig. 16.

172. Standard quarry, ¼ m. S. E. of Slatedale, 300×50×114′ deep ; beds 20′, 8′ and 16′ ; 3 of gravel and 6′ of loose slate over the quarry ; the 16-foot bed worked ; a large bed at west end did not work well ; rocks sculp and split nicely and come out of the quarry in good sized blocks.*

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*Grey slate shows in the southwest corner of the township, dipping 30°, S. 20° W. *The sandstone* strata seen on the railroad one mile below Slatington makes a high hill which extends west more than two miles back from the river. No solid outcrop shows, but the ground is covered with loose pieces,

North Whitehall township.

175. North Peach Bottom Slate Co.'s quarry, 2 m. S. W. of Laury's Post Office; 250×200×90 at the deepest place; slate beds horizontal, with slight rolls; cleavage about horizontal; joints vertical, but make different angles with each other; blocks 20′ square got; largest bed between loose ribbons 3′ thick. About 30 feet from the surface there are segregated *veins of quartz* that split the cleavage for some distance around the veins. At the top of the quarry there is a bed of sandy slate which does not split well, but the slates made are black, with a good ring and smooth surface; the second quality slates have a very uneven surface and look poor. A factory connected with the quarry was engaged on an order for flooring for the Patent Office in Washington, 1882.*

Heidelburg township.

182. Diamond Slate quarry (Fig. 17), leased by Bartley & Bar; opened 1854; 250×150; two large beds, one 24 and and the other 30 feet thick, separated by 5 feet of small beds; on top of the 24-foot bed a few *quartz veins;* a few also in the slates above it; beds rise slightly E. along the strike. At 500′ N. of the main quarry is an old abandoned quarry; dip 45°, S. 10° E., and nothing to be seen.†

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*There are very few exposures in the township at which the dip can be obtained. On the small creek that empties into Jordan creek in the southwest part of the township, there are two dips to be had just east of the school house, the slate dips 10° to the south and a quarter of a mile above the mouth of the creek the slates are flat, with a few small rolls in them for half a mile on each side.

†At S. end of Germanville slates dip 55° S. On Jordan creek 1 m. E. Pleasant Corner, *a sharply folded anticlinical* shows dipping 60° to the south. On the south side dip 50° S.; north side 70° S. This shows a tight compression and overthrow. Half a mile south slates dip 50° south. 1½ miles up a small creek that runs into the Jordan at this point, there is an abandoned slate quarry with nothing to be seen. 1¼ m. E. of Pleasant Corner slates dip 30° S. 20° E.

South Whitehall township.

183. An abandoned slate quarry on the Huckleberry ridge synclinal ½ m. S. of Guthsville, 200×100, full of water; slates vertical; cleavage 45° S.; slates all thin bedded.*

Lynn township.

192. Laurel Hill Slate Co.'s quarry, 1 m. N. E. of Lynnport; 75×50×60; dip vertical; cleavage steep to S. 40° E.; beds worked are 26′, 10′, 8′, 6′ and 2′ in length along the cleavage

193. Lynnport Slate quarry, at Lynnport, north of the railroad, 150×100×60 feet.*

194. Two abandoned quarries at Slateville; the one beside the road shows the northern half of the *anticlinal axis*, with one bed 4 feet thick; the other quarry shows the slate dipping about 45° S., with one bed 4 feet thick.

195. Star Slate quarry (Fig. 18), George W. Griesheimer & Bro., at New Slateville, one mile northwest of Steinville; started about 1868; worked by the present owners since 1876; make about 7500 squares a year. The cross section Fig. 18 shows one large bed 30 feet thick.

Quarries in Berks county.

Albany townshiy.

195. Centennial quarry, 1½ m. W. of Steinsville, Faust, Heinly & Bros., 150×50×80; 80°, N. 20° E. The section

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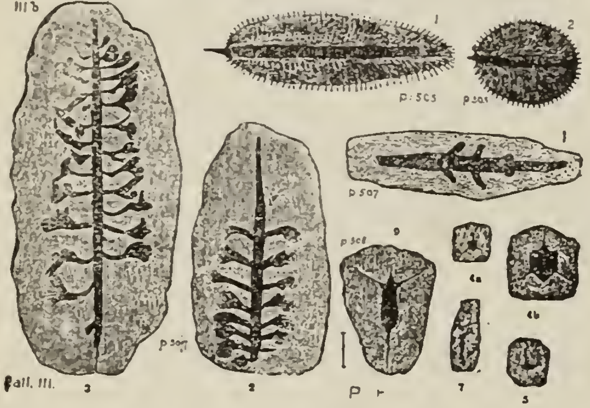
**Low Hill township* has no quarries. At its N. E. corner slates dip 15°, S. 60° W.; ½ m. further down a small run the dip is 45° N. with cleavage 45° S. curled. Just below Low Hill on the Jordan slates dip 30° S., cleavage curly. A few hundred yards further down the dip is 30° S. 1½ m. down the creek slates dip 50°, N. 10° W., dark blue, thin bedded, with no regular cleavage. ½ mile further down the dip is 50°, S. 20° E., slates massive, cleavage irregular. In the road across the Weidasville bend in the creek *the ground is covered with pieces of quartz.* 1½ miles down the creek from Weidasville the slates are flat. Half a mile S. of Low Hollow P. O. slates dip 50°, S. 10° W.; cleavage parallel to dip. At the northwest corner of the township slates dip 80° S. One mile N. E. of Lyons Valley P. O, slates are flat. One mile S of Claussville slates are flat; and on the creek in the southwest corner of the township veins of *quartz* show in the slate.

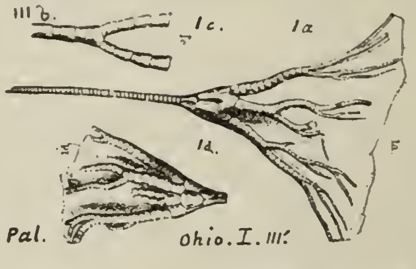
*1½ m. E. of Lynnport slates dip 55° S.

No. III b. Hudson River Slate Fossils.

Phyllograptus typus. A graptolite figured by Hall, Pal

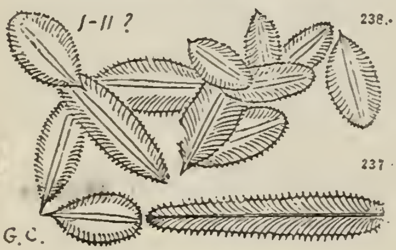


Poteriocrinites **(Dendrocrinus) caduceus,**



Poteriocrinites **(Dendrocrinus) posticus,**

Phyllograptus angustifolius, Hall.

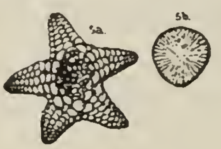


Dendrocrinus) cincinnatiensis,

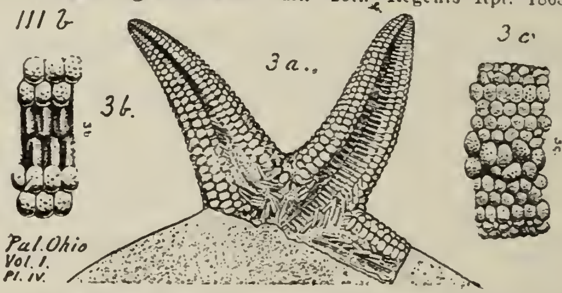
Dendrocrinus) caseyi,

Poteriocrinites **(Dendrocrinus) polydactylus;**

Palæaster incomptus,

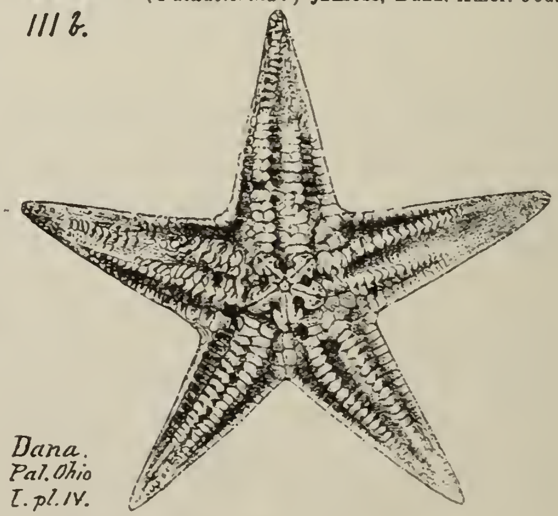


Palæaster granulosus. Hall. 20th Regents Rpt. 1868.

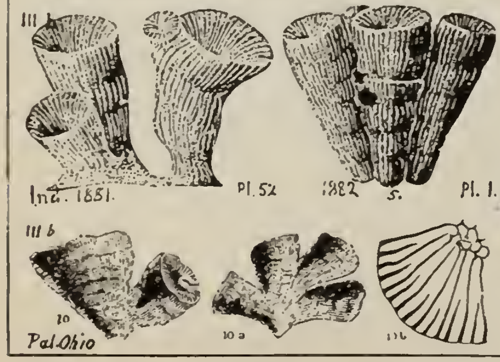


Palæaster ? dyeri. Meek, American Jour. Sci. Vol. 3,

Palæaster ? (*Palæasterina ?*) **jamesi,** Dana. Amer. Jour.

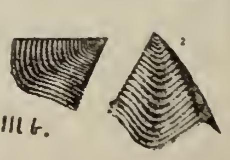


Palæophyllum divaricans. (*? Cyathophyllum*



Petraia canadensis. Billings,

Plumulites jamesi.



cut shows the quarry and a small opening made on the large bed to the south.

196. An abandoned quarry, east of the Centennial, nearly on the county line; bed 20 feet thick, dipping 70° N., cleavage vertical.

Weisenburg township.

199. Old quarry, east of Siepstown, near the township line; dip 70°, S. 20° E; cleavage 20°, S. 20° E., tolerably perfect; slates look like good roofing slates.*

Albany township.

205. John Gilt's flagstone quarry is two miles from Kempdon station. The *sandstone* dips 65° south. The strike of the rocks would carry it directly into the point of the mountain. The sandstone comes out of the quarry with rough faces, but after being dressed it looks good. Just north of the quarry slates dip 35° south.†

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*One mile south of this slates dip 10° N.; and ½ m. further south, in upper Macungie township, slates dip 20° to the south. 1½ miles N. of Seiberlingsville an outcrop of *red slate* shows in the road, but it is not roofing slate. One mile north of Seiberlingsville, along the curve of the hill, there is an outcrop of thin bedded grey *sandstone;* also some light green slate. This outcrop shows for about a mile.

† At Trexler's station the slates dip 20°, S. 20° W. ½ a mile west they dip 45° to the south. Just east of the Mountain Post Office the dip is 64°, S. 10° E. ½ a mile west of the Post Office it is 80°, S. 20° E. 1½ miles west of the Post Office the dip is 63°, S. 10° E. Going on west into the cove at *Digby Miller's* the dip is 80°, S. 10° W. At S. Knesler's it is 52°, S. 10° E. At William Bolick's it is 90°, S. 10 E., and, also, near the same place it is 75°, S. 10° E. At John Berg's it is 90°. At this place there are thin bedded dark gray slates, with inter-bedded *sandstones.* The sandstone is fine grained and in thin layers. The outcrop shows *500 feet of slates and sandstones.* At the new Bethel church the slates are vertical. Just north of the church they dip 45° to the south;

One mile east of J. Gilt's quarry there is *red slate* with dip of 20°, S. 10° E. The slate has patches of green in it. On the road just below the grist mill slates and inter-bedded *sandstones* dip 45°, S. 20° W. 200 yards south *red slates* show 40 feet thick; dip about 60°, S. Opposite the school house, light greenish *sandstone* makes the high ridge to the east called Round Top. 1000 feet further down *red slate* shows. ¾ m. south of the grist mill thin bedded olive slates dip 80° N. A shaft on Stone run 1½ miles above its mouth was sunk on *red slate,* 20 feet deep; red slate 20 feet thick, some of it has spots of green in it; also, some green slate; no roofing slates; cleavage not good. ½ m N. of this, a gray *sandstone* dips 90°, S. 10° W. ½ m. N. of

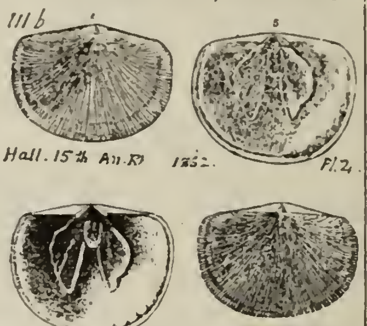
LV.

No. III b. Hudson River Slate. Orthidæ.

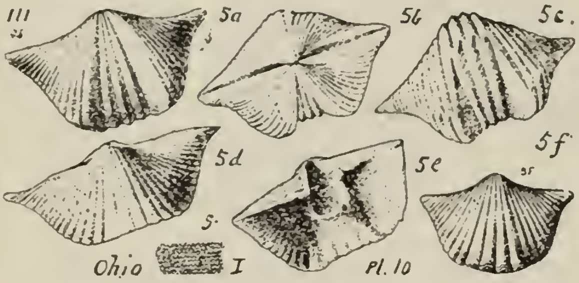
Orthis (*Platystrophia*) biforata, Var. dentata.

Orthis dichotoma.

Orthis clytie, Hall, 14th Annual

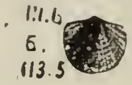


Orthis (*Platystrophia*) biforata, Var. acutilirata. (*Del-*



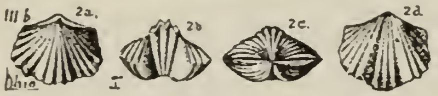
Orthis jamesi,

Orthis crispata.

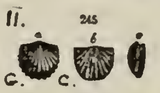


Orthis (?) ella, Hall, 13th

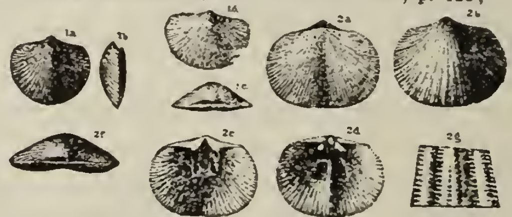
Orthis (*Platystrophia*) biforata. (*Terebra*



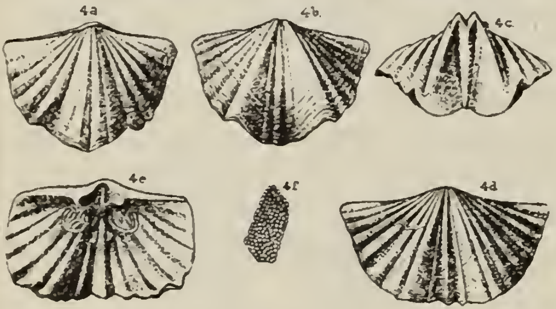
Orthis orthambonites,



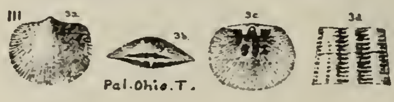
Orthis emacerata, Hall, 13th Rt. 1860, p. 121;



Orthis (*Platystrophia*) bifor,ata, Var. laticosta, James

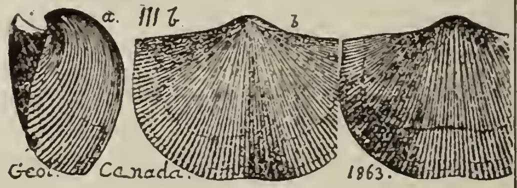


Orthis emacerata, var. multisecta,

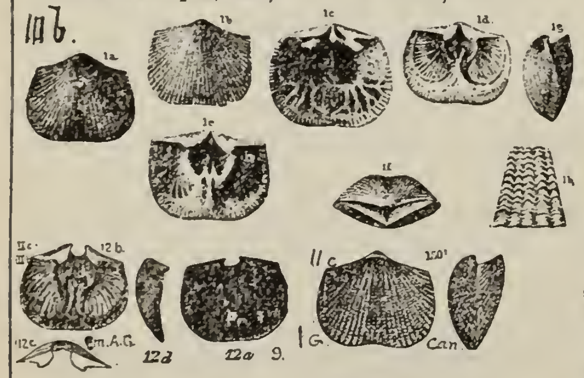


Orthis fissicosta, Hall. Pal. N. Y. Vol. 1, 1847. Em-

Orthis occidentalis, Hall, Pal. N. Y. Vol. 1, 1847.

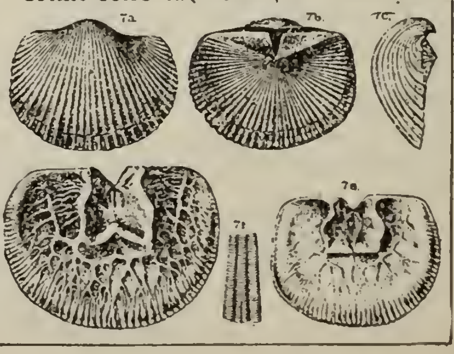


Orthis insculpta, Hall, Pal. N. Y. Vol. 1, 1847.

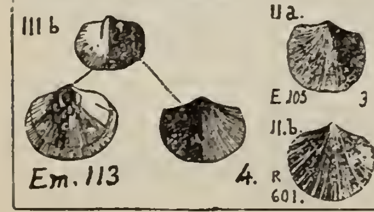


Orthis plicatella, var. triplicatella Hall, Pal. Ohio, Vol. 1

Orthis retro sa? Salter, Geol. Survey of O



Othis testudinaria. Emmons



Orthis bellula, James.

Wessnersville slates dip 45°, S. 10° W. Half a mile south of Wessnersville *red slates* dip 90° S. 2 m. S. E. of Wessnersville olive slates dip 50°, S. 30° E. 1 m. W. of last is a *red slate* outcrop.

Greenwich township has no quarries. On the railroad ½ m W. of township line, slates dip 58°, S. 20° E. Opposite Lenhartsville, slates and thin bedded sandstone dip 55°, S. 20° E. At the road crossing *red slates* show. On the small creek 2 m. N. E. of Lenhartsville *red slates* dip 55° S. 1½ m. E. of Smithsville, a fifty foot outcrop of *red slate* in the road. ½ m. N. of Smithsville *red slates* crop out. 2 m. W. of Smithsville, 15 feet of *red slate* dip 55°, S. 20° E. At Klinesville, *red slate* outcrop. The hill 1 m. S. of Klinesville is made of fine grained, thin-bedded *sandstone.* On the south side of the hill *red slates* show in layers as far as the school house and along the road to the east for a mile and a half. 1 m. S. of Smithsville slates dip 20°, S. 40° W.

Half a mile further there is an outcrop of massive flaggy *sandstones.*

There are two small outcrops of *limestone* in the township; the northern is on S. D. Kohler's farm; length of outcrop unknown owing to loose slate covering it. Just north of this outcrop the slates dip 35°, S. 20° E.

The other *limestone* outcrop is half a mile south of W. Heffner's grist mill; dip 10° N.; *limestone* blue and thin bedded.

Maxatawny township has no quarries. 1½ m. N. of Kutztown the slates are flat; also ½ a mile north of this, on top of the hill above the junction of the slate and limestone, the slates lie flat, but at the lower side of the same cut dip 45° west.

Richmond township has no quarries. E. of Virginsville one mile, *limestone* outcrops; the most northern dips 30° N. A quarter of a mile south (with slate showing between) the *limestone* lies flat with rolls in it. Half a mile south of this, with slate between, the *limestone* dips 30° north; it is dark blue, thin bedded, and shows 100 to 200 feet, and *has the appearance of the Trenton.* Along the small creek half a mile east of this there is no limestone to be seen; therefore the outcrop is probably that of a sharp anticlinal.

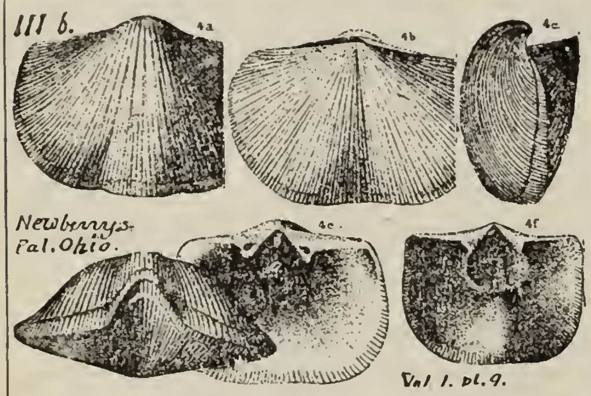
Two and one-half miles E. of Virginsville thin bedded *sandstone* dip 30° S. ¾ m. E. of Merkel's saw mill slates dip 90° W.; also some fine grained *sandstone.* Just below Merkel's saw mill slates dip 35°, S. 30 E. On the hill north of Moselem furnace slates dip 15°, S. 60° W. ¾ m. S. of Moselem furnace slates dip 20° north. 1 m. W. of the furnace the dip is flat.

Windsor township has no quarries. At school house No. 4 slates dip 90°, S. 30° E. with some slaty sandstone. 300′ S. *red slate* shows for half a mile east. ½ m. S. of St. Paul's church *red slates show for 600 feet across*the outcrop; no dip visible; ¼ m. E. the same dip S. 60°, S. 30° E. 1½ m. E. of Hamburg slates dip 50° south. 1 m. E. at the old railroad grading *alternate beds of slate and sandstone* dip 52° S. 20° E. At the east end of Hamburg sandstone outcrops in the road. 1 m. N. of Hamburg *alternate beds of slate and sandstone* dip 75°, S. 10° E. waving. ¼ m. below the lock-house sandstone dips 10° E. (massive *sandstone of IV*). 500′ further up the river dark gray slates dip 50°, S. 20° E. 200 feet shows underneath gray slate, slaty sandstone and thick bedded *sandstones.*—1 m. E. of Hamburg slates dip 60° S. ¼ m. further east fine grained olive sandstone, 15 feet thick, thin bedded, dips 80°, S. 10° E. South of the run *red slate,* 30 to 50 feet, dip 50°, S. 10° E. 1 m. N. of Windsor Castle slates dip 60° south. ½ m. N. of Windsor Castle slates dip 35° south. 1½ m. E. of Windsor Castle slates dip 60° south.

LVI.

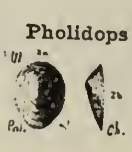
No. III b. Hudson River Slate. Fossils.

Orthis sinuata, Hall. Pal. N. Y. Vol. 1, 1847, *Hud. River*



Pleurotomaria (*Scalites?*) tropidophora, Meek.

Pholidops cincinnat

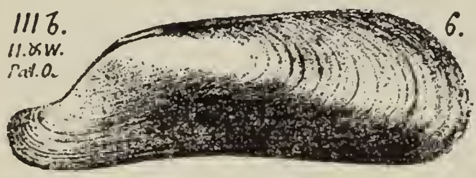


Pleurotomaria bilix (now Cyclonema bilix) Conr.

Orthodesma rectum, H. & W. Pal. Ohio, Vol. 2. 1875.

Orthodosma contractum, Hall.

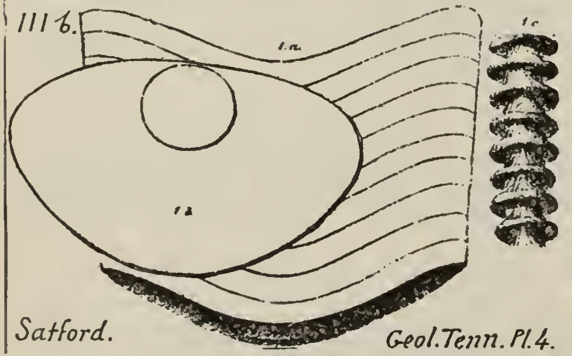
Orthodesma curvatum, H. & W. Pal. Ohio,

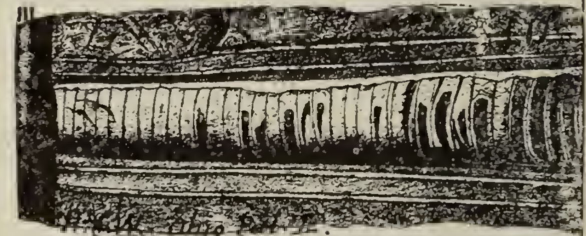


Orthodesma parallelum. (*Orthonota parallela.*

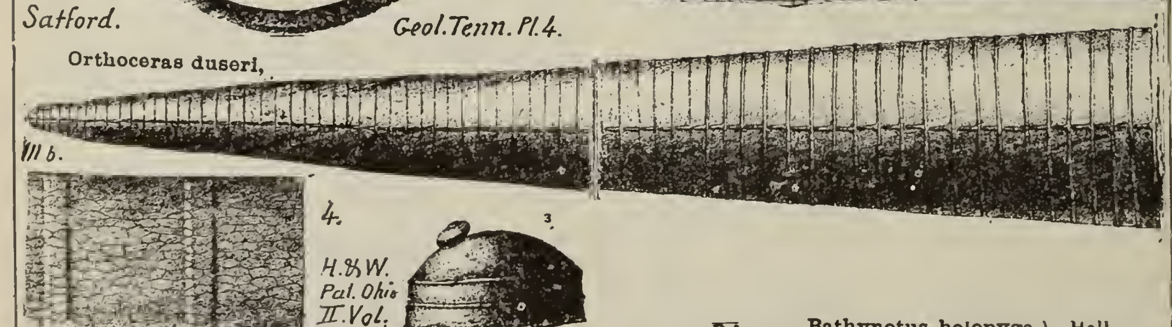
Orthoceras ortoni, Meek,

Orthoceras capitolinum, Safford. Geol. Tenn. 1869,

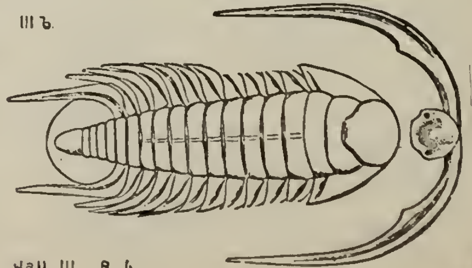




Orthoceras duseri,



Peltura (Bathynotus holopyga.) Hall.



Orthoceras turbidum, H. & W. Pal. O

Orthoceras crebriseptum

Perry township.

244. A flagstone quarry, at the northeast corner of the township, worked by Jacob Derby. The stones make good flagging, and are taken out generally 2′×3′×3″ in size. Some are 10 feet long. They are dark gray and come out regularly. The sandstones roll to the north and south and dip to the northeast.*

250. W. Collier's flagstone quarry, ¾ m. N. E. of Shoemakersville, is 150 feet long. 10 feet of flagstone exposed has from 5 to 10 feet of broken slate on top. Stones, from 2′ to 4′×5′ to 8′, show dark gray generally, 2 inches thick, with smooth faces. The joints are not regular, making a loss of about one-third in squaring them up. Half a mile southeast of this quarry the slates dip 80° south.

251. A small *flagstone quarry*, two miles east of Shoemakersville, 20×30×10 feet. The stones on the pile are 6×6×3 feet; quarry full of water. One mile south the slates dip 50°, S. 10° W.†

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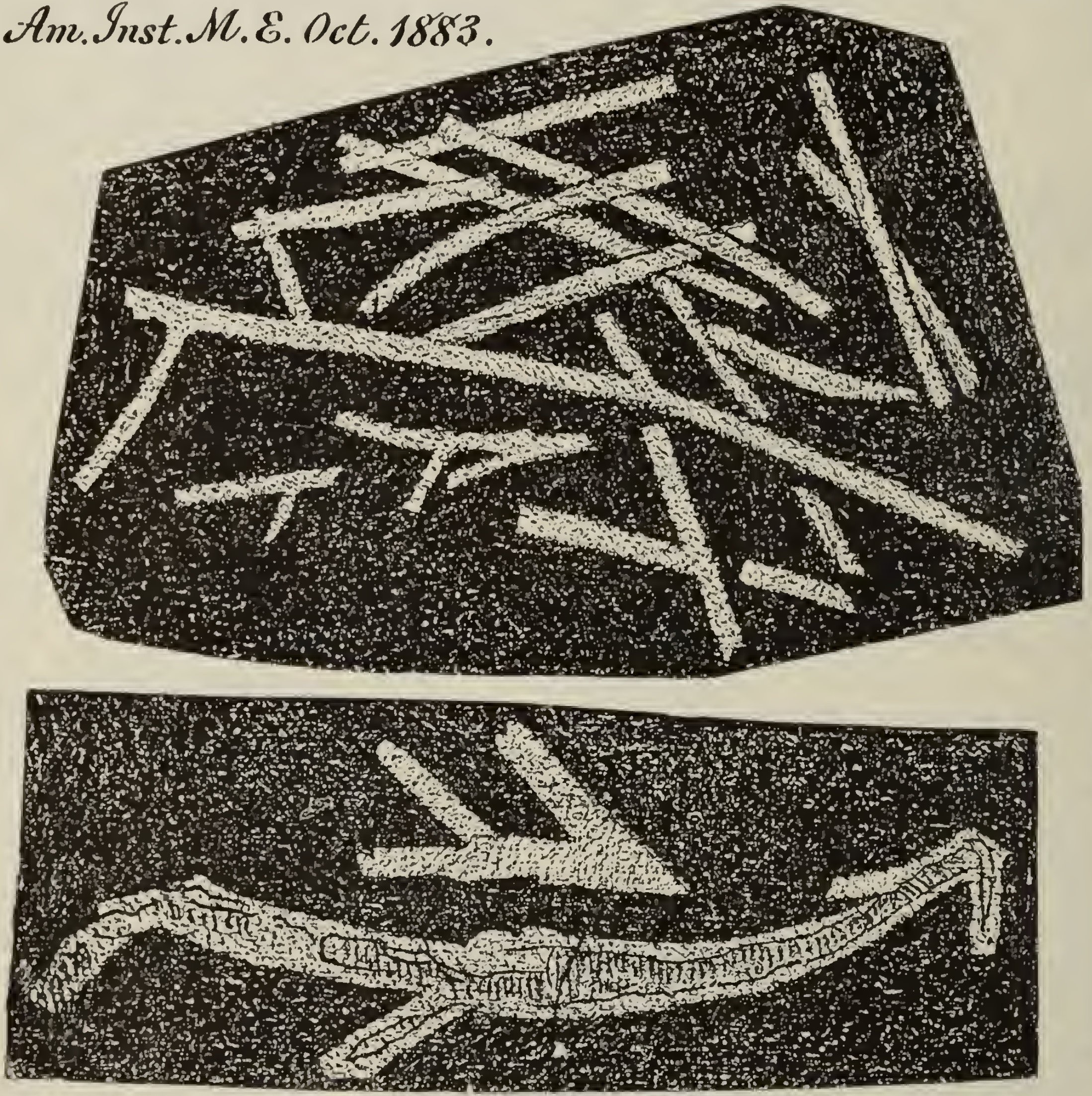
*Half a mile west slates dip 50° south. 500 feet south *limestone* outcrops; 30 feet; shows west for three miles. Just west of the Zion church it is flat with rolls in it. ¼ m. N. of the church slates dip 50° south. 1000 feet south of the limestone *red slate* outcrops. One mile south of the above *limestone* outcrop is another about parallel to it. On *Peter Folk's farm* the *limestone* dips under the slate at an angle of 20° to the south. At the corner of the roads the slate dips 18°, S. 70° west. 1 mile further west the *limestone* dips 32° south; light blue and broken. 1½ m. further west the *limestone* dips 20°, S. 20° E. Is light blue with some slaty limestone on top. Limestone shows again at the creek above the grist mill.

†At the north end of Mohrsville the slates are flat. 1½ m. N of Shoemakersville on the canal slates dip 45°, S. 30° W. 200 feet further north, dip 90°, N. 30 E.; probably an *anticlinal* brings up the limestone further east. 1 m. further up the canal slates dip 60° S. 30° W.

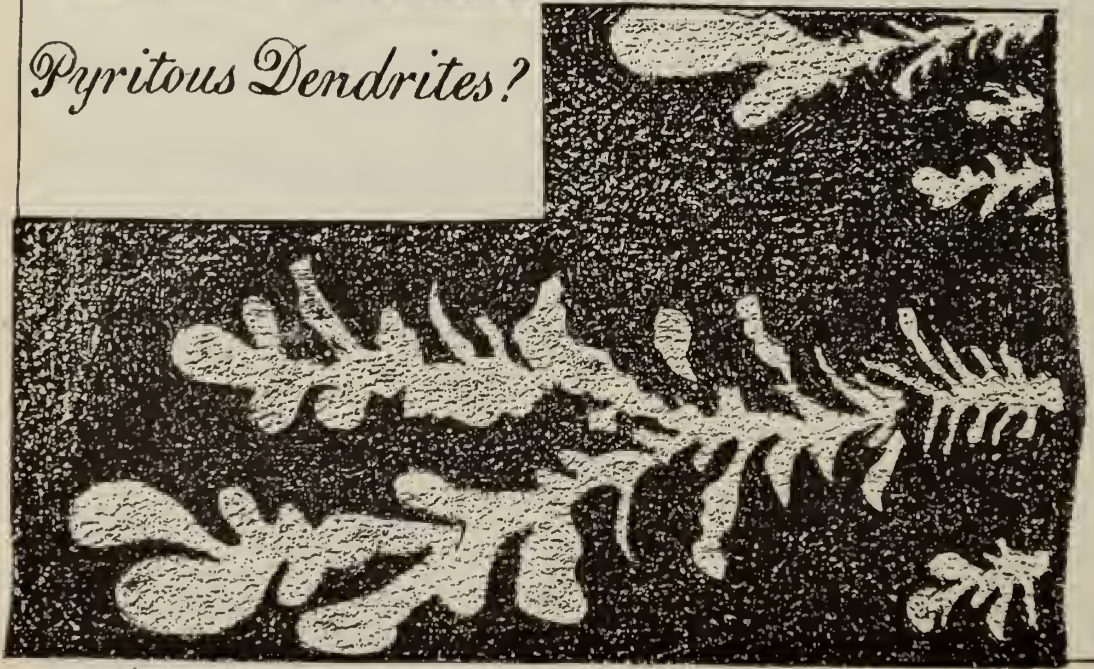
In *Ontelaunee township*, 1 m. N. of Evansville, *limestone* outcrops show 100 feet wide. 1¾ m. E. of Leesport slates dip 55°, S. 20° E. 1 m. N. of Leesport, slates and some slaty sandstone dip 40°, S. 20° E. The *Crane Iron Co.'s ore bank*, 2½ m. N. E. of Leesport consists of two open cuts now full of water. At one place could get a slate dip of 45° south. The surface is covered with loose slate, and pieces of slate coated with hematite. From the looks of the dump I should say that the mine had a great deal of slate in it.

LXX.

Fossil sea weeds on Peach Bottom slates,
Copied and reduced to 1/2 from figures by Dr. P. Frazer,
Am. Inst. M. E. Oct. 1883.



Pyritous Dendrites?



CHAPTER L.

The Fossils of No. III.

The Utica Slate (*IIIa*) formation is very fossiliferous in Newfoundland, Labrador, the island of Anticosti, Canada (as far west as Lake Huron, where it thins out), Vermont, New York, New Jersey and middle Pennsylvania. its characteristic fossil everywhere being a beautiful little quaker-like trilobite the *Triarthrus* (three jointed) *beckii* of Green*. On the Ohio river this fossil is abundant, associated with *Leptobolus lepis* and other Utica forms, not in black slate but in blue lime shales and marls, which are beds of passage from the Trenton limestone beds up into the Hudson River slates, as in Lebanon and Cumberland counties Pennsylvania; and also in the Western States. None of its characteristic fossils are found in the Galena limestone, and none of the characteristic Galena forms are found in the Utica.†

In Centre county, Professor Ewing cites Matternville as a good locality for seeing the sandy slates at the base of the Hudson River formation graduating downward into the Trenton through a series of limy layers which carry "fossils common to the Trenton and Utica.‡

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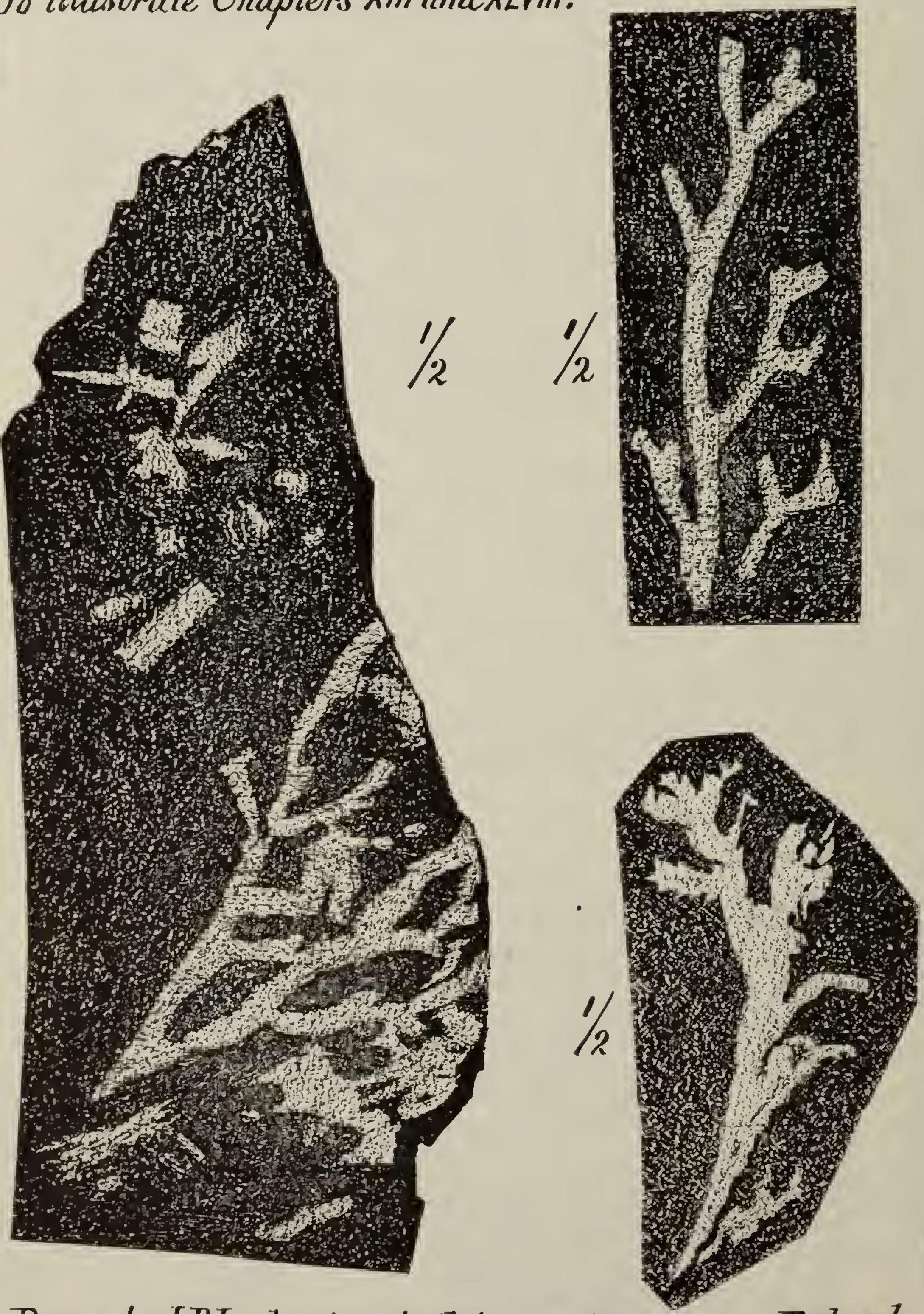
*Monograph of Trilobites, 1832. Other species of this genus are *T. canadensis*, Smith; *T. glaber*, Billings; and *T. spinosus*, all in the Utica and the last very abundant in Canada. S. A. Miller, p. 44. The figures of these trilobites are given life-size in my Dictionary of Fossils in Pa. Report P4, Vol. 3, 1890, pp. 1208, 1209; and reduced to one-half linear on plate 38, p. 526, and plate 43, p. 536, above.

†S. A. Miller, p. 44.

‡The whole of No. III, Utica and Hudson River combined seems to be only 800 feet thick. At Egg Hill in Penn's valley, and Spring Mills, transition (Utica) shaly limestones holding Trenton fossils are well seen. Between Jacksonville and Howard near the base of Bald Eagle mountain a tough black lime shale crops out (overturned to 60°); and near Hoy's house, at the base of the mountain (that is, high in III) fossils are seen like those at Egg Hill.

LXXI.

Fossil sea weeds on Peach Bottom slates,
from Humphrey's quarry, Slate Ridge, York county, Pa.
in the possession of Dr. I. F. Rendell. Lincoln University.
To illustrate Chapters XIII and XLVIII.



Drawn by J. P. Lesley from the slates. Dec. 1891.
Reduced.

Prof. Ewing makes no attempt to separate the Utica from the Hudson River, but names the following list of fossils of No. III as a whole as being in his collection :

Stems of *Glyptocrinus decadactylus ; Orthis testudinaria ;* a cast of *Orthis subquadrata* (?) *; Orthis* —— *; Strophomena alternata* ; *Leptæna sericea ; Bellerophon bilobatus* ; *Murchisonia gracilis ; Modiolopsis modiomorpha ; Modiolopsis curta ; Ambonychia radiata ; Orthonota*—— *; Trinucleus concentricus ; Callimene* (*Triarthrus*) *beckii ; Callimene* —— ; *Orthoceras* ——.*

The Utica fossils catalogued in C. Hall's special collection for the Survey (O3, p. 190 to 192) consist of 44 individuals of *Triarthrus* (*Calymene*) *beckii*, got by him at Bellefonte, with *crinoid stems*, fragmental and poor ; also 47 hand specimens collected by W. A. Fellows, along the Bellefonte outcrop, some of them slabs showing on their surfaces numerous fragments of that trilobite, mostly heads, comparatively few bodies, and these nearly all more or less crushed or distorted ; tail pieces comparatively rare. Also 35 other specimens of the same trilobite.

These suffice to show the vast abundance of this characteristic trilobite life in that part of the Utica sea which covered middle Pennsylvania. No doubt any collector could fill his cabinet with individual specimens at any place along the numerous and very extensive outcrop lines.

In Bedford county, the Utica black shales, about 200′ thick, containing a few compact slate layers an inch or so thick, show a few *graptolites.* They pass gradually upward into brown shales, and then into *non-fossiliferous* yellow shales which make up the mass of the Hudson River formation, some thin sandstones being seen near the top. The whole of III is only about 700′ thick.†

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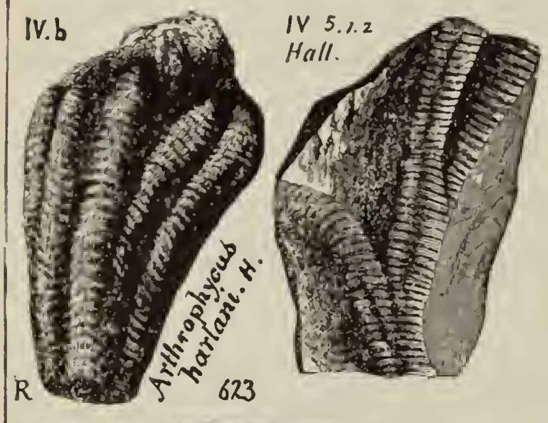
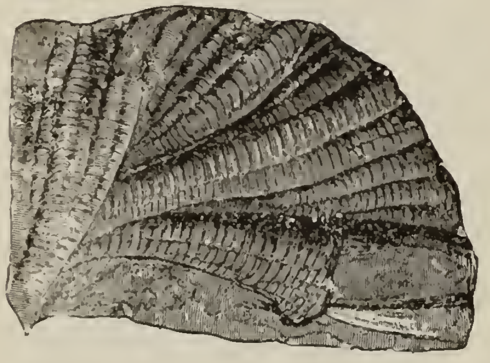
*Report Centre county, T4, 1884, page 427. He adds that most of these forms are found also in the Trenton limestones. So far as the fossils can guide us in the identification of strata at a distance it would seem as if in middle Pennsylvania only the lower half of No. III was deposited, the upper or roofing slate division being wanting. Yet the distance between Allentown and Bellefonte is only about 150 miles.

†Stevenson, T2, 1882, page 93.

CXI.

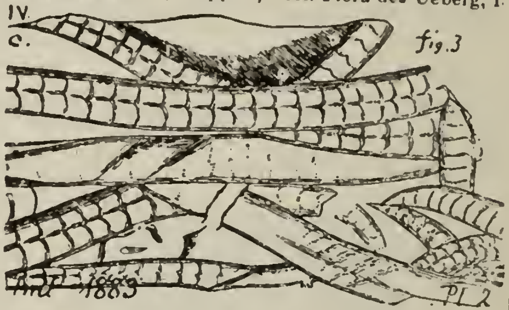
No. IV, Oneida (a) & Medina (b, c) sandstones.





Collected from IVa, at Port Clinton; and from IV b, c, at Greenwood Fur.

Harlania halli. (Goeppert, Foss. Flora des Ueberg, 1.



Clisiophyllum oneidense. (Billings. Canad.

☞ VIII a. Corniferous limestone

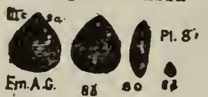
A. Win. 1885

Geo. St. p. 204.

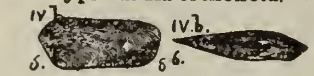
Lingula cuneata, Conrad. (II c. Trenton in Pa. See Rt T4, p. 424.)

Hall. IV. 10.

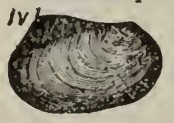
Lingula crassa Omitted from Trenton fossil plates, above.



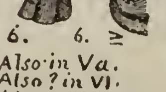
Cypricardia orthonota. Hall.



Modiomorpha alata. Hall. (Cypricardites alata, (Unio primigenius Conrad)

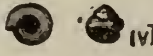


Bellerophon trilobatus (Planorbis trilobat Conrad)



Also in Va.
Also ? in VI.
Also in VIII g.

Euomphalus pervetustus (Cyclostoma (Pleurotoma



The Hudson River formation, *IIIb*, a marine deposit from the Gulf of St. Lawrence west to the Red River of the North, and south to Tennessee and Texas, varies in thickness from 6000′ on the Delaware and 2000′ in eastern Canada, to 1100′ at Toronto, 250′ in Missouri, and 100′ in the far northwest.

It is very fossiliferous around the Falls of the Ohio, where it consists of 800′ of blue lime shales and limestone layers. The seas swarmed with animal life and seaweed, and many of the strata are composed wholly of their remains.* Some fossil forms lived through the whole age, and occur from bottom to top:—*Callimene callicephala*; *Asaphus gigas*, and *megistus*; *Beyrichia chambersi*; *Leptœna sericea*; *Bellerophon bilobatus*; *Zygospira modesta*; *Strophomena alternata*; and *Orthis testudinaria*; and all of them (except the *Beyrichia*) have been found in older strata (No. II). *L. sericea* continued to live into a later age.

Other forms (at least in the Cincinnati country) seem to have had but a short range of life:—*Streptorhynchus hallianum* has a limited range in the lower part; *Streptorhynchus planoconvexum* and *sinuatum* are limited to strata below the middle; *Streptorhynchus nutans* and *sulcatum* are confined to the middle zone of the upper division; *Streptorhynchus subtentum* and *filitextum* are confined to the upper part. Of five species *of Lichenocrinus* three, *crateriformis*, *dyeri*, *pattersoni*, are confined to the lower half; two, *tuberculatus*, *affinis*, to the upper part. Of species of the trilobite *Acidaspis* one, *crossota*, occurs below; two, *anchoralis*, *cincinnatiensis*, in the middle; one, *coralli*, above.—*Rhynchonella capax* and *dentata*, *Streptelasma corniculum*, *Favistella stellata*, *Tetradium fibratum*, *Cypricardites*, &c., are confined to the upper

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*S. A. Miller's N. A. G. and P. Cincin. 1889, p. 46. He describes the outcrop from Cincinnati west, 50 miles, to Osgood in Indiana, N. to Dayton, and N. E. to Xenia. The hills at Cincinnati expose the lower half (400′). In Kentucky it makes a circular clay crop around the Bluegrass country. It is rare to find a layer of solid limestone (in the 50′ of clay) more than one foot thick. The stone is a mass of more or less ground up shells, corals and crinoids.

LXXII.

JACK'S MT. ANTICLINAL CROSSING, SIDELING HILL CREEK IN HUNTINGDON CO. PA.

part.—*Crinoids* as a rule have a limited vertical range, each species holding by its own separate horizon.

Characteristic and widely distributed species of *No. IIIb* are: *Aulopora arachnoidea*, *Stomatopora inflata*, *Orthis occidentalis*, *Orthis subquadrata*, *Orthis retrorsa*, *Pterinea demissa*, *Pterinea insueta*, *Cyclonema bilix*, and *Glyptocrinus decadactylus*.*

At Henrietta station, in Blair county, Mr. R. E. Sanders in 1875 obtained from the Hudson River slates ten specimens of brachiopods of undetermined species. (O3, p, 191.)

From the same slates, 1½ miles S. W. of the Henrietta mine, he got *Glyptocrinus decadactylus*, and other crinoid stem impressions. (O3, p. 191.)

From the same slates in Leathercracker cove, besides the crinoids, he collected *Schirodus æqualis*; *Triarthrus* (*Calymene*) *beckii*, a head of *Dalmanites limulurus* fairly well preserved: *Graptolithus mucronatus* (?); and poor, faint, indistinct impressions of other graptolites. (O3, p. 192.)

A collector of Hudson River fossils in Middle Pennsylvania must devote a long time and close attention to the business, and if successful, will find most of his specimens injured and distorted by the excessive pressure and shearing movement of bed upon bed which took place when the anticlinal and synclinal waves were produced

Peach Bottom roofing slate fossil seaweeds are figured on plates LXX, LXXI, on pages 616, 618, above, for comparison with the seaweeds figured on plate XXVI, page 502, and on plate CXI, page —, Chapter LIII on the fossils of Oneida and Medina, No. IV; and to illustrate what is said on page 183, above.

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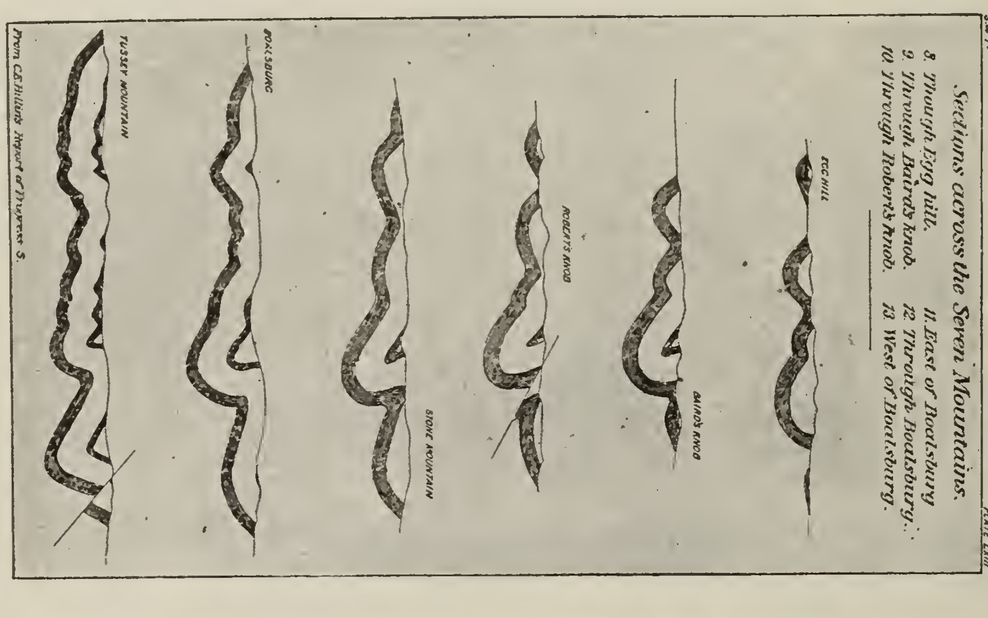
*S. A. Miller's N. A. S. and P., p. 47.—See also a full synopsis and discussion of the relationship of the Cincinnati rocks to No. III and No. II in the east, in Jos. F. James' paper "On the age of the Point Pleasant, Ohio, beds," in Journ. Cincin. Soc. Nat. Hist., July, 1891; in which the conclusion is arrived at that no beds as low as Trenton appear on the Ohio river within the limits of the State of Ohio.

LXXIII

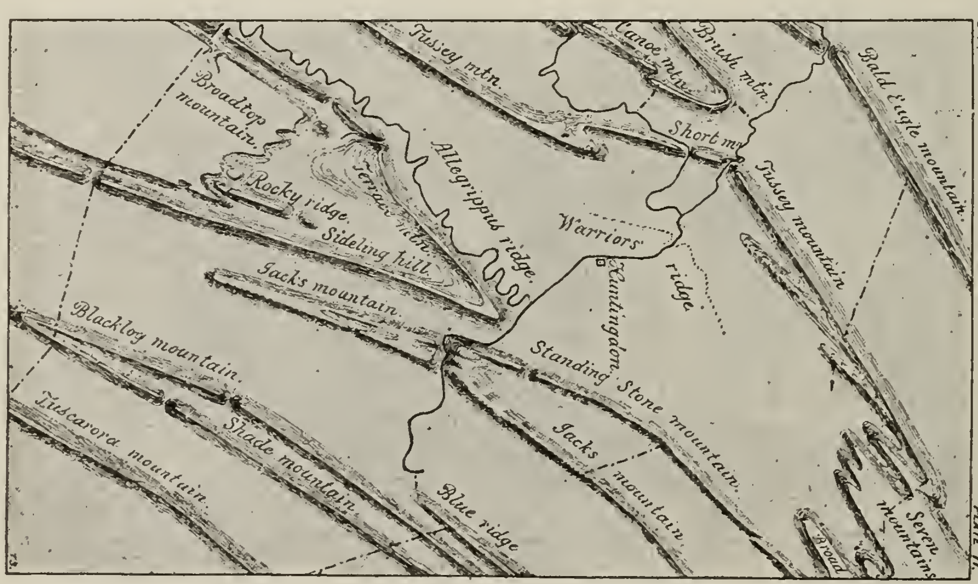
No. IV. Seven Mountains Cross Sections.

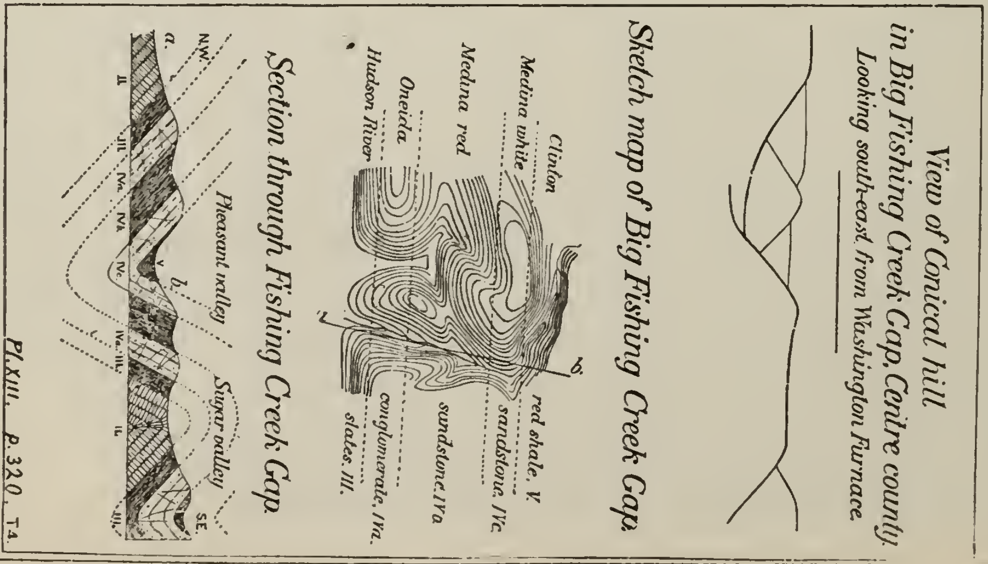


Sections across the Seven Mountains.

8. Through Egg hill.
9. Through Baird's knob.
10. Through Roberts knob.
11. East of Boalsburg.
12. Through Boalsburg.
13. West of Boalsburg.

From C.E. Hall's Report of Progress





View of Conical hill in Big Fishing Creek Gap, Centre county. Looking south-east from Washington Furnace.

Sketch map of Big Fishing Creek Gap

Section through Fishing Creek Gap.

Pl. XIII. p. 320. T.A.

CHAPTER LI.

Formation No. IV. Oneida and Medina.

Middle Pennsylvania west of the Susquehanna river is a labyrinth of parallel mountains, with straight sloping sides and sharp horizontal crests, none of them elevated more than a thousand feet above the valleys which they include. These mountains interlock in zigzags, sending out spurs and knobs into the large valleys, and enclosing longer or shorter narrow parallel coves. (See pl. 73, 74, &c.)

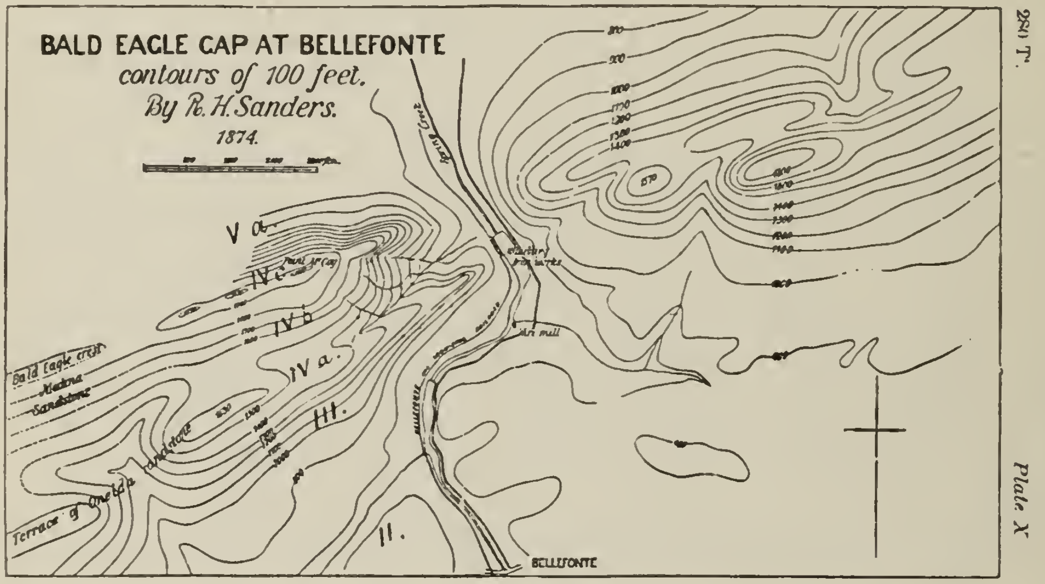
With three exceptions, to be noted directly, all these mountains are composed of Formation No. IV, subdivided into three sets of sandstone and sandy shale beds; the lowest one (*IV a*) known as the *Oneida conglomerate;* the middle set (*IV b*) known as the *Medina red sandstone;* and the upper (*IV c*) as the *Medina white sandstone.*

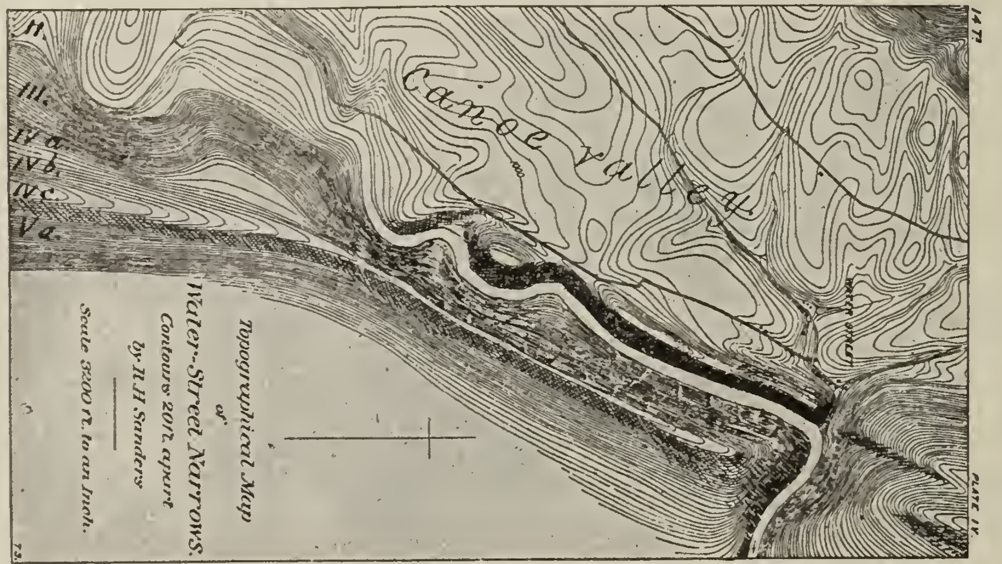
The Oneida conglomerate (*IV a*) was so named by the geologists of New York because of its coarseness, being a pudding stone or pebble rock; but in middle Pennsylvania its beds are mostly a gray sandstone interleaved with a few beds of conglomerate. Professor Rogers therefore called it the *Levant gray sandstone*, because the aspest of the rock is that of ordinary sandstone. The *Medina* or *Levant red sandstone* (*IV b*) contains so many interstratified softer shaly beds, and is so charged with iron, turning red when exposed to the air, that it makes a visible division between the lower and upper parts of the whole formation. The uppermost subdivision, the *Medina* or *Levant white sandstone* (*IV c*) is not only characterized by its purer color, or rather absence of all color, but by its greater massiveness, so that it constitutes the real backbone of the mountains, cropping out along their crests.

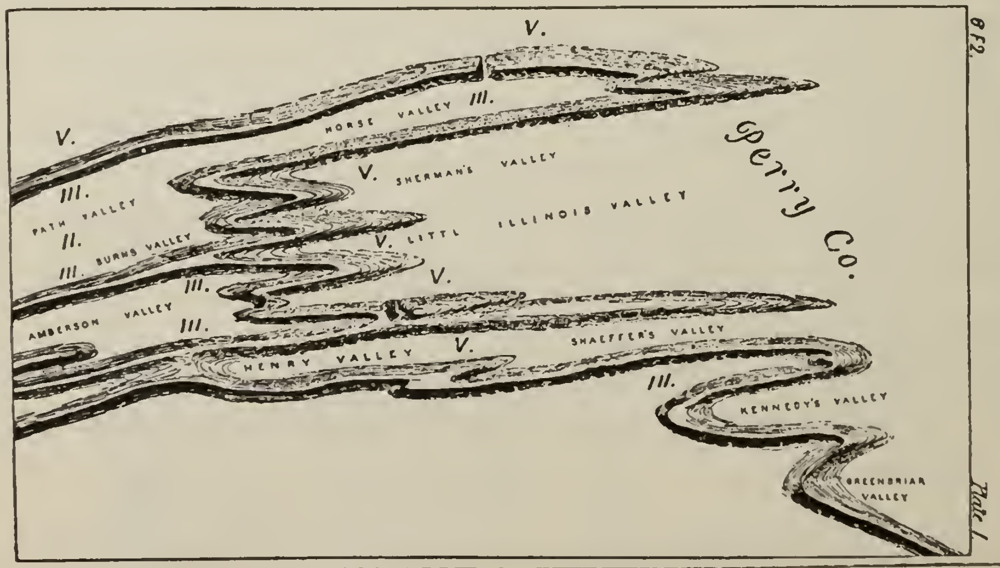
Formation IV has been a boon to Appalachian geologists. It gave them at the very outset, fifty years ago, a key

LXXIV

No. IV, Oneida and Medina topography.







to the structural geology of the whole region from Tennessee to New York. It marks the maps of Pennsyvania, Maryland, Virginia and Tennessee with topographical lines not to be overlooked or misunderstood. It furnished a safe basis for that enthusiastic investigation which resulted long ago in the establishment of the science of geological topography or Topographical Geology. By means of these numerous bold mountain outcrops the plication of the earth-crust along the Appalachian belt was at once comprehended and could be estimated at its full value ; could be measured, sectioned, mapped, and modelled in solid form ; and a number of such models have been made by the Pennsylvania Geological Survey. In the latest of these models the formations which cover No. IV have been lifted off, and the great arches in the air (long since destroyed and carried into the Atlantic) have been restored ; so that the complicated structure of the region is now as well known as the internal anatomy of the human body. And this is due, chiefly, to the great thickness of Formation No. IV, and to the extensive outspread of its sandy sediments over the bed of the Appalachian sea.

For a description of this model, and two photographs of its surface, see the close of Chapter LII.

I will first consider the thickness of the formation ; secondly the variations which obtain in its internal constitution in different parts of its outspread ; and, thirdly, the effect which these variations have had in producing different topographical aspects of the country, and the lessons which they teach respecting the formation of mountains in other parts of the world.

The thickness of No. IV.

First : As to the thickness of the formation as a whole ; and then, as to the variation in thickness of its subdivisions.

In measuring the thickness of any of our greater formations there is almost always some uncertainty as to where the measurement at the bottom is to begin, and as to where

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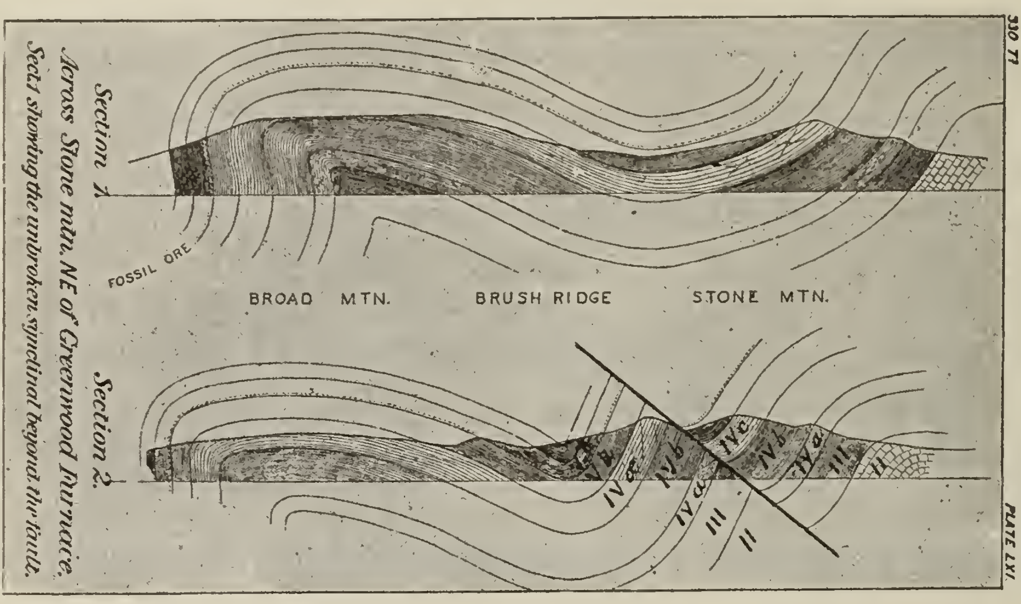
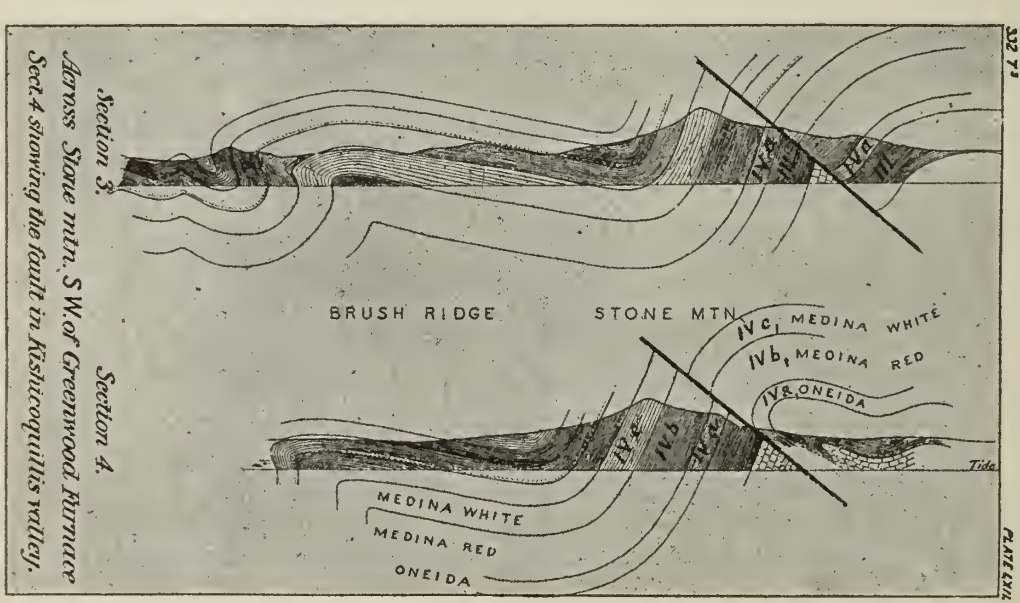
Oblique fault through IV in Mifflin Co.



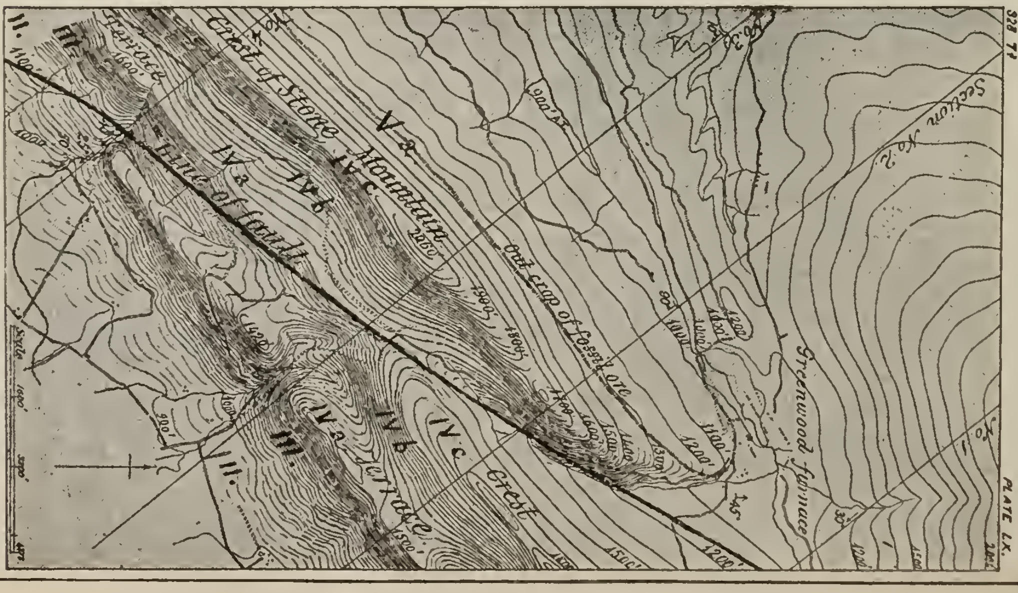
Section 1. Across Stone mtn. NE of Greenwood furnace. Sect.1 showing the unbroken synclinal beyond the fault.

Section 2.



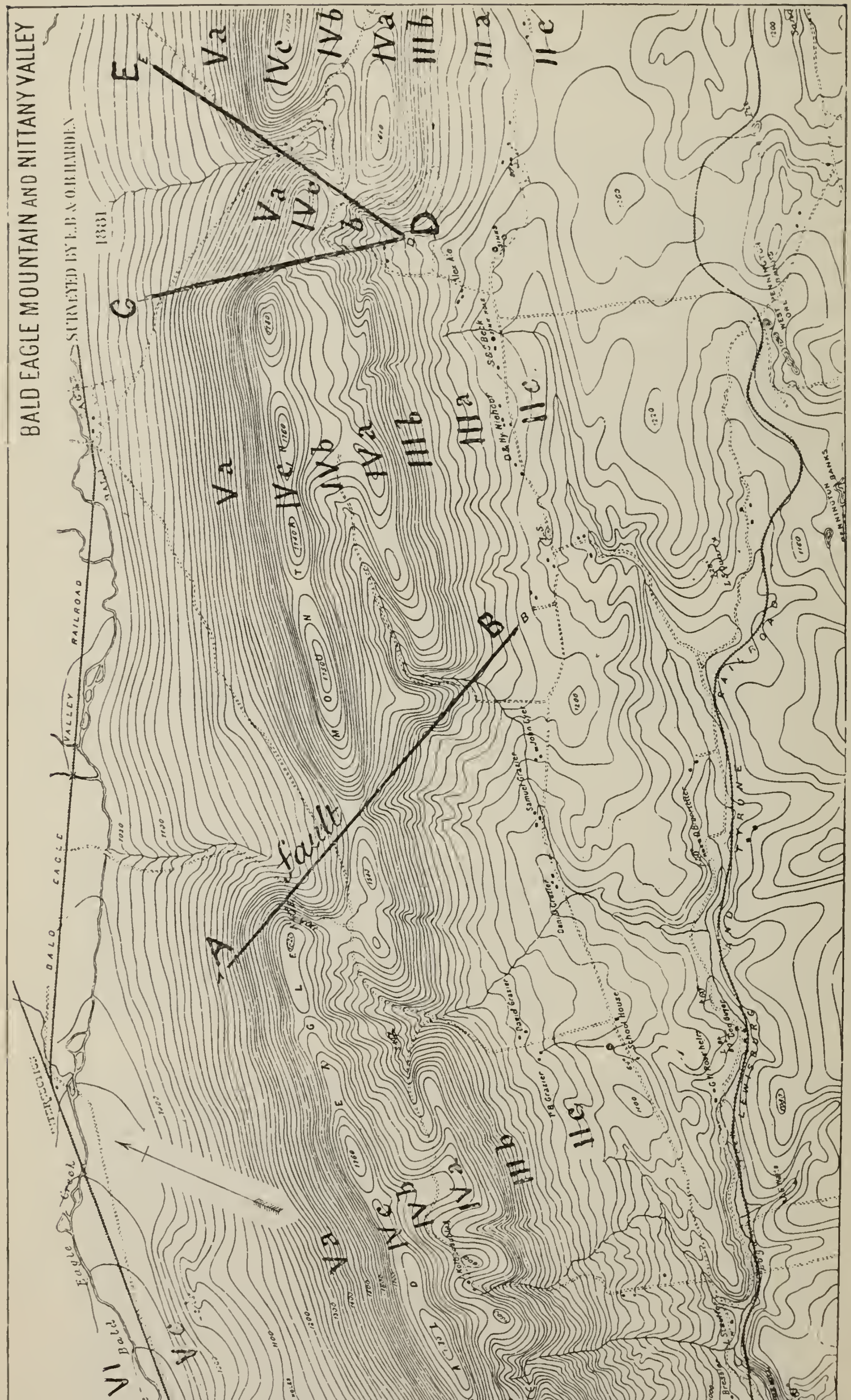
Section 3.

Section 4. Across Stone mtn. S.W. of Greenwood Furnace Sect.4 showing the fault in Kishicoquillis valley.



the measurement is to end at the top; for, as I have already sufficiently set forth, there never has been stop or pause in the tribute of the rivers to the sea; and there never has been uniformity in the nature of that tribute; sand being deposited in one place at the same time that mud was being deposited in another; and innumerable alterations of sand and mud of every possible variety have taken place through the entire process. The bottom of a formation in one place may not exactly correspond to its bottom in another place; and the same is true of its top. Nature has never written its historical memoir of geological operations in distinct and well-rounded sentences; has never numbered and headed its chapters; has seldom drawn strong black lines between its paragraphs. The formations grade and fade away into each other; and that, both downward and upward; and the geologist who attempts to measure any formation at any place must simply do his best to select some bottom rock to begin it with and some top rock to end it with. But in doing this he is always liable to mistake. He must make his selections on his own responsibility. He can never confidently assert that the bottom and the top of his formations are established facts of science. When he multiplies his measurements of a formation in various places in order to obtain by comparison a knowledge of its variations in thickness he subjects himself to the risk of multiplying his errors. Sometimes, indeed, a special bed at the bottom or at the top of a formation is so flagrantly different in constitution, in color, or in its fossil forms, from all the other beds near it, that he can adopt it as a key rock with considerable confidence. But this is rarely the case; and even when such a key rock presents itself in one part of his district, and another such key rock almost or exactly like it presents itself in another part of his district, there is always a possibility that the two are not continuous; that they were not deposited at exactly the same time throughout the region; and that perhaps nature has repeated the deposit locally and subsequently.

In measuring No. IV therefore we have been obliged to assume as its bottom limit the first massive sandstone to be


BALD EAGLE MOUNTAIN AND NITTANY VALLEY
SURVEYED BY E.B. & O.B. HARDEN
1881
E
G
D
A
B
fault
VI
Vc
Va
IVc
IVb
IVa
IIIb
IIIa
IIc
BALD EAGLE VALLEY RAILROAD
TYRONE AND LEWISBURG RAILROAD
Little Bald Eagle Creek
BALD EAGLE MOUNTAIN
PENNINGTON BANKS
WEST PENNINGTON ORE BANKS
School House

seen lying regularly upon the upper or roofing slate division of Formation No. III; and we have been obliged in like manner to assume as the upper limit or top of No. IV, the highest massive white sandstone bed which presents itself at any given locality overlaid by the softer although still sandy reddish shale beds of No. V hereafter to be described. Very exact instrumental measurements of No. IV have been made in accordance with this plan, that is, between such assumed bottom and top limits, in many parts of Pennsylvania: at the Delaware, Lehigh and Schuylkill Water Gaps; at the Susquehanna gap above Harrisburg; at Logan gap near Lewistown; at Rockhill gap near Orbisonia; at the Bald Eagle gaps near Bellefonte and Tyrone City; and at the gaps near Bedford. But as these measurements were made by different assistants of the Geological Corps they can be compared together only by making allowance for the inevitable differences of personal opinion respecting the best top and bottom limits of the formation. Yet, after all, these differences are so moderate as not to vitiate the conclusions drawn from the comparison; and we have moreover on record for comparison the equally intelligent and conscientious measurements of the assistants of the First Geological Survey under Professor Rogers, which serve in a measure to check, and in fact help to verify their accuracy.

The measurement of No. IV by Mr. Sanders in Blair county sums up 2896′; that of Mr. Dewees at Logan gap in Mifflin county, 2722′; that of Mr. Billin in the south of Centre county, 2440′; that of Dr. Chance in Clinton county, 2301′; that of Professor White at Spruce Creek tunnel in Huntingdon county, 2000′ (made uncertain by a fault); that of Mr. Ashburner in southern Huntingdon county, 1808′; that of Professor Stevenson, in Yellow creek gap, Bedford county, 2035′ (diminishing toward the Maryland line to less than 1000′); and in Fulton county about 1600′; (according to Professor Rogers' *estimate* in Cove mountain 2100′, and in Tussey mountain 1650′). In the Lycoming county gaps Mr. F. Platt estimates it at 1375′. Dr. Chance's measurement at the Schuylkill Water Gap was 1400′; at the Lehigh

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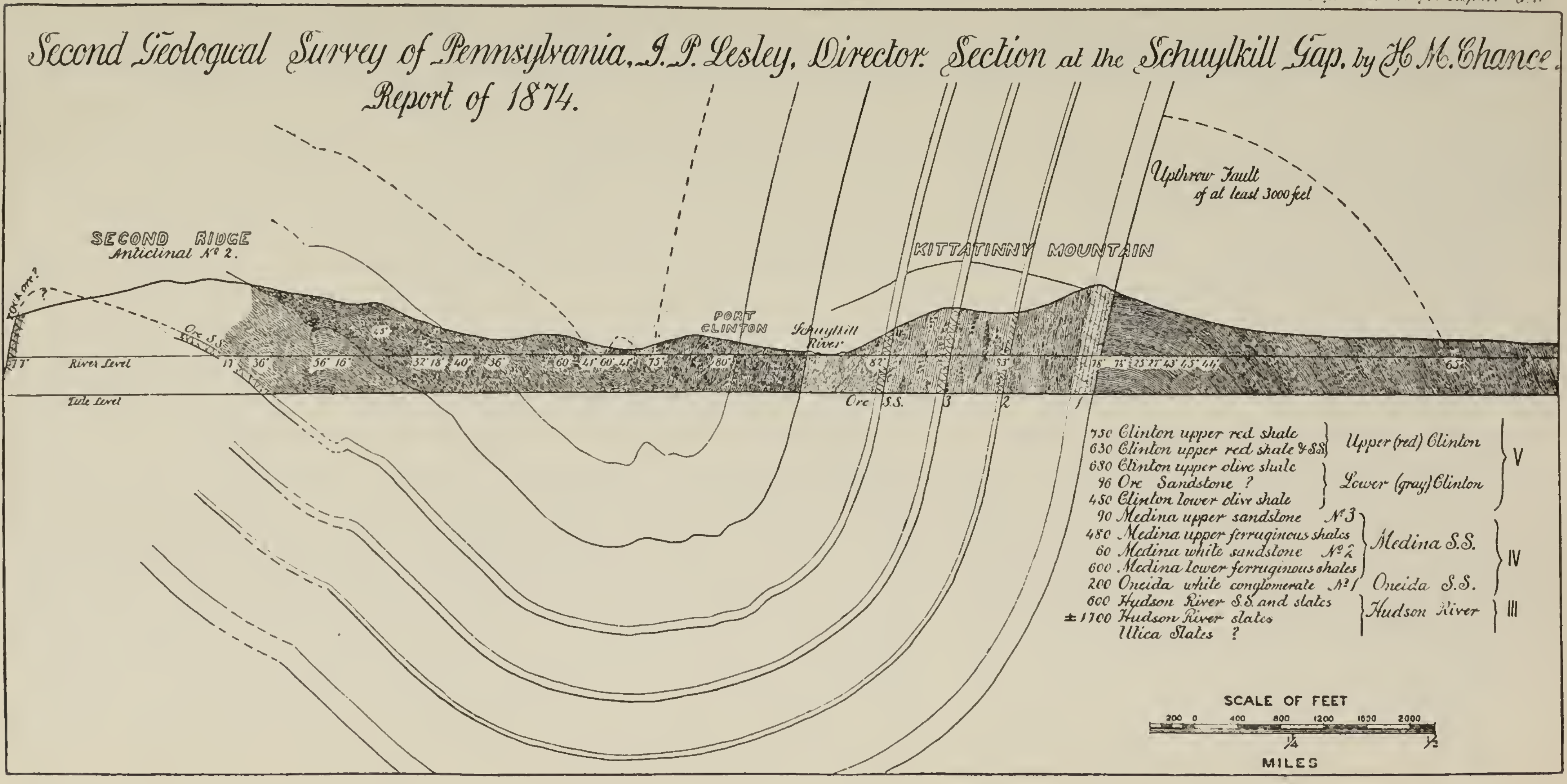
Plate V. 1882. Report G.6



Second Geological Survey of Pennsylvania. J. P. Lesley, Director. Section at the Schuylkill Gap, by H. M. Chance.
Report of 1874.

Water Gap (complicated with a fault) 1125′; and at the Delaware Water Gap 1565′.

It will be seen by the above statement that the greatest observed thickness of No. IV is in the center of the State, and that it evidently diminishes in all directions from that central district. When followed southward through Virginia it thins, at first gradually, and then rapidly, to such an extent that the whole formation appears to be only about 40′ thick at its outcrop west of Knoxville, in Tennessee.* Westward, under western Pennsylvania and Ohio, it has not been reached by the deepest borings; but that it diminishes in that direction also, is evident from the fact that its outcrop is too small to be recognized in the Columbus and Cincinnati region. Under northern Pennsylvania and central New York it is also completely concealed; but it must diminish in that direction also, for its outcrop along the Mohawk valley amounts to only 400′, diminishing toward Albany; and it makes no appearance at all around the eastern foot of the Catskill mountains. This is a remarkable phenomenon not to be easily explained. To most geological minds it will seem quite sufficient to say, that dry land existed there while two or three thousand feet of sand and gravel were being floated into a deep sea in middle Pennsylvania. The difficulty of this explanation is increased when one follows the lofty crest of the Kittatinny mountain along the north line of Berks, Lehigh and Northampton counties in Pennsylvania, crosses the Delaware at the Water Gap into New Jersey, and follows the equally high crest of the Schawngunk mountain into New York, to see it suddenly cut off a few miles east of the hotels at Lake Mahunk, to appear no more until the western border of New England is reached. Now, when a mountain ridge, the bold outcrop of a great sandstone formation 500 miles long suddenly terminates, not as an anticlinal nose descending underground, not as a cynclinal knob rising into the air, but as if the end of a slanting board had been sawn off,

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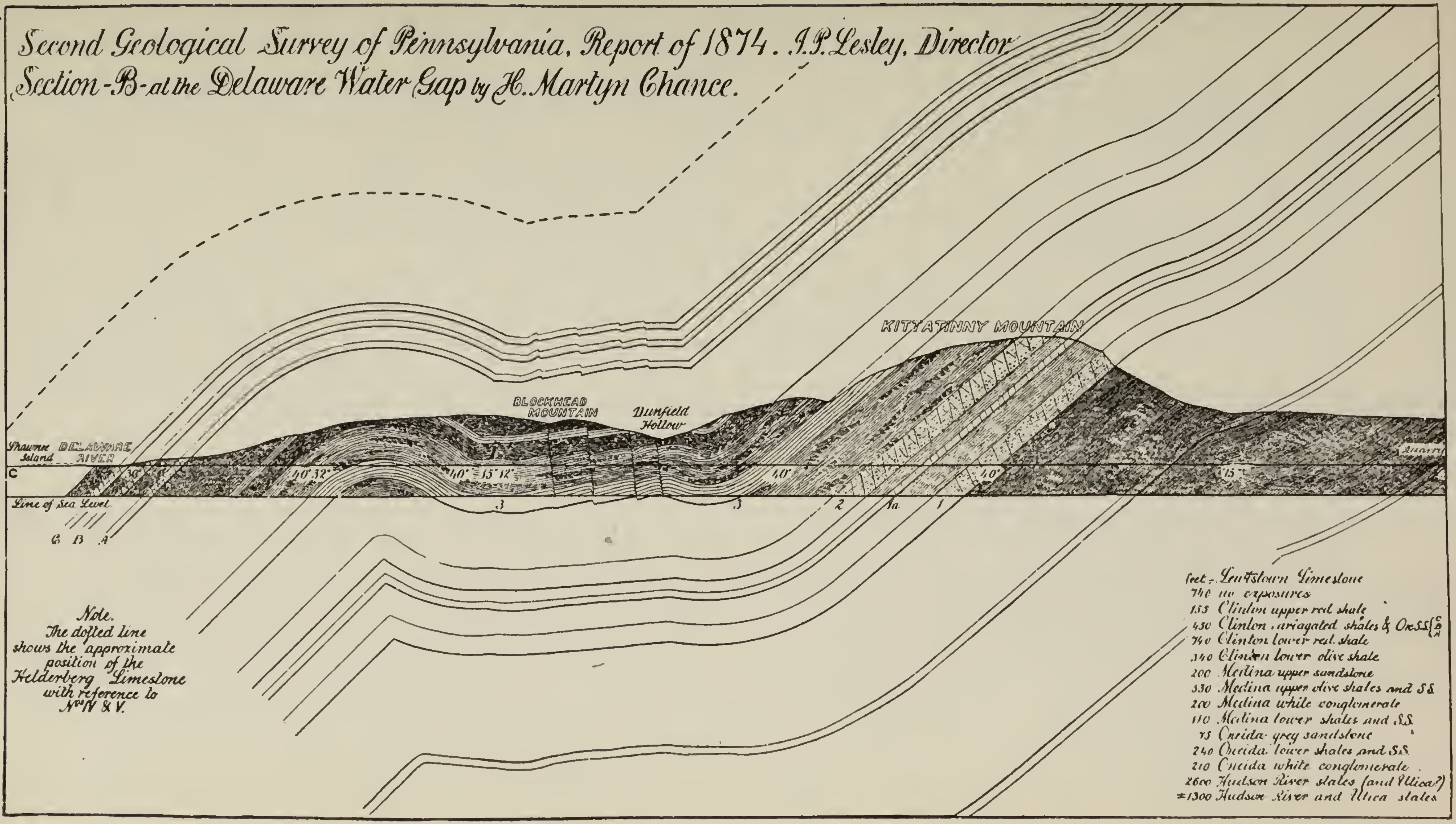
*In the White Oak mountains of East Tennessee, however, it measures between 800 and 900′.

LXXVIII.



Second Geological Survey of Pennsylvania, Report of 1874. J. P. Lesley, Director

Section-B-at the Delaware Water Gap by H. Martyn Chance.

Note.
The dotted line
shows the approximate
position of the
Helderberg Limestone
with reference to
Nos IV & V.

the structural geologist cannot doubt that the formation has been swallowed by a fault.*

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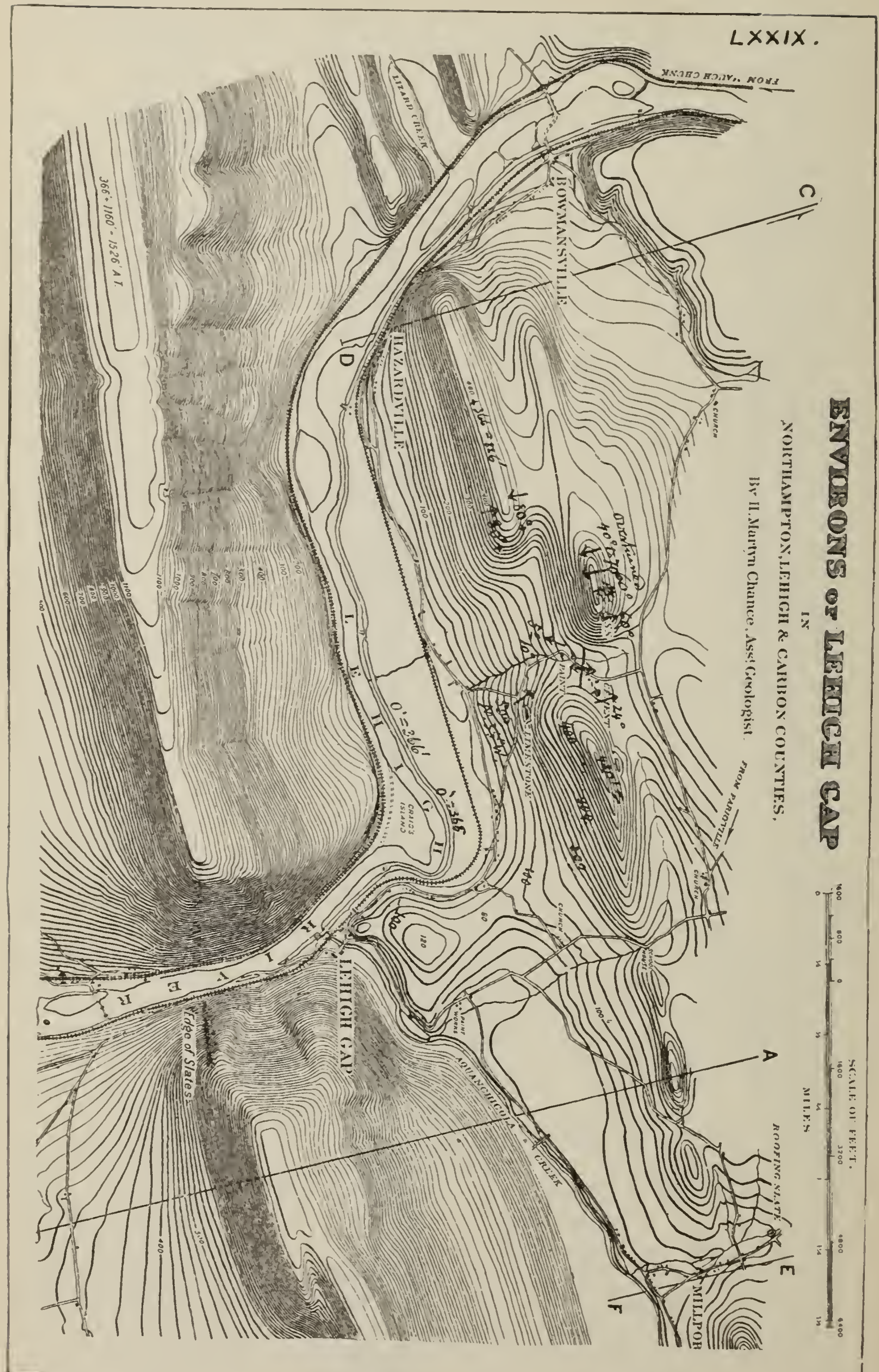
* Dr. Mather, Geologist of the First District of the New York Survey, in his quarto report of 1843, pages 355 to 361, describes this shattered condition of the mountain. He says that the Indians called the mountain Swanggum, that is "white rock." The sandstone mass he called "Schwangunk Grit," and gives its thickness as variable between a maximum of 500 feet and a minimum of 60, "its usual thickness being between 60 and 150." It is traversed by two systems of faults, one parallel to the strike (N. 20°, E.), and the other transverse (N. 60° W.). The cross faults are few between the Delaware river at Carpenter's Point (Port Jervis) and Ellenville and Wawarsing in Ulster county, where the mountain is traversed by great breaks and faults. "The ridge then sinks and rapidly disappears beneath the valley, while several wrinkles or parallel axes of elevation spring up on the east at the same height, run eastward between the Stony Kill, Mule Kill, Sanders' Kill, etc., sink down gradually towards the mouths of these streams, and finally disappear below the valley in Rochester and Marbletown, or show their continuation only by low broken ridges of upheaved limestone. These axes of elevation are terminated apparently on the south by the high cliffs along the transverse lines of fault. On the east of these minor axes the main axis of elevation takes its rise from High Point, which is a high cliff of grit rock on the main fault, and ranges thence northeastward, more or less broken and dislocated by minor transverse and oblique faults, and diminishing in height until the Shawangunk mountain and its grits, which envelope most of its higher parts, entirely disappear below the limestone and quarternary deposits at and near Rosendale. Several high points with mural fronts and ends are seen between High Point and Springtown, as Sam's Point, Great Mogunk, Puntico Point, etc., all of which are caused by faults along the main features of the mountain. It has been mentioned that the wrinkles or subordinate axes of elevation seem to terminate at these rocky points on S. E. side of the mountain, but the termination is only apparent, caused by transverse fractures. The ridges almost all slope down to the N. and N. E. from where the main fractures cross each other, and the rocks disappear below the more recent formations, while their southward extremities almost always present high precipitious and often vertical cliffs.."

Although these statements of Mather are not very lucid, they are substantially correct, as any geologist may observe who makes one of the great summer hotels, the Mohunk or the Manawaska, his headquarters. Overlooking lakes which lie on top of the mountain, surrounded by vertical cliffs of sandstone and conglomerate, and dammed by glacial moraines, these comfortable and hospitable places furnish unrivaled facilities for exploring one of the most interesting and instructive fields of geological research in America. Mather's illustrations of the Shangunk grit and its fractures on plates V, f. 13; VI, f. 7; VIII, f. 2, 3, 4; VIII, f. 4; XV, f. 3; XXVI, f. 4, 5, 6, 7, and XXXIX, f. 1, 2, 3, are so bad as to serve no purpose but that of contrasting the slovenly and absurd drawings of his day with the precise and mathematical sections of our own. Yet even then the best geologists like Hall, Logan, Lyell and Murchison illustrated their lucid English text with wood cuts hardly since surpassed for correctness and beauty.



LXXIX.

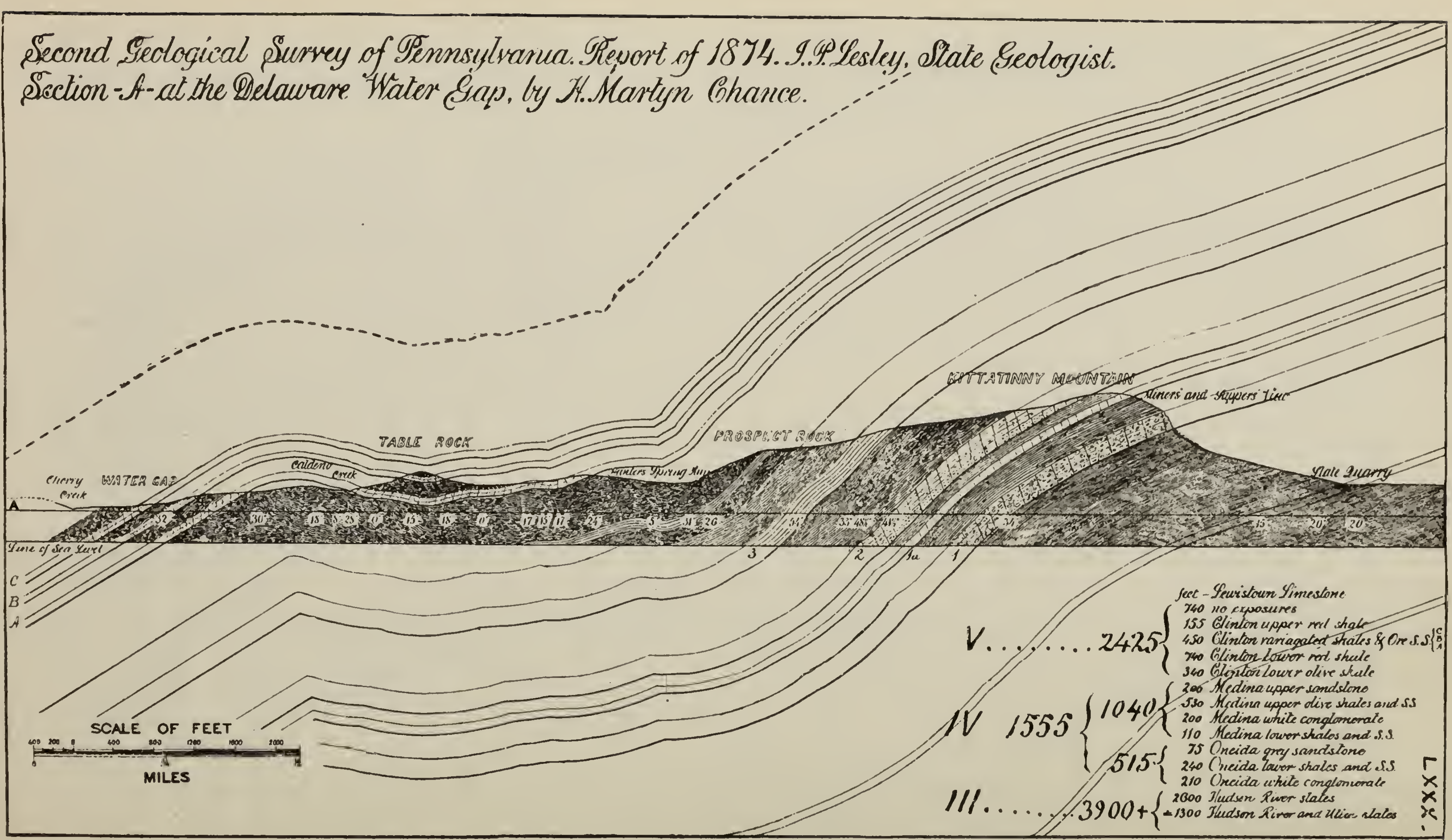
ENVIRONS OF LEHIGH GAP IN NORTHAMPTON, LEHIGH & CARBON COUNTIES.

By H. Martyn Chance, Ass't Geologist.

At the Gap above Harrisburg.

From the list of localities above mentioned where Formation No. IV has been measured to obtain its total thickness, one locality has been omitted because it requires a separate and special consideration, namely, the gap of the Susquehanna above Harrisburg. Three separate measurements have been made in this gap by Professor Rogers by Mr. Sanders, and by Professor Claypole, without, however, reaching absolutely sure results, owing to the overturned and somewhat crushed condition of the formation. Everywhere else along the line of the Kittatinny, Blue or North mountain, from the Delaware to the Potomac, the beds of No. IV slope northward and westward at various angles from 20° up to 80° and even 90°. But where the Susquehanna breaks through, the earth movement from the south has done more than press up the beds into vertical attitudes; it has pushed them over 20° beyond the vertical, overturning them to a *south* dip of about 70°. It will be shown in the next chapter that this overturn or inversion affects not only Formation No. IV, but all the overlying formations up to No. XI; and that the squeeze produced by folding 20,000′ of rock into a sharp synclinal basin has resulted in a large amount of sliding and slipping of one group of beds upon another, in the production of minor irregularities of dip and strike, occasional rolls, small faults, etc., and perhaps in the lessening of their original thickness. How much No. IV has suffered in this respect is uncertain; but it is evident that under such circumstances the measured thickness of any formation, whether hard or soft, cannot be implicitly accepted as the real or original thickness. At all events it would be unsafe to draw the same conclusions from measurements made at such a place that we can safely draw from measurements made of it at places where no such violent upturning and overturning has occurred.

The measurement of No. IV in the Susquehanna gap sums up less than 500′. This is at the southeast corner of Perry county; but in the western and northern parts of that same county No. IV appears to be about 2000′ thick.



Second Geological Survey of Pennsylvania. Report of 1874. J. P. Lesley, State Geologist.
Section -A- at the Delaware Water Gap, by H. Martyn Chance.

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Following the mountain only a few miles *eastward* from the Susquehanna, to where the beds of No. IV lean in their natural attitude (dipping north) the formation becomes of its usual thickness; and following the mountain *westward* from the Susquehanna not more than 15 miles, the usual thickness of the formation is again resumed. We have, therefore, some right to ascribe its abnormal thickness at the Susquehanna to the overturn. Another explanation however has been suggested and will be described in the next chapters, since it affects still more seriously Formations No. V and No. VI in this locality.

The thickness of Formation No. IV as a whole is of course the sum of the thickness of its three subdivisions, (lower, middle and upper) *Oneida*, *Medina red*, and *Medina white*. If the relative thickness of these divisions remained constant, and if the hardness and softness of the beds of the three divisions were everywhere the same, it is evident that the shape of a mountain of No. IV would be always the same. But the law of universal geological irregularity operates upon all three subdivisions. In fact each subdivision of No. IV has as much right to be considered an individual and distinct formation as if it had no topographical relationship with the other two; and the only reason why the three subdivisions of No. IV have been grouped together into one formation is the fact that the three together always make one mountain; the shape of which, however, necessarily varies with the variations in solidity and thickness of the subdivisions, as will be shown directly. For the present we will regard simply the thickness of the subdivisions; repeating, however, and insisting still more earnestly upon it, what has already been said respecting the indefiniteness of the bottom and top limits of all formations and groups of beds. If the three subdivisions of No. IV had been made by a stone cutter out of three slabs of rock placed one upon another there would be no uncertainty as to their thickness; but seeing that they are three artificial groupings of an immense number of sand and mud deposits, each varying in its individual character and thickness, white and gray sandstones alter-

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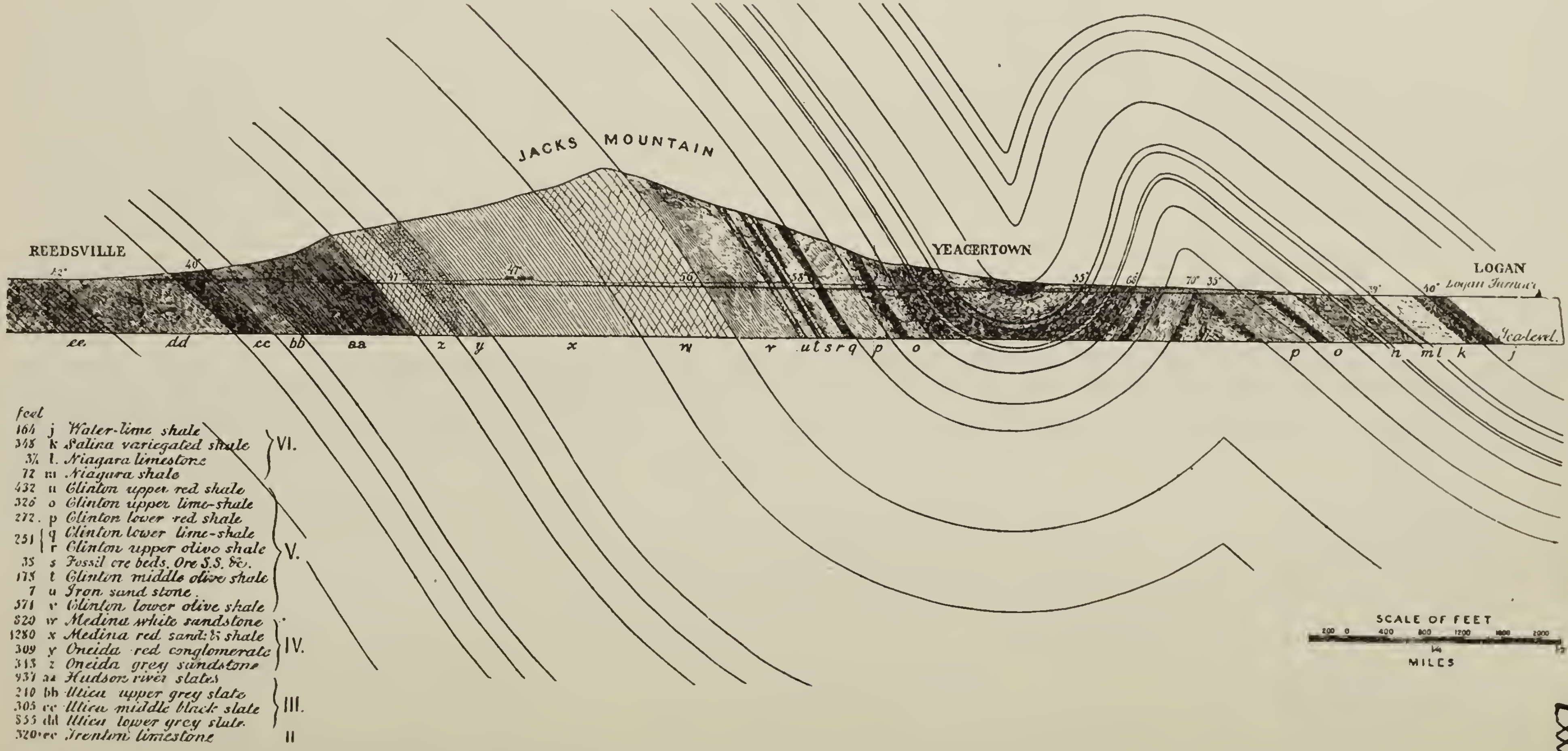
Second Geological Survey of Pennsylvania. 1874. Juniata district. J. H. Dewees. Asst. Geol.
Logan section. Calculated and drawn by Chas. A. Ashburner.



nating with gray and reddish muds, it is extremely difficult to decide upon any fixed planes of division between them. All that we can do is to group the lower gray sands togther as the *Oneida*, the upper white sands together as *Medina white*, and call the softer and more or less reddish beds between them as the middle division, or *Medina red;* and arrange their thicknesses at the various places where they have been measured in a table like the following:

At the Delaware Water Gap. H. M. Chance:[*]

Medina upper sandstone,	200′	1040′
" upper shales, etc.,	530,	
" white conglomerate,	200′	
" lower shales, etc.,	110′	
Oneida gray sandstone,	75′	525′
" lower shales, etc.,	240′	
" white conglomerate,	210′	1565′

At the Lehigh Water Gap. H. M. Chance:[†]

Medina upper sandstone,	85′	665′
" upper shale,	180′	
" gray sandstone,	70′	
" lower shale,	330′	
Oneida cong. sandstone,	290′	460′
" conglomerate,	170′	1125′

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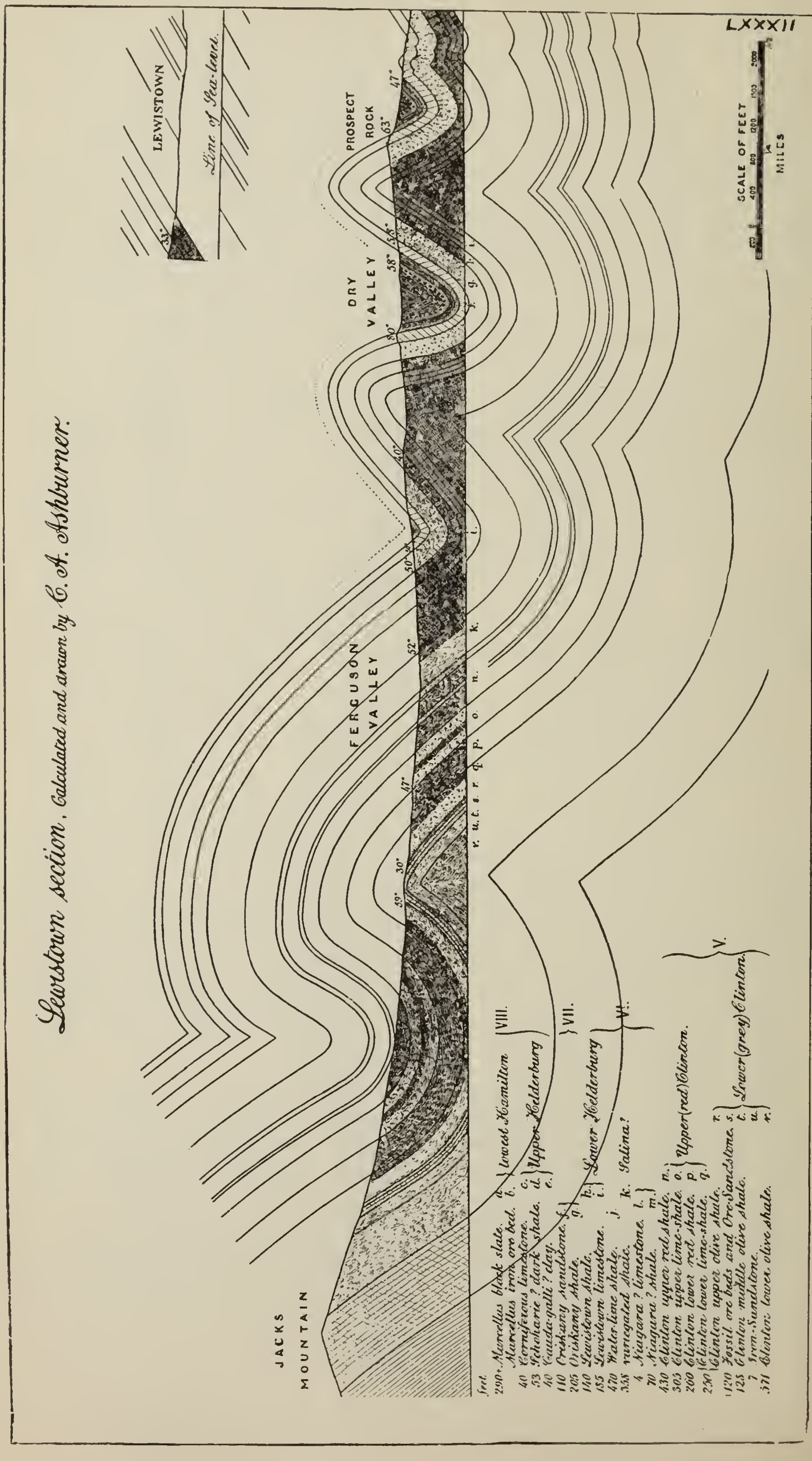
[*] H. D. Rogers gives different measurements of No. IV at the three water gaps, in Geol. of Pa., 1858, Vol. I, p. 126 to 130.

At the Delaware: *Levant White* sandstone (some sparsely pebbly beds) making a prominent rib of the mountain, 200′, (overlying sandstone and slate alternations, may be added, or may be thrown into the formation V.) 2. *Levant Red*, wanting. 3. *Levant Gray* (Oneida), upper division thin bedded, soft sandstones, 400′; lower pebbly member, 300′. Total, 900′, instead of Dr. Chance's 1565, the latter being the result of instrumental measurements of subdivisions.

[†] H. D. Rogers, at the Lehigh: 1. *Levant White;* top division, massive grey and red sandstone with shale partings, 100′; shales and flags, 300′; sandy shales, 30′; sandstones and shales, *with fucoidal markings*, 50′; sandstones and shales, 100′; white and gray pebble rock, 80′; concealed (sandstone and shale) beds, 200′; total 760′. 2. *Levant Red*, wanting. 3. *Levant Gray* (Oneida) fine sandstone, small conglomerate and shale, 200′; coarse pebble rock and sandstone, 75′; fine sandstone and coarse conglomerate, 75; very coarse pebble rock at bottom, 50′; total, 400′. Total thickness of IV, 1160′, agreeing remarkably with Dr. Chance's instrumental measure above, 1125′.



Lewistown section, Calculated and drawn by C. A. Ashburner.

At the Schuylkill Water Gap. H. M. Chance :[*]

Medina upper sandstone,	90′	1230′
" upper iron shales,	480′	
" white sandstone,	60′	
" lower iron shales,	600′	
Oneida white conglomerate,		200
		1430′

At the Susquehanna Gap. H. D. Rogers.[†]

Medina upper,	300′ to 400′	max. 470′
" lower (red),	0′	
Oneida,	60′ to 70′	

In the Juniata gaps of Perry county. E. W. Claypole :

Medina sandstone and shales	1500′	2000′
Oneida conglomerate and sandstone,	500′	

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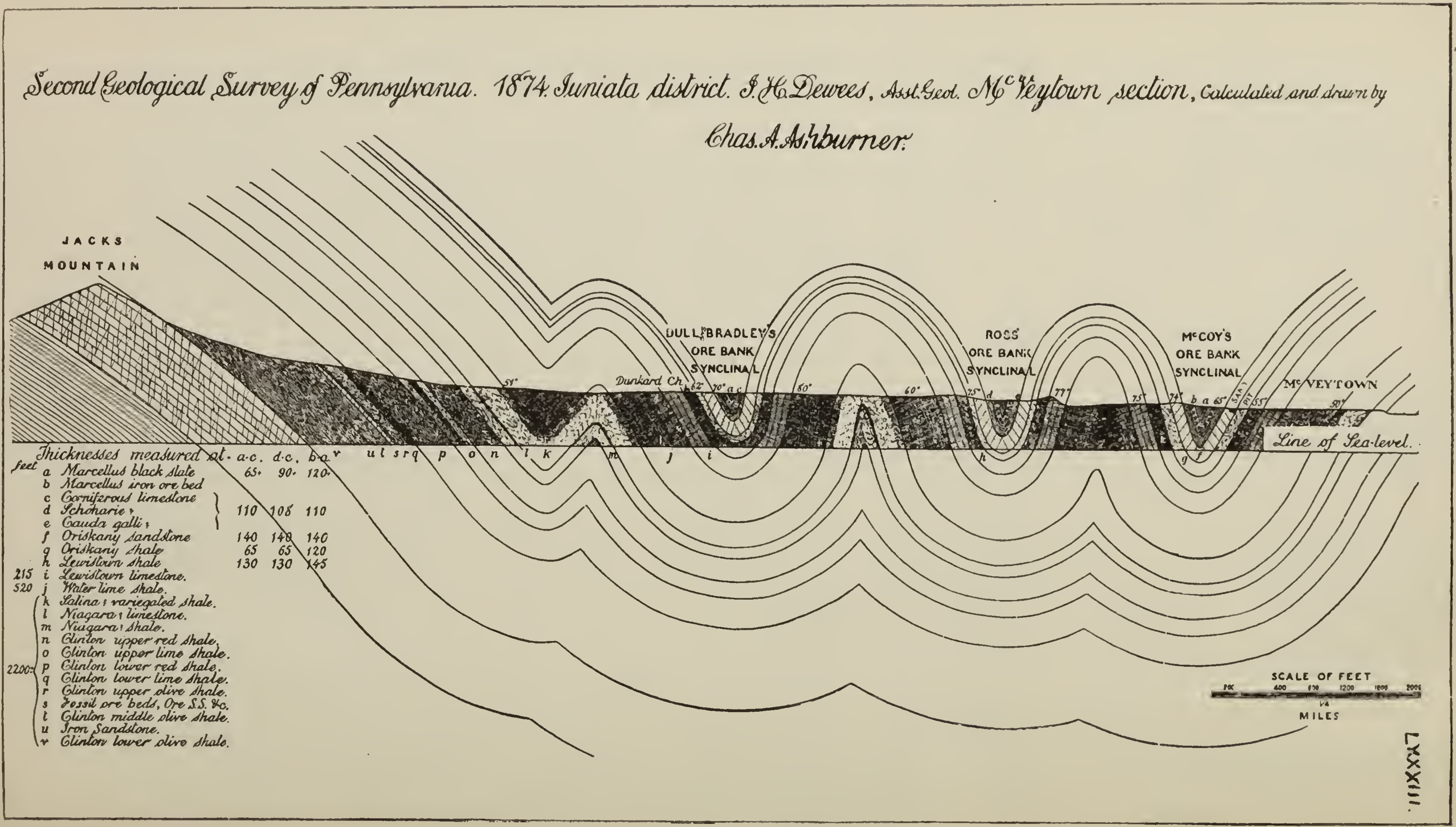
[*] Rogers gives no measurements at the Schuylkill and Swatara Water Gaps.

[†] The bottom coarse red pebble rock of the Oneida, only 5′ thick, with white coarse sandstone, full of fault slips which suggest a greater thickness than 40′, is separated from the visible upper limit of No. III slate by a concealed interval of 50′ more or less. Prof. Claypole in his report on Perry Co., F2, 1885, p. 310, describing Rye township, makes the Medina rock rib of the mountain to be only 100′ thick, and says nothing about the Oneida. He places 500′ of "soft material" between the top of the Medina and the bottom of the Clinton Iron Sandstone rib which makes the other crest of the North mountain at Sterrett's gap, the Medina crest being the lower of the two and in Cumberland county. In Carroll township, he says, the Medina makes little or no show, running along south of the county line on the crest (F2, 159). The same in Spring township (p. 333). Tyrone township, next west, gives vertical Medina at McClure's gap (p. 370). I have expressed my belief and the reasons on which it is based, that this excessive thinness of No. IV and the total disappearance of one or two thousand feet of overlying measures in Perry county, west (and east) of the Susquehanna Water Gap, described by Prof. Claypole in F2, p. 303 (see illustration p. 304), and assumed by him as good evidence of the existence of a district of dry land in Upper Silurian times in that district of the State, is rather to be explained by the upturned and overturned condition of the south side of the Cove synclinal and Dauphin county coal basin, producing not only the oblique fissuring of the Oneida outcrop in the Gap, but, as I believe, great slip-faults paralled with the strike, swallowing up and pressing underground the softer formations. I do not believe that No. IV was *originally* any thinner at the Susquehanna than at the Schuylkill or Delaware, or than it seems to be in the gaps of the Juniata river, even in Perry county, where in the Tuscarora mountain, etc. Prof. Claypole gives it a total thickness of 2000′ (F2, page 36).



Second Geological Survey of Pennsylvania. 1874. Juniata district. J. H. Dewees, Asst. Geol. McVeytown section, Calculated and drawn by Chas. A. Ashburner.

Logan's gap, Mifflin county. C. A. Ashburner:

Medina white sandstone,	820′	2100′	2722′*
Medina red sandstone,	1280′		
Oneida red conglomerate,	300′	622′	
Oneida gray sandstone,	313′		

Jack's Narrows, Mifflin county. H. D. Rogers:

Levant top red sandstone,†	30′	450′	1350′‡
Levant upper white sandstone,	420′		
Levant red sandstone and shale,		650′	
Levant lower white sandstone,		250′	

Rockhill gap, Orbisonia, Huntington county. Ashburner:

Medina white sandstone,	400′	1330′	1898′
Medina red sandstone,	930′		
Oneida red conglomerate,	158′	568′	
Oneida gray sandstone,	410′		

Canoe Mt. gap, Huntingdon Co. H. D. Rogers:

Levant (upper) white sandstone,§	550′	2100′
Levant (middle) red beds,‖	1050′	
Levant (lower) gray sandstone,¶	500′	

Bald Eagle Mt. gaps in Blair Co. R. H. Sanders:

Medina white sandstone (north crest),	1068′	2907
Medina red alternations,**	520′	
Oneida gray sandstone (south brow),	1319′	

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*Rogers does not measure the Upper division of IV here (Geo. Pa. I, p. 130), but subdivides the Middle division into (at top) dark red flags with some *red shale pebbles*, 500′; coarse friable red sandstones, iron-specked, 100′; pink sandstones with layers of quartz, slate and other older pebbles, 400′; total 1000′. The lowest (Oneida) division, fine massive gray sandstone, iron-specked, he makes 300′. Total only 1300′.

†Some of the layers are covered with a net-work of the sea weed, *Arthrophycus harlani.*

‡These and other asigned thicknesses given by Rogers in his Geo. Pa. 1858, have been proved incorrect by the close instrumental field work of Billin and Ashburner, Sanders and Chance since 1874.

§ "Measured with precision." Ponderous, homogeneous, fine grained white and gray sandstone beds." Geo. Pa. I, 130.

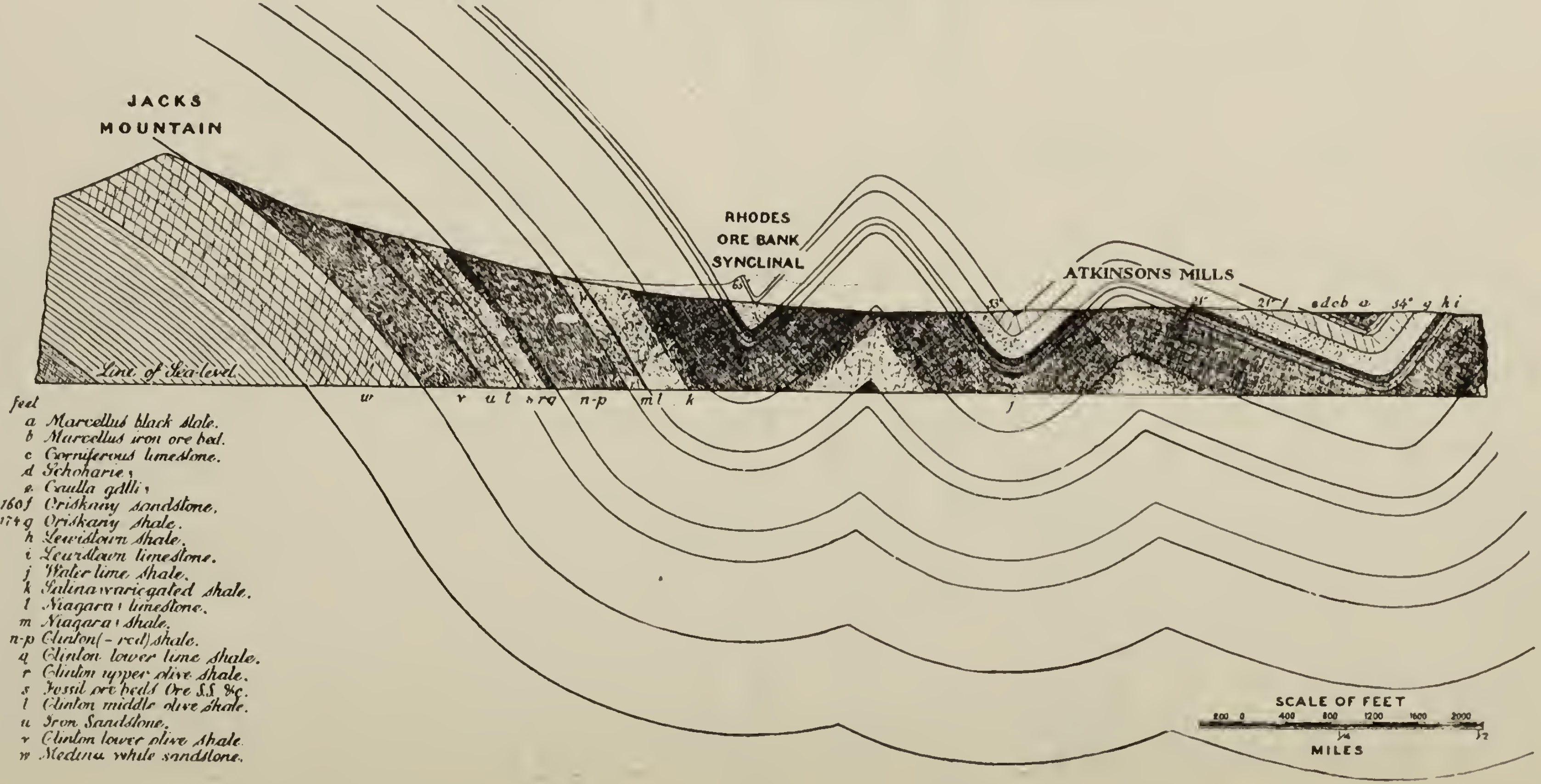
‖ "Reddish brown, rather argillaceous, with beds of gray sandstone, all alternating with much red shale," p. 129.

¶ " Wears its usual character of grey-greenish and pinkish hard siliceous massive sandstone beds, p. 127.

**The detailed section of these alternations will be found in Report T, on Blair county, by Franklin Platt, 1881, p. 17, discussed on p. 47. The description is minute and very interesting. The division made in the text is liable to a great modification, inasmuch as the north crest of the Bald Eagle

LXXXIV

Second Geological Survey of Pennsylvania. 1874. Juniata district. J. H. Dewees, Asst. Geol.
Long Hollow section. Constructed by Chas. A. Ashburner.



feet		
	a	Marcellus black slate.
	b	Marcellus iron ore bed.
	c	Corniferous limestone.
	d	Schoharie;
	e	Caudla galli;
160	f	Oriskany sandstone.
174	g	Oriskany shale.
	h	Lewistown shale.
	i	Lewistown limestone.
	j	Water lime shale.
	k	Salina variegated shale.
	l	Niagara limestone.
	m	Niagara shale.
	n-p	Clinton (- 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.
	w	Medina white sandstone.

Bald Eagle, Bellefonte gap. H. D. Rogers:

Levant white sandstone,	400′ to 500′		1550′
Levant red sandstone and shale,*	about 500′		
Levant upper green sandstone,†	380′	550′	
Levant lower gray sandstone,‡	170′		

Bald Eagle, Mill Hall gap. H. M. Chance:§

Medina upper (north crest),	695′	2301′
Medina middle (vale),	705′	
Oneida (southern crest),	901′	

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is really made by 100′ of white sandrocks at the top of the section, supported by 255′ of red sandstone beds parted by layers of red slate from 6 inches to 5 feet thick. Underneath this 355′ the rocks are concealed for 540′, and the detailed alternations begin and go down for 1000′, leaving the bottom division to be 1309′ thick. In fact only 400 or 500′ of the upper division of 1068′ answer to the description of the White (upper) Medina; the Red (middle) Medina is really 500+520=1020′ thick. All this is merely a matter of classification and does not at all invalidate the correctness of the detailed section. The Medina White is made up of hard white and greenish gray flinty sandstones, fine grained, compact, homogenous, with almost none of the pebbles which make it so coarse a pebble rock in the North, Blue or Kittatinny mountain outcrop. Its top beds are thin, mottled red and grey, and often covered with sea weed impressions. They are parted by or alternate with soft greenish non-fossiliferous shales. They are much specked with yellow pits of decomposed iron. The Medina red upper member is made up of red clay flagstones, with (toward the bottom) some other layers of small quartz pebbles. *Flattish fragments of red shale occur throughout the pile of sandstone beds.* Such is its general character in Mifflin county. The Oneida in Mifflin county has *pebbles* of quartz and slate and sandstone apparently derived from some antient land or coast of No. III and No. I. But in Blair county the Oneida shows obscure *vertical plant stems.* Stevenson does not recognize the Oneida in Bedford county. The Oneida is characteristically speckled and pitted by the decomposition of minute granules of some iron ore, perhaps pyrites. Its upper subdivision is a clayey sand, greenish gray, *slightly micaceous*, ochre-pitted, and its rock beds parted by thin fissile yellow shales. The lower is an ochre-pitted hard gray sandstone. (T, 48.)

*Thin grey and red clay sandstone layers, alternating with a fourth part red, grey and greenish shale partings. High in the division are found *vertical plant stems* like Hall's *Scolithus verticalis* at Medina, N. Y.

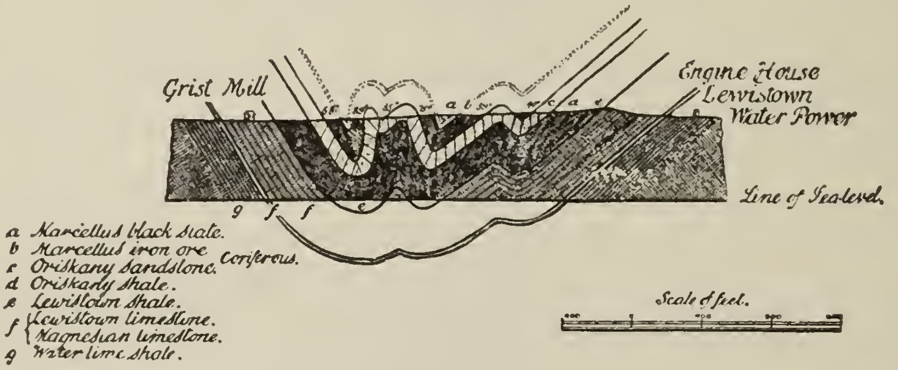
†Greenish grey *slightly micaceous*, specked with ochre, with thin fissile greenish slate partings. In Pleasant Gap, Center county, it is quarried for flagstones. (T4, 428.)

‡ Hard gray sandstone without pebbles, but full of yellow specks.

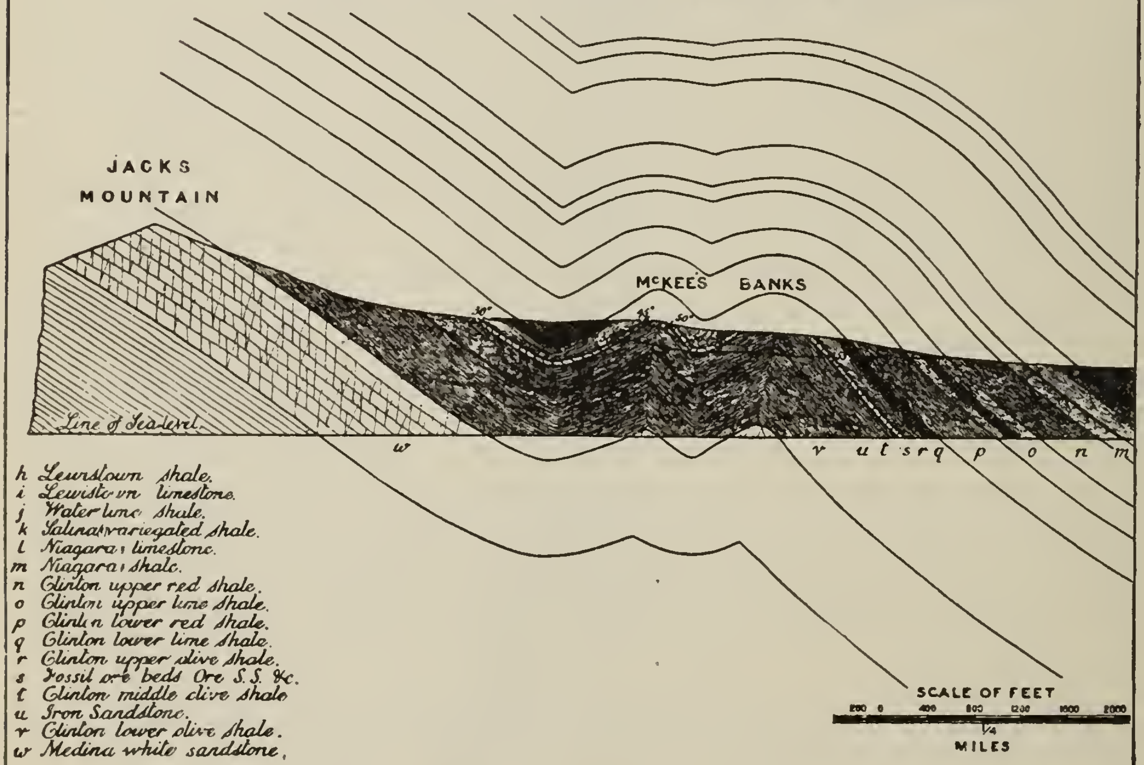
§ See detailed section in Report G4 on Clinton county, 1880, p. 120. The subdivisions are empirical. The upper hard, massive, red, grey and white sandstones are not well exposed. The middle softer sands and shales make the little trench between the crests. Then come hard, massive, white (with a few speckled) sandstones, 188′: concealed, 118′; hard, massive, siliceous dark grey and greenish grey speckled beds, 155′; and at the bottom a mass not well exhibited, but principally hard massive sand rocks, 410′.

LXXXV.

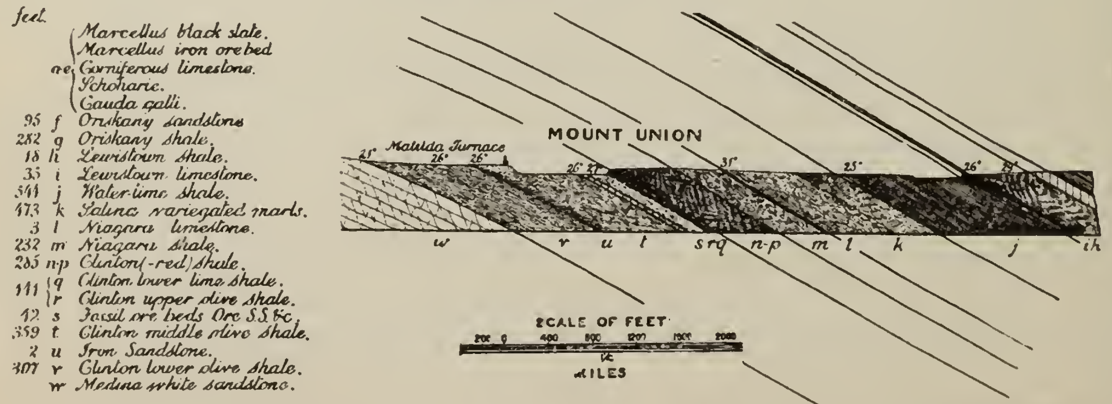
Kishicoquillas section, Constructed by C.A. Ashburner



Mc Kee section, Constructed by Chas. A. Ashburner.



Mount Union section.



Bald Eagle gaps in Lycoming county. F. Platt:[*]

Medina upper hard sandstone,	100′	1375′
Medina middle red beds,	1200′	
Oneida hard sandstone,	75′	

Wills' Mt. gap, Milligan's cove. H. D. Rogers.

Levant white sandstone,	400′	1300′
Levant red sandstone,[†]	800′	
Levant grey sandstone,	100′	

No. IV thins southward into Virginia and Tennessee. On the James river the whole Medina measures only 300′ and whole Oneida only 90′; together 390′.[‡]

Stevenson calls the Medina in Waldron's ridge, Lee Co. Va., "evidently more than 300′."[§]

West of Knoxville, in Tennessee, I saw it represented by only 40′ of sandstone.

Towards the west it entirely disappears from the Ohio and Kentucky column.

Northward it thins away in an equally remarkable manner. At Niagara the Medina is 300′ or 400′; and the Oneida, in Oneida county, N. Y., only 100′ to 120′.

But going eastward along its northern outcrop it increases. Prof. Prosser's general section of Western Middle New York State gives Red Medina sandstones and shales, 942′. [‖]

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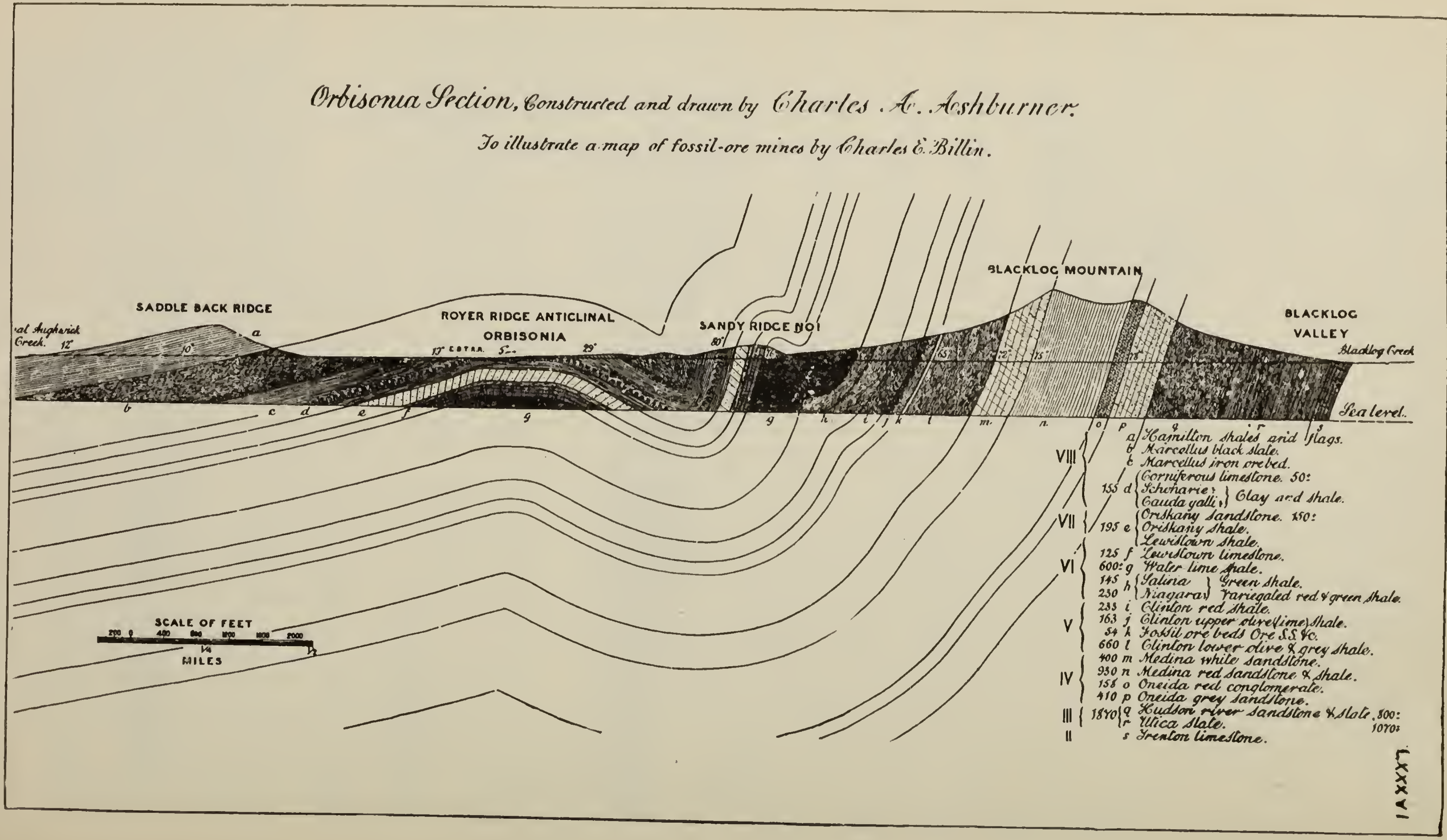
[*] Mr. Platt says in Report G2, p. 29, that no exact measurements were made for want of satisfactory exposures, and that the figures given above are only probable.

[†] Includes here a larger amount of grey sandstone than on the Juniata. Rogers says that in this main gap through Wills' mountain into the cove the Oneida is last seen going south. He suspects a fault swallowing up a part of the formation, "a conjecture suggested by the vertical and shattered condition of the strata in Buffalo ridge the western barrier of the cove." Geo. Pa. 1858, p. 128.

[‡] J. L. Campbell, Geol. Rich Patch in "Virginias," Vol. I, No. 12, Dec., 1880, illustrated with sections.

[§] Proceed. Am. Philos. Soc. Phila., Aug., 1880.

[‖] "Thickness of Devonian and Silurian Rocks, etc." Amer. Geologist, Oct., 1890, p. 205. His section is made up from well-borings. Under his Medina the Oswego sandstone, 210′, is placed in No. III. In the Walcott well on Lake Ontario, red shale and red siliceous sandstones alternating, measure 690′; but they may be Clinton; under them Oswego sandstone, 210′. In the Clyde well, Wayne Co., N. Y., Medina red shales, etc., 24′, 3′, 915= 942′. At the bottom of the Seneca Falls well, Medina red shales and sandstones, 150′; how much more unknown. At Rochester Logan made the Medina 600′. Geo. Sur. Canada, 1863, p. 310.



Orbisonia Section, Constructed and drawn by Charles A. Ashburner.

To illustrate a map of fossil-ore mines by Charles E. Billin.

No. IV at Logan Gap. Pl. LXXXI, p. 640.

The best place perhaps for studying No. IV is at the Gap through Jack's mountain in Mifflin county.

Here the *white Medina sandstone* beds measure 820′; most of them consisting of massive lawers of exceedingly hard rock varying from 2′ to 4′ in thickness; some of them fine grained; some of them slightly argillaceous, that is the grains of sand are imbedded in a matrix of clay. They slope up from the floor of the gap at the south end and make the upper part of the mountain and its high, bold rock-covered crest, running eastward toward the Susquehanna, and westward toward the Juniata; and it is the great thickness of these *Medina white* sand rock beds that makes Jack's mountain one of the highest in middle Pennsylvania. The weather acting upon the slight cement, dissolves it, and sets free the sharp grains of sand, producing along the top of the mountain collections of glass sand. Some of the more solid beds, resisting dissolution, break up into great blocks which slide down and cover the upper part of the northern slope.

The *Medina red* middle division of No. IV in the heart of the gap is 1280′ thick. It consists of laminated reddish sandstone layers, too soft and friable for building purposes, interstratified with red sandy shales. On the surface of these shales ripple marks and the impressions of sun cracks like those seen on a modern sea shore abound, leading one to suspect that the waters of that ancient time were shallow, and the sea bed in places exposed to the air and sun. But at the same time, many of the strata are obliquely cross-bedded, as if deposited in swiftly flowing currents.

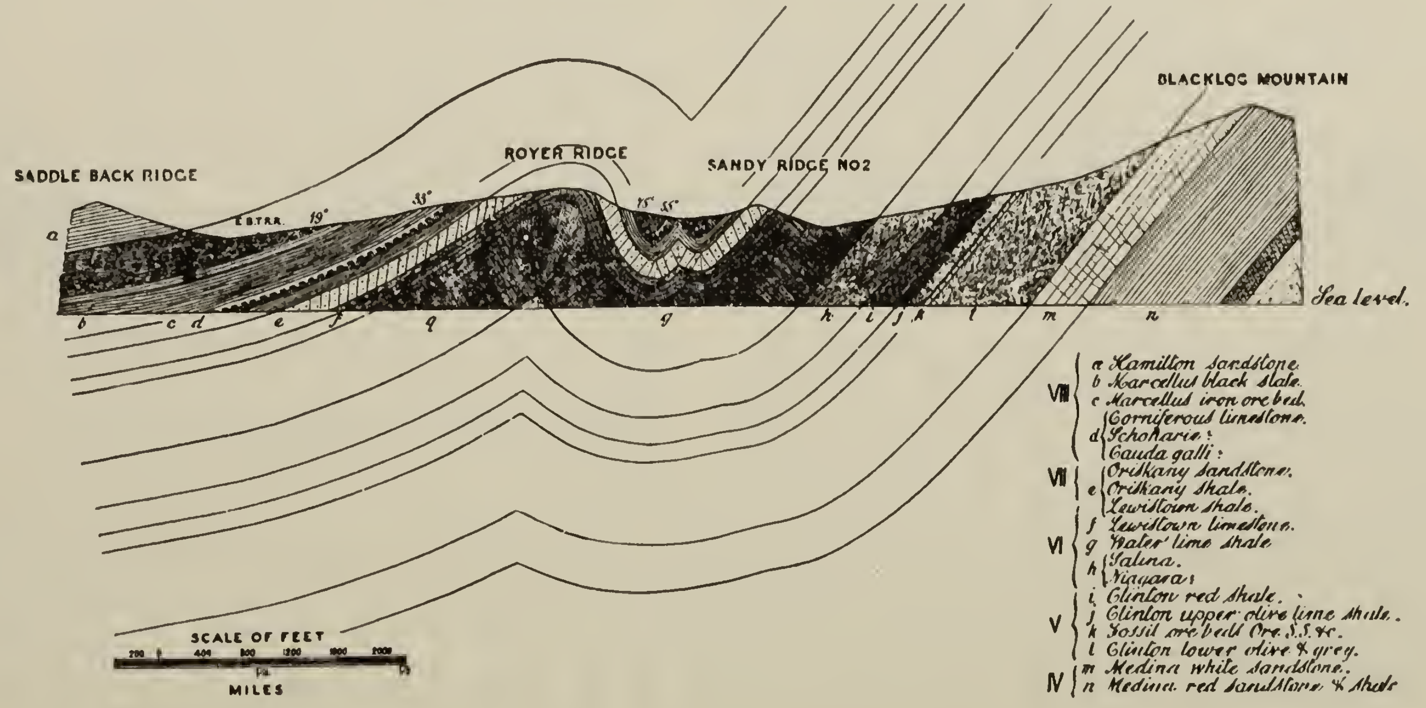
Beneath these lie the *Oneida rocks*, divided into an upper and a lower group, called the *Oneida red conglomerate* and the *Oneida gray sandstone.*

The upper group consists of massive sandstone strata, reddish in color, very coarse, full of small pebbles which in some places become as large as hens' eggs; the layers varying from 1′ to 6′ in thickness, so that large stones are quarried from them in the gap. This mass of pebble rock

LXXXVII.

Second Geological Survey of Pensylvania, 1874'5. Juniata district. J.H.Dewees.
Orbisonia Section. No. 2, north of Black-log Gap, by C.A.Ashburner.

Showing the ranges of brown-hematite ore-beds.



rising at an angle of 55° to the brow of the famous terrace which surrounds Kishacoquillis valley is 310′ thick.

The lower group measures also 310′, and is made up of very hard greenish gray sandstone, the grains of sand coarse and strongly cemented together, mixed with pebbles of quartz, none of them as large as those in the group above. Some of the beds are five grained, equally hard and massive, and contain small scattered pebbles. Some of the beds show a good deal of disseminated oxide of iron.*

About 25 miles west of Logan Gap the Juniata breaks through the mountain at Jack's Narrows.

Here the *Medina white* sandstone is only 450′ thick, the 30′ of beds at the top being a group of alternating red, pink and gray sandstone layers and red and green shales; some of the sandstone layers being covered with a net-work of sea weed markings (*Arthrophycus harlani*). The remaining 420′ consists of strata, massive and compact, of white and greenish gray sandstone, with scarcely a trace of any organic life. Under these lie 650′ of soft clay sandstone generally red, and speckled yellow with iron, current bedded to a great degree, and interstratified with beds of very soft red shale. Under these lie 250′ of greenish white, hard, sandstone, down to the bed of the river in the gap, beneath which nothing can be seen, as the exposure is anticlinal.

No. IV at Orbisonia. Pl. LXXXVI, p. 650.

At Orbisonia, 10 miles further south, Black Log mountain shows No. IV in Rockhill Gap in its three divisions.

The *Medina white*, 400′ thick, consists of massive white and gray, fine-grained, hard sandstone beds alternating in the upper part with red and grayish shales. The *Medina*

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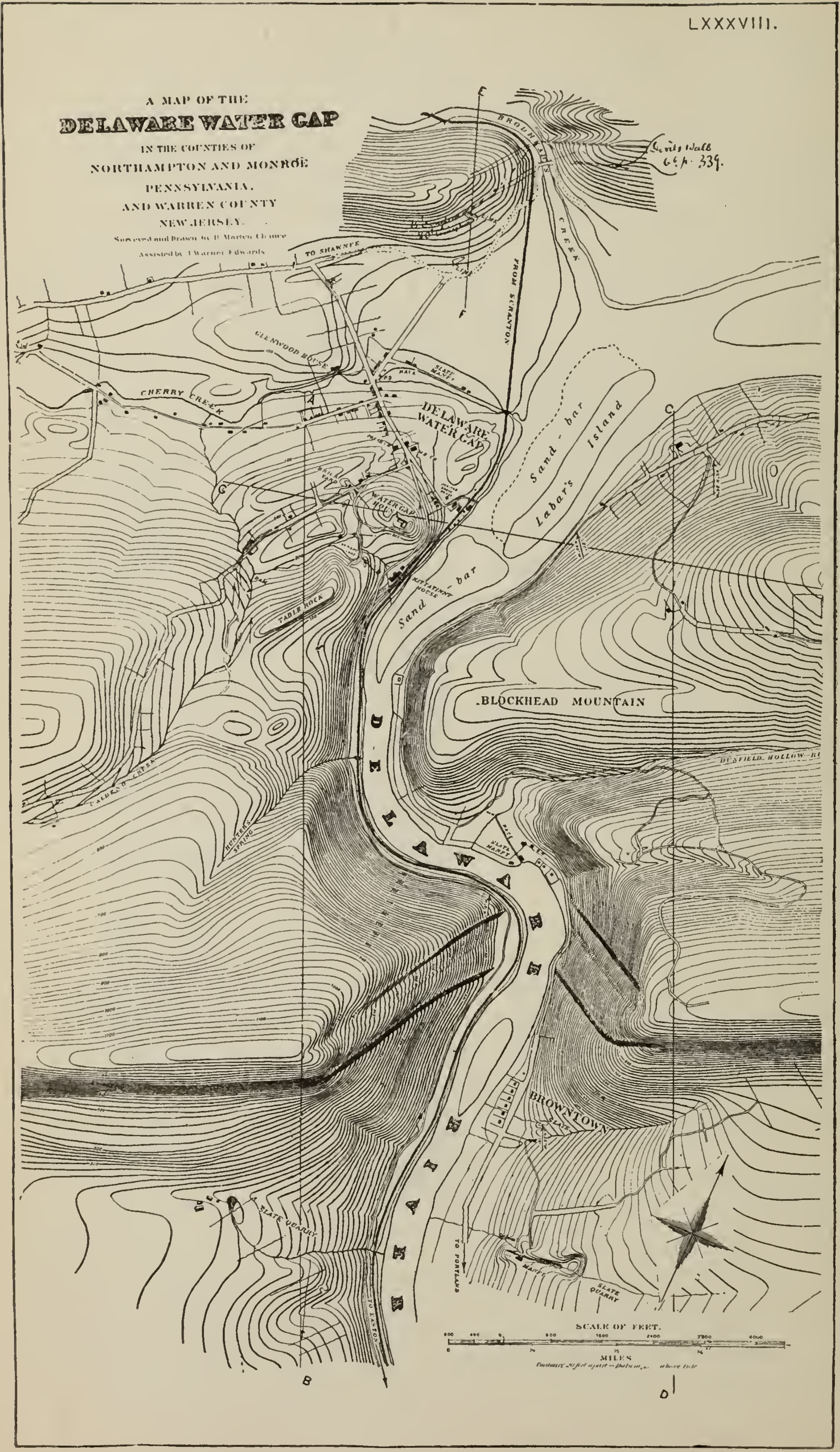
*Professor Rogers estimated the middle division of No. IV in Logan Gap, at 1000′; of which the uppermost 500′ consists of dark red flaggy beds of mixed sand and mud, some of which contains curious *pebbles of red shale* of unknown origin. Under these lie 100′ of coarse red sandstone, loosely cemented together, friable under the weather, some of them sprinkled with small pebbles and showing a great number of iron stained spots. Under these lie 400′ of pale red sandstone beds containing pebbles of quartz and *fragments of slate* apparently like No. III. These 1000′ of reddish and more or less pebbly soft rocks constitute the middle division of No. IV.

LXXXVIII.


A MAP OF THE
DELAWARE WATER GAP
IN THE COUNTIES OF
NORTHAMPTON AND MONROE
PENNSYLVANIA,
AND WARREN COUNTY
NEW JERSEY.
Surveyed and Drawn by D. Martyn Clause
Assisted by I. Warner Edwards
Devil's Wall
G⁶ p. 339.
TO SHAWNEE
BRODHEAD'S CREEK
FROM SCRANTON
GLENWOOD HOUSE
CHERRY CREEK
SLATE MANFY
DELAWARE WATER GAP
WATER GAP HOUSE
KITTATINNY HOUSE
TABLE ROCK
Sand-bar
Labar's Island
Sand-bar
BLOCKHEAD MOUNTAIN
DUNFIELD HOLLOW
CALDENO CREEK
HUNTERS SPRING
DELAWARE
SLATE MANFY
BROWNTOWN
SLATE QUARRY
TO PORTLAND
TO EASTON
MANFY
SLATE QUARRY
A
B
C
D
E
F
G
SCALE OF FEET.
800
400
0
800
1600
2400
3200
4000
0
¼
½
¾
MILES

red, 930′, consists of soft brown and red clay sandstones and shales; the sandstones in the central part softer and more friable and specked with iron. The *Oneida* is divisible here also into two groups, the upper (158′) consisting of hard red and greenish gray, broken up sandstones with conglomerates; the lower (410′) of hard massive greenish sandstone and gray conglomerate strata.

No. IV at Spruce Creek Gap.

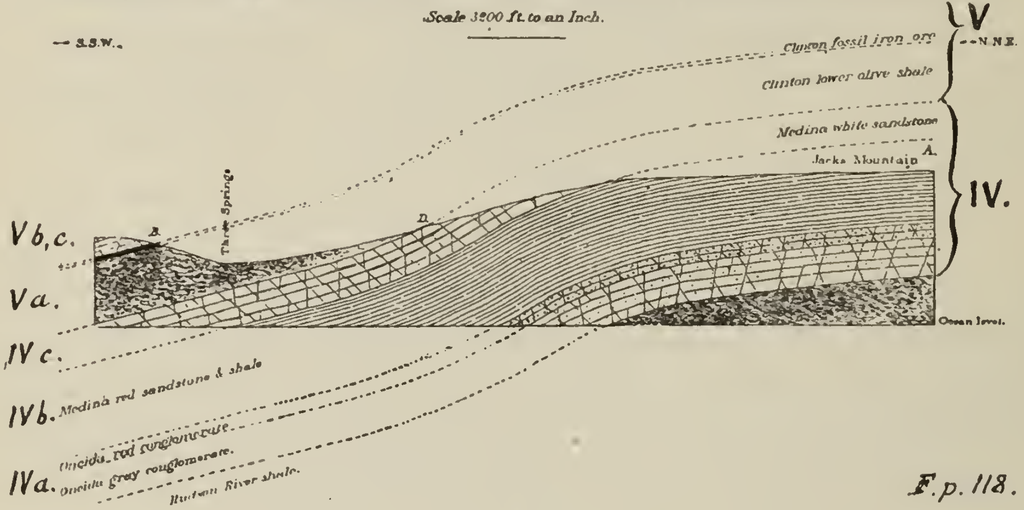
In the gap of the Little Juniata through Tussey mountain 20 miles northwest of Jack's mountain narrows, the *Medina white* sandstone, 1000′ thick, showing few pebbles, but many impressions of the sea weed above mentioned, descends from the crest of the mountain to the bed of the river southward on a slope of 20°. Under this lies 700′ of *Medina red* sandstones and shales. The next underlying 200′ are concealed but probably belong to the middle division, making it 900′ thick. Under these concealed rocks, the *Oneida conglomerate* appears with its massive coarse and pebbly beds, apparently only 100′ thick; but the Spruce creek tunnel fault at this place obscures the section. Fragments of the Medina white, sliding from the crest of the mountain, cover its southeastern slope and also the upper part of its northwestern side; for the thin beds broken up by the weather into innumerable flagstones slide upon each other down that slope; and in this respect the surface show of Medina formation in this part of the region is peculiar. The best place to see this operation of gradual destruction is in Jack's Narrows before mentioned; where the formation is thrown into a double anticlinal arch cut through by the river. The two walls of the gap are slopes of about 30°, entirely covered from the crest of the mountain to the bed of the river with a smooth and regular universal stone slide, composed of millions of broken flags slipping over each other farther and farther in their slow but never ceasing descent. The material thus provided by nature has been thankfully accepted by man; and railroad engineers find in this great stone slide an inexhaustible provision for the finest railroad ballast that can be conceived.

LXXXIX.

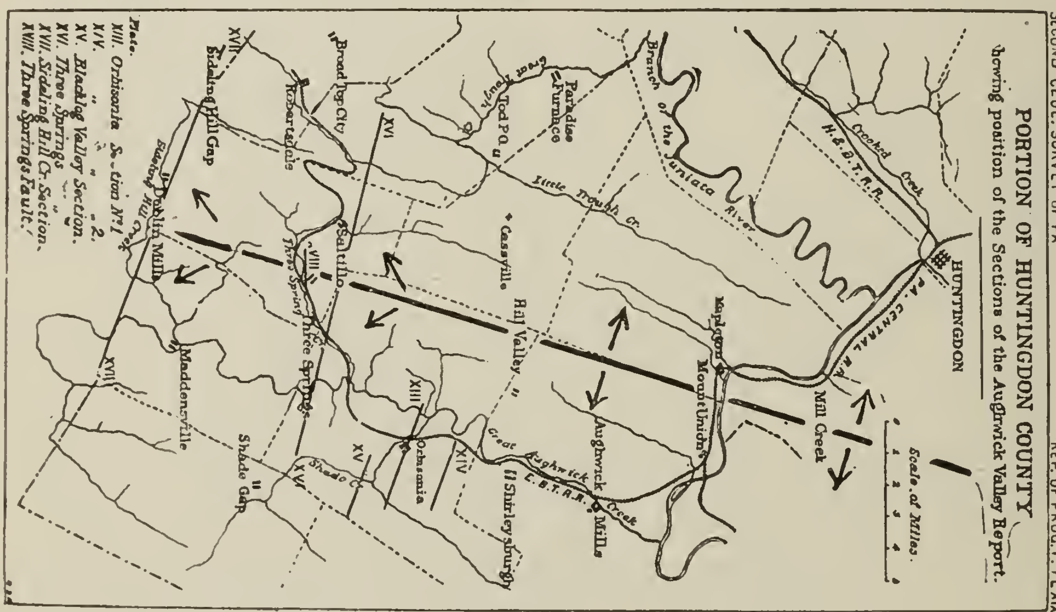
No. IV. South end of Jacks Mtn. Huntingdon Co.

Longitudinal Section of Jacks Mountain midway between Three Springs and Saltillo showing the subsidence of the Anticlinal at the end of the Mountain. by Chas. A. Ashburner.

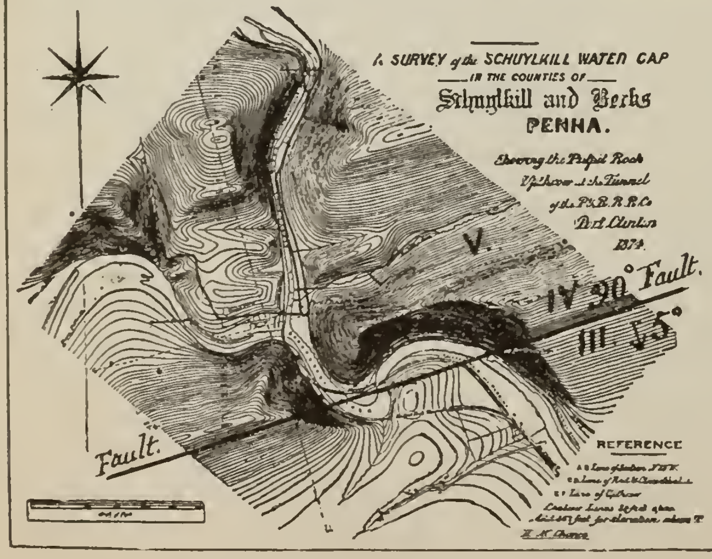
Scale 3200 ft. to an Inch.

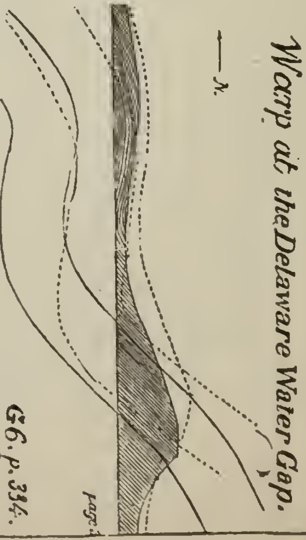


F. p. 118.



Port Clinton Fault. III against IV.





Warp at the Delaware Water Gap.

G6. p. 334.

The ravine which descends into Spruce creek gap has been excavated in the *Medina middle;* and the Juniata river makes its very remarkable bend below the Spruce creek station in order to use the lower part of this ravine for a water way. The long hog-back in the bend (through which the Pennsylvania tunnel has been driven) is made by the *Oneida conglomerate;* the outcrop of which slopes up the mountain side and becomes the brow of the terrace which surrounds Nittany and Canoe valleys. This terrace is the prominent feature of the northwest slope of Tussey mountain for many miles eastward.

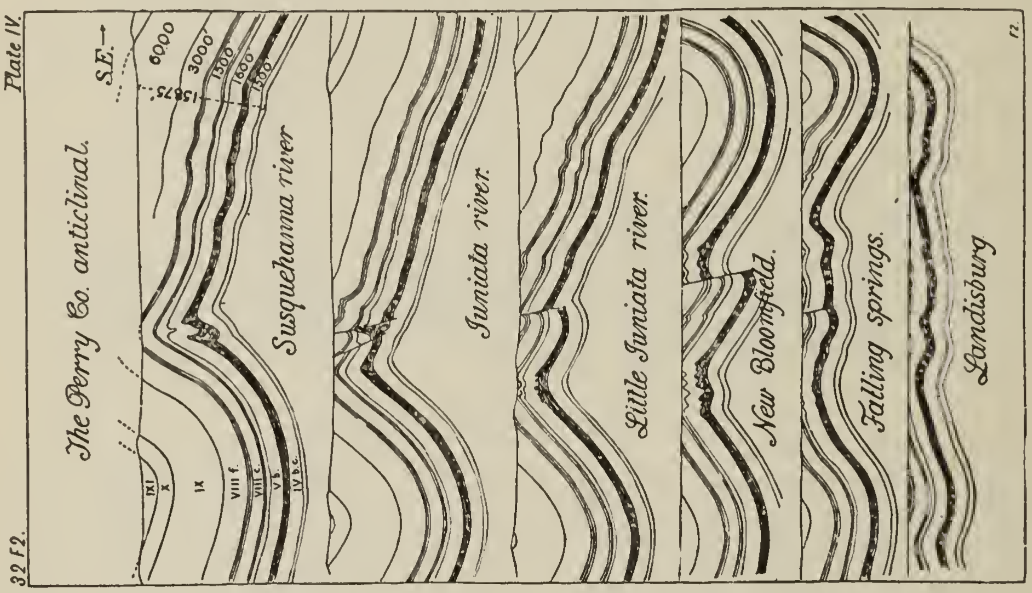
No. IV at Tyrone Gap.

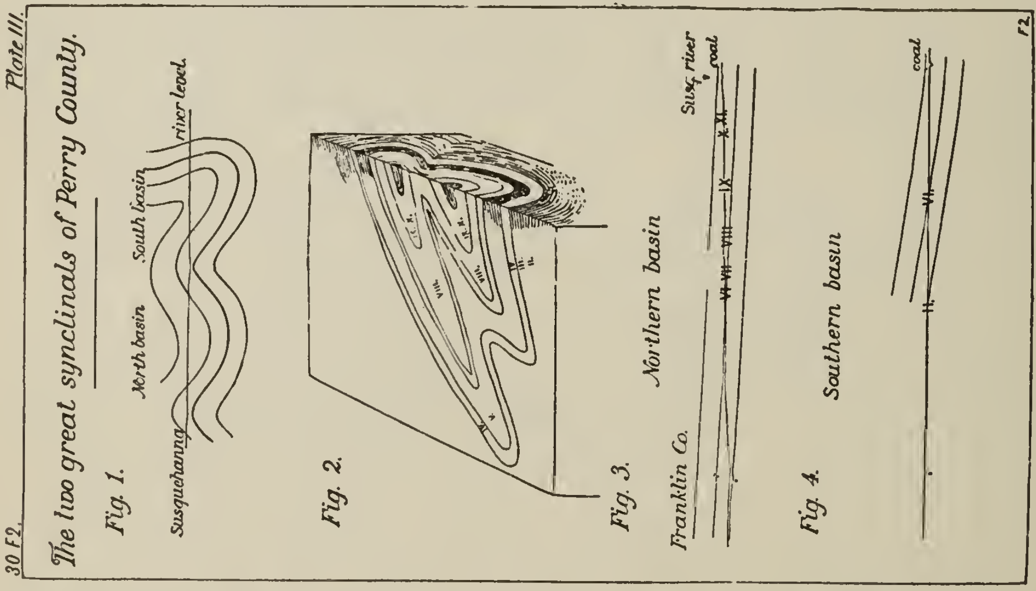
In the gap of the Little Juniata through Bald Eagle mountain at Tyrone City, Formation No. IV stands vertical, affording a fine opportunity for the study of its beds. But all the beds are not visible, being concealed by the material which has slidden from above. The section published in Report T, page 17, and Report T3, page 144, is as follows:

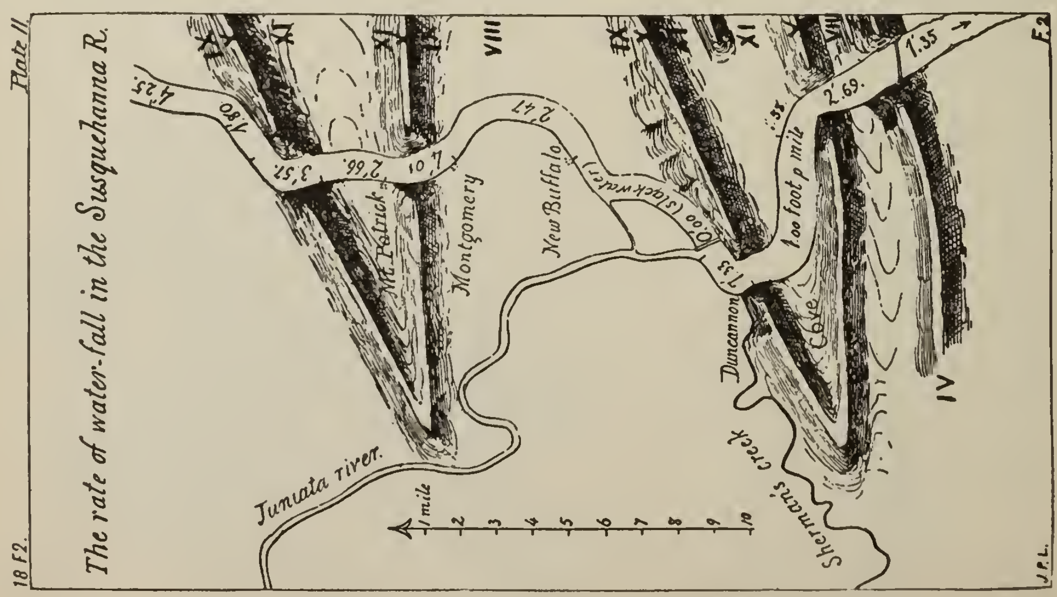
Sandstone, white Medina,	100 ±
Sandstone, red, with layers of red slate from 6″ to 5′ thick,	255′
Concealed interval,	540′
Sandstone, red massive,	84′
Sandstone, green slaty,	1′ 8′
Sandstone, red, with a few layers of red shale,	87′
Slate, green,	0′ 6″
Sandstone, red,	10′
Shale, red,	5′
Slate, green,	5′
Sandstone, red,	5
Sandstone, gray,	20′
Shale, red,	1′
Sandstone, gray,	10′
Shale, red,	0′ 6″
Sandstone, red,	10′
Sandstone, grayish red,	15′
Slate, red,	1′
Slate, green,	1′ 6″
Sandstone, gray,	15′
Slate, gray,	1′
Sandstone, brown,	20′
Slate, gray,	1′
Sandstone, brown,	8′
Shale, red,	0′ 6″

XC.

No. IV. Arches, Basins and Faults in Perry Co.







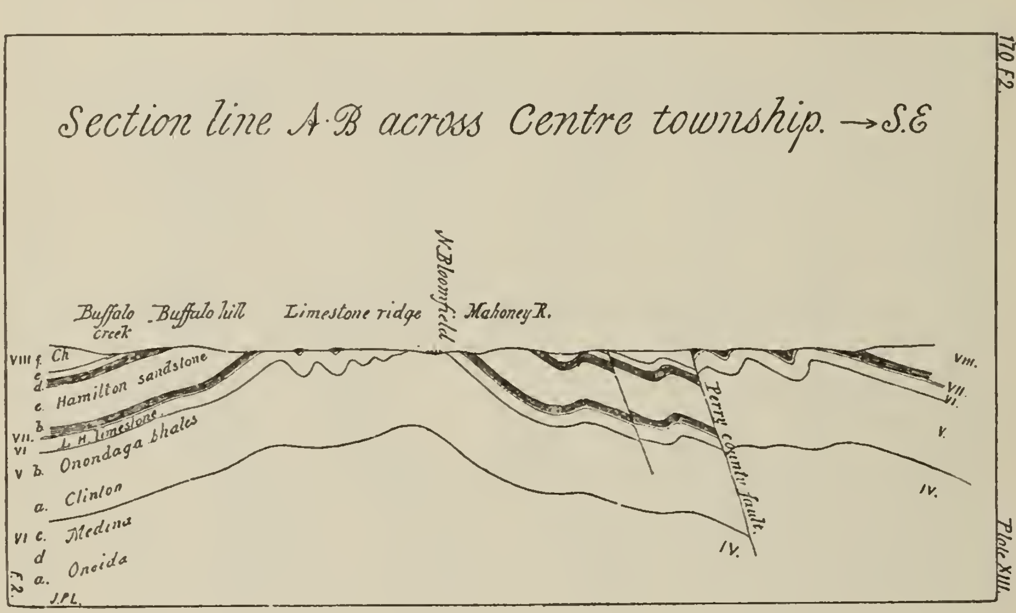
Sandstone, reddish brown,	75′
Slate, red,	1′
Sandstone, red and gray,	200′
Sandstone, red,	9′
Shale, red,	4′
Sandstone, red,	2′
Slate, red,	3′
Slate, green,	1′
Slate, red,	4′
Slate, green,	2′
Sandstone, red,	6′
Sandstone, red, some little of it gray,	15′
Sandstone, red,	10′
Slate, gray,	2′
Sandstone, red,	18′
Slate, gray,	0′ 5″
Sandstone, grayish brown,	12′
Shale, red,	0′ 3″
Sandstone, brown,	20′
Shale, green,	0′ 2″
Sandstone, brown,	4′
Shale, red,	1′
Sandstone, brown and gray, and concealed,	150′
Sandstone, gray, and concealed,	409
Sandstone, gray,	320′
Sandstone, gray, and slaty sandstone,	440′
	2906′ 6″

In Tyrone gap, according to Mr. Sanders, the *Medina white* measures 1068′, the *Medina red* 668′, and the *Oneida* 1160′ making a total of 2896′. A crush fault (apparently of no great magnitude) makes the statement a little doubtful. It is evident from the section above given, that the whole formation has a very different character along this its westernmost Bald Eagle outcrop, from its character along the Jack's mountain outcrop, 25 miles to the southeast. Many of the beds of the *upper Medina*, although massive, have a red color and might justly be thrown into the middle division (*Medina red*).

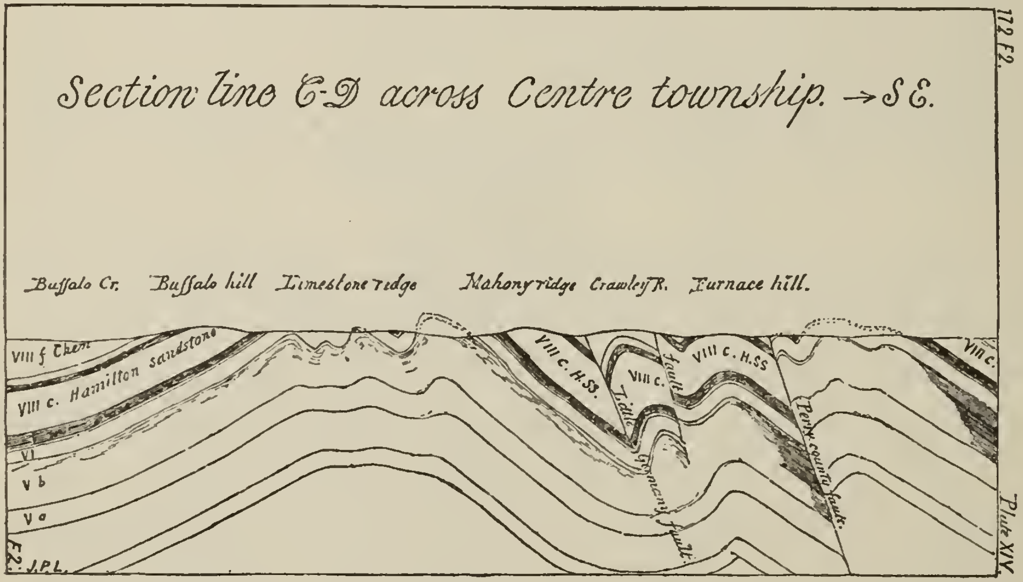
No. IV in Mill Hall Gap.

In the Bellefonte gap through Bald Eagle mountain, 30 miles to the northeast of Tyrone gap, the *Medina white* may be said to have a thickness of 400′ or 500′. The *Medina red* here consists of thin bedded gray and red clay sandstones, constituting three parts of the whole mass, XCI

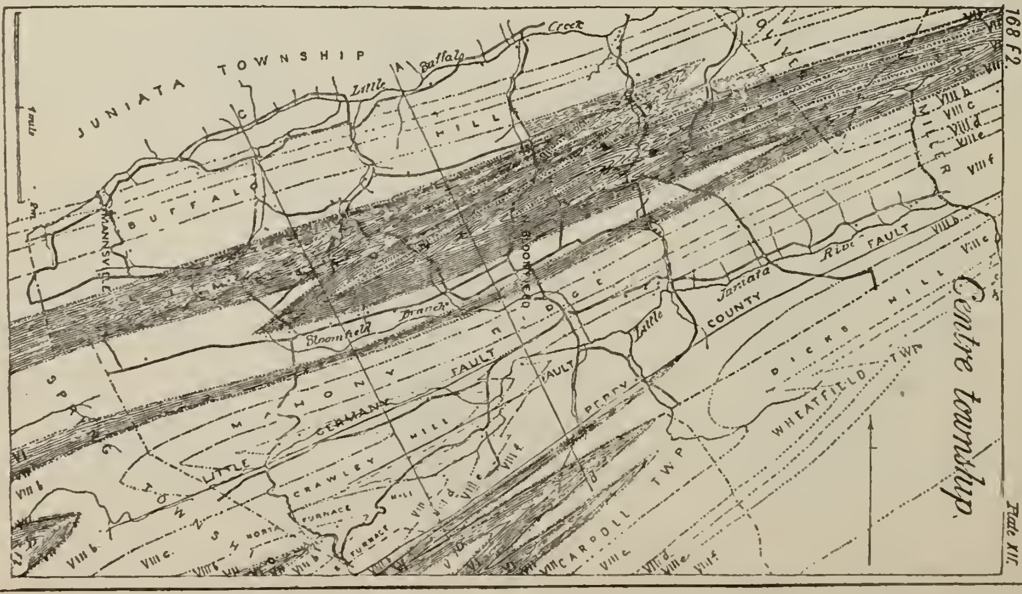
No. IV. Perry Co. Anticlinal und Faults.



Section line A-B across Centre township. →S.E



Section line C-D across Centre township. →S.E.



separated by and alternating with beds of red, gray and greenish shale. In the uppermost beds have been found stem-like vegetable forms (*Scolithus verticalis*) which are probably the casts of the burrows of worms going down and coming up in the sand on the shore of the sea; its total thickness say 500′. The *Oneida* is here again divisible into two groups, the upper (380′ thick) composed of greenish gray slightly micaceous sandstones, specked with iron ochre, and separated from each other by thin layers of finely laminated greenish slates; the lower (170′ thick) a mass of hard gray sandstone beds, entirely without pebbles, but completely covered (where exposed to the weather) with yellow ochre specks produced by the decomposition of iron pyrites disseminated through the whole rock, in what original form has not been investigated. This iron speckled aspect of the *Oneida* division of Formation No. IV is characteristic of it throughout the central region of the State, and is a peculiarity which marks it quite as plainly as the flagstone slides mark the *Medina upper* division.

No. IV in Williamsburg Gap.

In the gap of the Juniata river through Canoe mountain in Blair county, the *Medina white* is a mass of white and gray, fine grained heavy sandstone beds, 550′ thick. The *Medina red* consists of softer, reddish brown, clay sandstone beds, a few beds of gray sandstone, and a great many beds of red shale, subdividing a total thickness of 1050′. The *Oneida* is as usual composed of massive greenish gray and pinkish, iron speckled, very hard sandstone beds, in all 500′ thick.

No. IV in the Bedford Gaps.

In Bedford county the *Medina white*, still making the crests of the mountain, is a mass of almost snow white, fine-grained, very hard and gritty rocks, 860′ thick in the Yellow creek gap through Tussey mountain, but growing thinner southward, so that it is only 300′ thick in the Raystown Juniata gap through Tussey mountain, near Bedford, XCII.

No. VIII b, Marcellus (Corniferous?) limestone faulted against Chemung in Perry Co

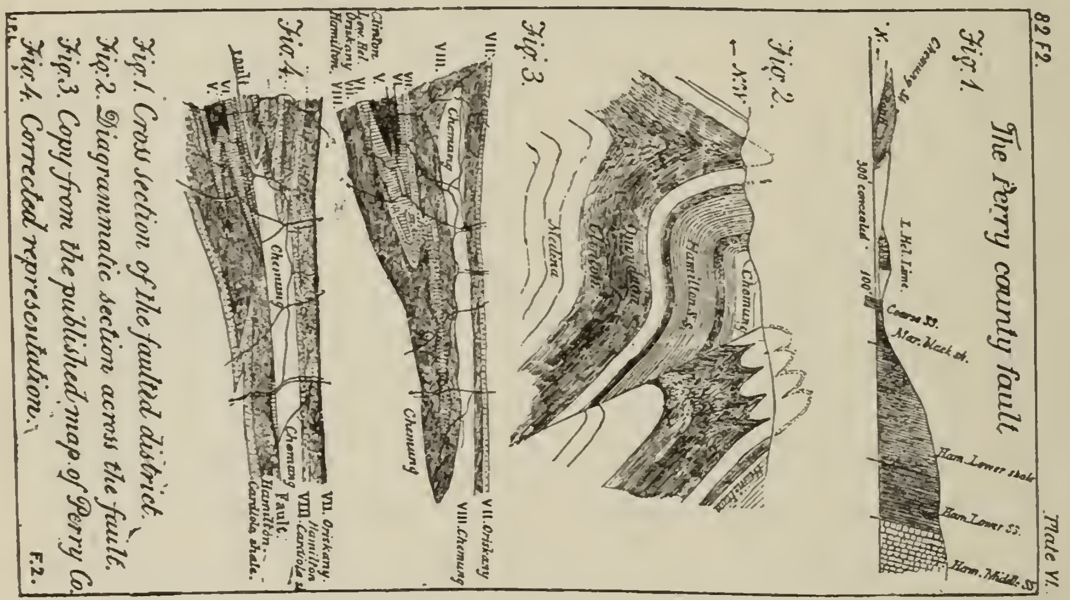
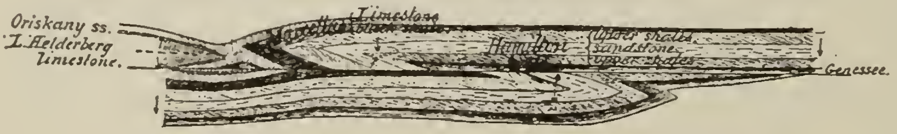
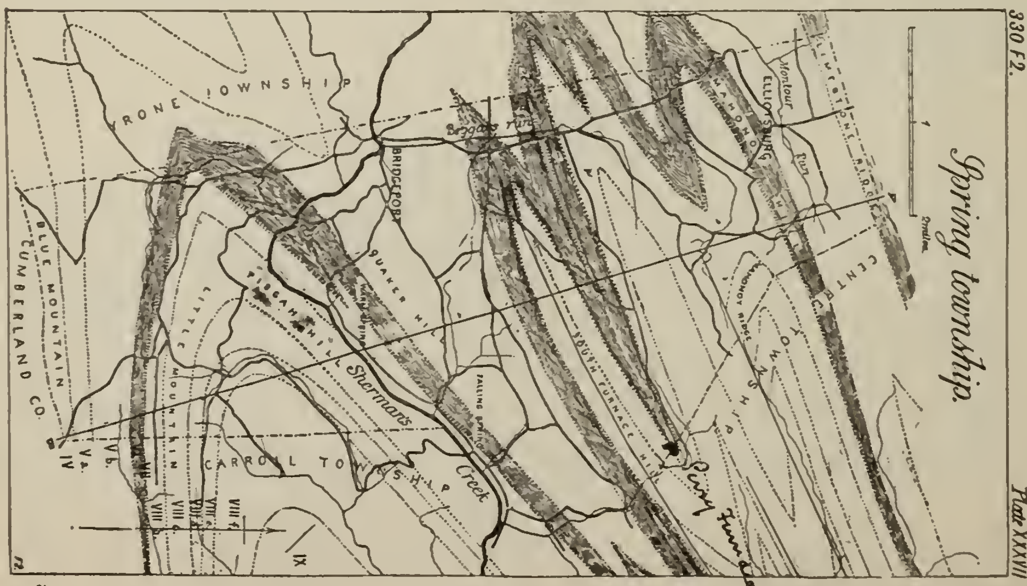


Fig. 1 Cross section of the faulted district.
Fig. 2. Diagrammatic section across the fault.
Fig. 3. Copy from the published map of Perry Co.
Fig. 4. Corrected representation.

Little Germany fault in Spring and Centre townships.





and 200′ in the gap through Evitt's mountain (T2, p. 91); no fossils but the sea weed *Arthrophycus* being seen in it at any exposure. The *Medina red* in the Bedford district contains comparatively little soft shale; its beds being chiefly hard fine-grained red sandstone grits; containing innumerable pellets of ochreous clay, which when exposed to the weather are dissolved out, leaving the rock in a curiously pitted, or finely honeycombed condition. Flattened lumps of red clay may be found by breaking the rock of many of the beds; and these suggest an explanation for the universal iron speckled condition of the Oneida beds.*

As for the *Oneida* or lower division of No. IV in Bedford county, Dr. R. M. S. Jackson of the First Geological Survey could find only 100′ of beds which he could so call in the gap of Will's mountain into Millikin's cove. He suggested that the lower part of it might be concealed by a fault along the western edge of the cove, seeing that the strata in Buffalo ridge are much broken and turned up vertical. But Professor Stevenson, in report T2 on Bedford county, could not recognize any *Oneida* rocks south of Morrison's cove. Gray sandstones indeed appear in Raver's creek gap through Tussey, on the Henrietta road in Wood-

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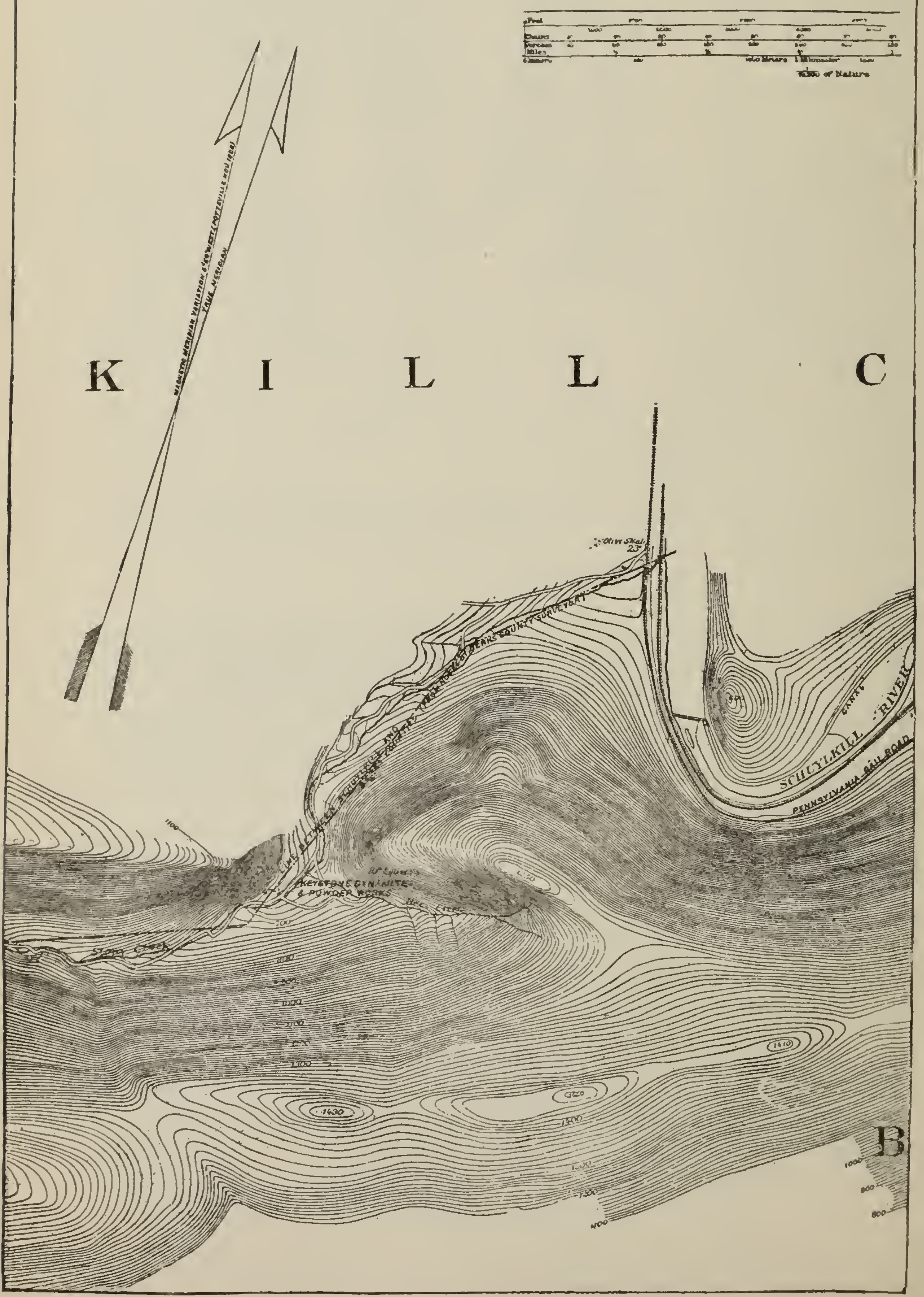
*How these balls of clay enclosed in fine sand originated is a curious question. It is also a matter of some moment to get any answer to the enquiry, whether they were originally round, or whether they were deposited in their present flat shape. For if they were originally round their flattened condition now must be ascribed to pressure, that is, to the consolidation of the Formation No. IV under the burden of all the formations up to the Coal measures, which were afterwards laid down upon it. And this would introduce a subject which has hardly yet received attention from geologists, namely, the amount of compression and loss of bulk *vertically* which all our formations have suffered in the lapse of time, partly by the closer packing together of their sand and mud grains, but chiefly from drying out of the original sea water with which they must have been for many ages completely soaked or water logged. For if this diminution of bulk could be shown to bear a considerable proportion to the original thickness of sand and mud deposits, the calculation, if made upon a sound basis of fact, would materially modify the speculations now so popular, oftentimes so rash, and in all cases so unsatisfactory, respecting the mutations of the sea level in various geological ages. For if our formations in drying have lost only 5 per cent. of their thickness, the total shrinkage in thickness of say 40,000′ of Palæozoic strata would amount to 2000′.

XCIII

No. IV The Kittatinny or Blue Mtn, at taken from the central portion of the map published in Atlas to Schuylkill county.



berry township, and obscurely at two places on Bunning's mountain ; but *Oneida* beds are certainly absent along the Raystown Juniata in both Tussey and Evitts mountain gaps. In fact *Oneida* sandstone beds were seen by him at no locality in Bedford county more than 35′ thick. At the two places last mentioned there can be no question of concealment by faults, for the top layers of No. III are regularly overlaid by *Medina red* or brownish red shales containing two fossils which unmistakably belong to that division(*Ambonychia radiata* and *Rhynchonella capax*)and the *Hudson river slates* pass without any break of sequence upward into *Medina shales ;* so that there can be no doubt that the *Oneida formation* was not deposited in the bed of the sea in this locality, even in the condition of fine sand. Yet it must not be rashly concluded from this fact, that dry land existed here. For had dry land existed it must have been land of No. III raised above the sea level and afterwards submerged to receive the deposit of No. IV. But the moment a portion of sea bottom is lifted above water level rain-erosion commences, and continues until resubmergence ; and rain-erosion must leave its marks in the shape of hills and hollows however small or low. Some break in the continuity of the deposit must take place, and must remain visible ever after wherever the consolidated rock strata are now exposed to examination. If no such break appears we may be sure that the sea bottom has not been lifted to the air. Therefore if the *Oneida formation*, thick and pebbly further northeast, grows thinner and finer and at length disappears going south, allowing the *Medina* above it and the *Hudson river* below it to come quietly together, it is certain that its disappearance is really and surely due to the fact that the sediments were floated further out into deep water according to their fineness, until at length the finest material was exhausted, or, mingled with equally fine material floated in from other directions.

XCIV.

the Schuylkill Water Gap, Port Clinton.
in 10 foot contours made by Geo. M. Lehman
and here reduced to ½ linear.

No. IV in Clinton, Centre and Lycoming.

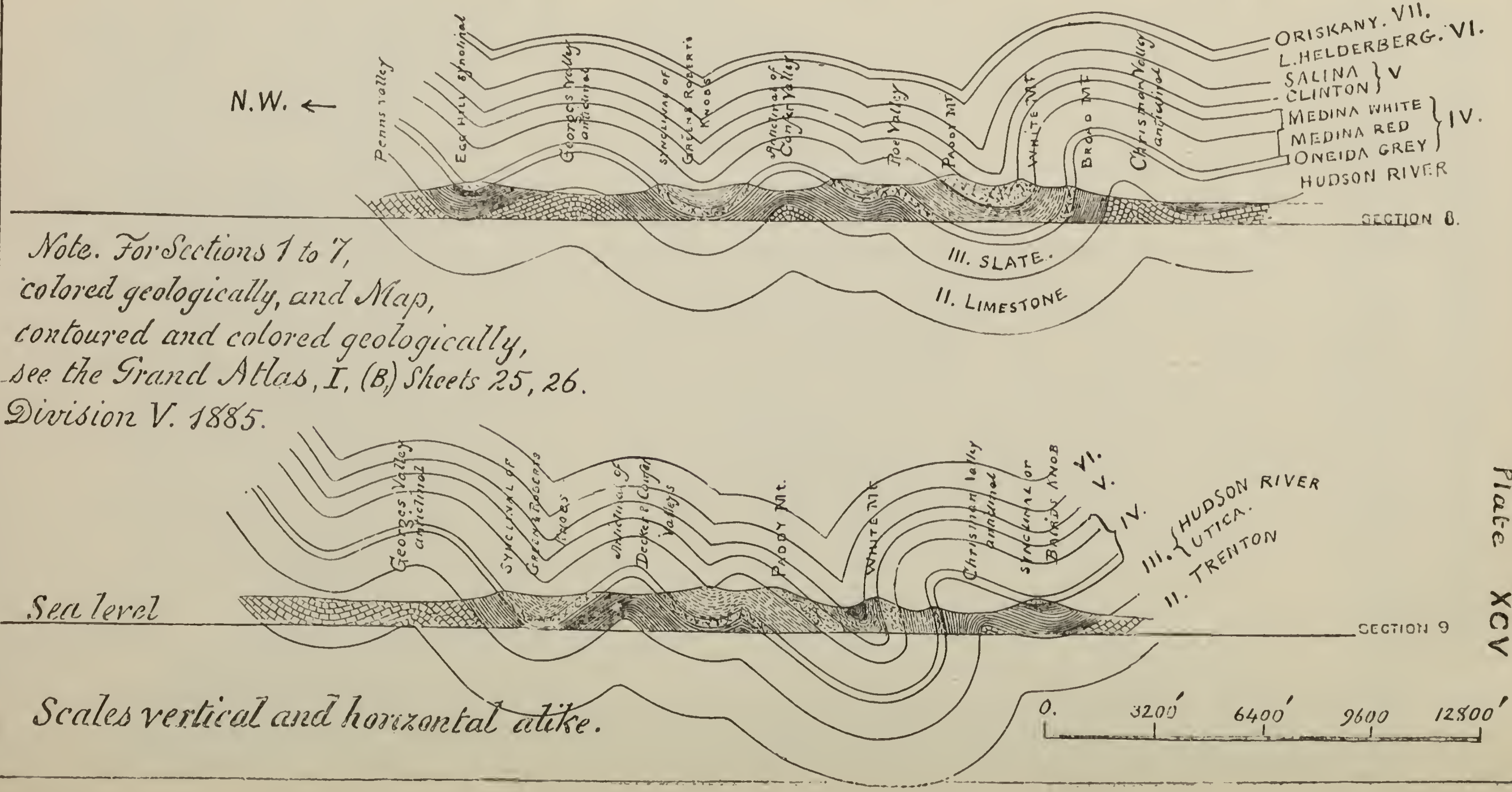
Following the Bald Eagle outcrop of IV eastward into Clinton county, the gaps at Lock Haven, Jersey Shore and Williamsport furnish sections of it along a stretch of 40 miles.

In the gap at Millhall, near Lock Haven, the *Medina upper* hard massive white, gray and red sandstones, not very well exposed measures 695′. The *middle division* of interstratified softer sandstones and shales measures 705′. Under these lie hard massive sand rocks mostly white; with a few beds of gray, mottled with iron rust, 188′. Under these, partly concealed, softer sandstones and shales, some of them red, 118′. Under these, massive, hard, dark gray and greenish gray, iron specked, flinty sandstones, 155′. Under these are hard and massive sandstones with concealed intervals of softer rocks, 440′; which makes a total thickness of 2301′. (G4, 129). It is evident that no useful classification of the beds of the whole formation into three divisions can be made out of the mere terms of this section; but it will be shown in its proper place that where the eye of the geologist is at fault, the hand of nature works with unerring certainty, and carves the shape of the mountain in accordance with the larger groupings of the hard and massive beds.

In the gaps issuing from Nippenose valley and Mosquito valley in Lycoming county the rocks of No. IV are not well exposed. The *Medina upper* hard sandstone is estimated by Mr. Platt at only 100′; the *middle* red division he makes 1200′; and the *Oneida* hard sand rock only 75′; the total being only 1375′ (G2, 29). The contrast between the section at Mill Hall carefully measured by Dr. Chance and this roughly estimated section of Mr. Platt at Jersey Shore and Williamsport is very striking, and not easily explained. It certainly affords no safe basis for generalizing on the extent, thickness or method of the deposits.

Plate XCV

Sections 8 and 9 across the Seven Mountains of Middle Pennsylvania. C.E.Billin.



Note. For Sections 1 to 7, colored geologically, and Map, contoured and colored geologically, see the Grand Atlas, I, (B) Sheets 25, 26. Division V. 1885.

Scales vertical and horizontal alike.

No. IV along the Great Valley.

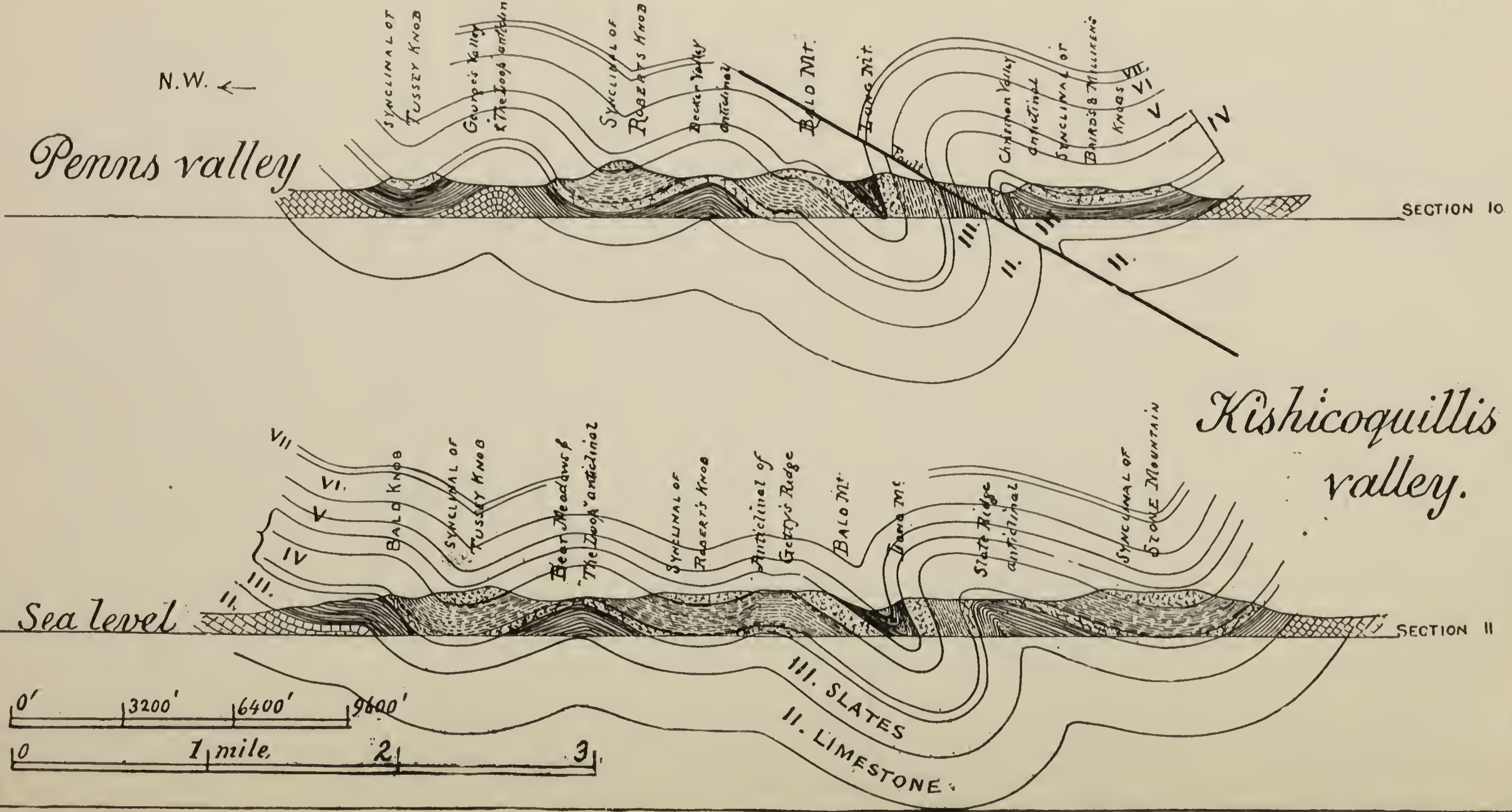
Passing now to the long outcrop of No. IV, which borders the Great Valley, we have, first, at the gap of the Susquehanna above Harrisburg an expression of the formation totally different in character from anything observable in the outcrops northwest of it toward the Allegheny mountain. The *Medina upper* division consists of a series of comparatively thin white sandstone beds, alternating with greenish and yellowish slates; some reddish sandstones occurring among the upper layers showing impression of marine plants; altogether making only 300′ or 400′. The absence of massiveness here in the upper division of No. IV is quite remarkable. The consequence is that instead of making the crest of the mountain, these upper beds crop out below the crest on the southern side, over the outcrop of the Oneida; the crest being made by the Iron sandstone of the Clinton formation No. V, that is, in Perry county.

The *Medina middle* soft red division of No. IV is here entirely wanting; and the geologist must travel along the mountain westward toward Franklin county to find it again appearing in the ridges which enclose Path Valley, but only feebly developed. Or he must cross Perry county northwestward to find it coming into the series in the gaps of the Tuscarora range. If he continues further northward to the Shade mountain, Blue Ridge and Black Log mountain gaps, he will find it much increased in thickness. Beyond these to the northwest are the sections in Jack's mountain, Tussey mountain, and the Bald Eagle range, which have already been described, where it attains its maximum thickness.

No. IV at the Susquehanna Water Gap.

But, in the Susquehanna gap above Harrisburg the *Oneida* makes a great mark rising steeply to the top of mountain, along which its rocky outcrop runs, on the southern slope. It is about 70′ thick, 40′ of which consists of white sandstone beds containing pebbles; under this an exceedingly

Sections 10 and 11 across the Seven Mountains in Union and Huntingdon.

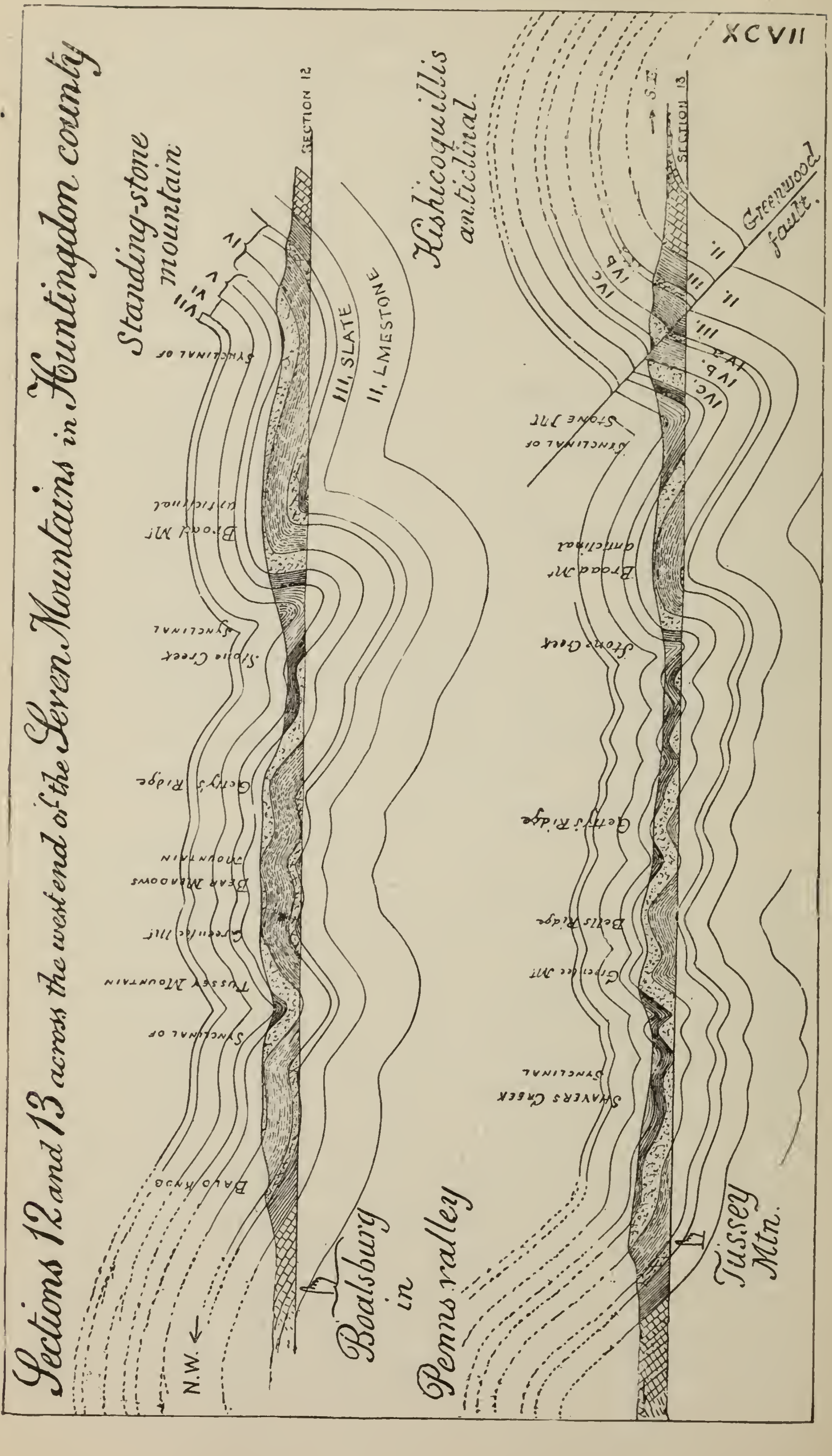


XCVI.

coarse, heterogeneous, red pudding-stone, 5′ thick. Under this, between it and the uppermost layers of *Hudson River slate*, there is a concealed space of 40′ or 50′. How much sliding and faulting has taken place in this interval, or how much of it is occupied by concealed sandstones cannot be made out. The wall of *Oneida* exhibits so many oblique slips and fault joints that its present thickness may be different from that which it had when it lay horizontally at the bottom of the sea. The most interesting feature of this famous exposure (apart from the fact already mentioned that the formation is here pushed over the vertical to a reversed south dip of 70°) is the five foot coarse pudding-stone. As this lies at or near the bottom of No. IV, and more or less directly upon the slates of No. III, it is certainly an indication of some disturbance having taken place in some other and perhaps distant district of the earth's surface. But it is useless to speculate upon the origin of a bed, composed of pebbles and fragments of all kinds, since we are entirely ignorant of the depth of water which then and there existed, of the nature of the tide-runs or other currents which could transport the material, and of the shape, character or location of the shore lines which bounded the then water basin.

It serves no good purpose to suggest that we have here a shingle on a sea beach. It would be equally useless to suggest an isolated gravel bank in the midst of the sea. Towards the west, for a thousand miles, no land could have existed at that time; nor for less than three or four hundred miles towards the north. Our South mountains, and in fact all southeastern Pennsylvania was then not only under water, but covered by the limestone and mud formations No. II and III. If the great mountain mass of North Carolina was at that time out of water, which is very doubtful, it was nearly 500 miles distant to the south. All the highlands of New Jersey were at that time submerged. The Adirondack mountains in northern New York, and perhaps parts of New England, may possibly have been out of water, and possibly the Oneida pebbles were derived from those sources (but were certainly subsequently

XCVII



Sections 12 and 13 across the west end of the Seven Mountains in Huntingdon county submerged, as the Barnardston fossils show). But it would defy the keenest genius to make out the case, or paint the picture of the transaction in colors which would not fade into an undistinguishable gray under the light of precise enquiry. And the hopelessness of the attempt is accented by a fact which seems to be never alluded to by those who generalize on such subjects; namely, the fact that our formation No. IV while being deposited in the Appalachian sea of America was at the same time being deposited in the prolongation of that sea which reached Europe; being recognized in England under the name of the *May Hill sandstone;* and it will be shown in discussing Formation No. VII that this critical fact was repeated in the case of the *Oriskany sandstone* which was deposited in the United States at the same time that it was being deposited in France; specimens from that formation, full of the same animal forms and presenting exactly the same aspect, having been collected from the outcrops on both sides of the present Atlantic.

No. IV at the Schuylikll Water Gap.

A topographical contour map of the Schuylkill Water Gap at Port Clinton made by Mr. Chance, with careful measurements of the five groups into which No. IV is there subdivded, gives us the following description of it:

Three prominent ribs of sandrock rise vertically from the bed of the river to the north slope of the crest of the mountain. No distinction can be made in the *Medina* between an upper white and a lower red division. At the top rest 90′ of *Upper Medina* gray sandstone beds, supported by 480′ of iron stained shales; under which are 60′ of *Lower Medina* white sandstone beds supported by 600′ of iron stained shales; and at the bottom, 200′ of *Oneida* white sandstone and gravel beds, which make the crest.*

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*This is a rare occurrence, due to the great thickness and massiveness of this rib. The terrace on the north slope is made by the outcrop of the comparatively thin and *unsupported Upper Medina* rib. See cross-section, fig. 4, plate LII, on p. 554 above.

At this interesting locality the bottom of No. IV is wholly separated from the slates of No. III by a vertical fault, on the north side of which the sandstones of IV rise vertically into the air, making the crest and north slope of the mountain. On the south side of the fault the slate formation No. III is sheared off like a cake of cheese, the edges of the slates abutting nearly horizontally square against the upturned bottom plate of Oneida conglomerate. It is impossible to affirm that it is actually the bottom layer of the Oneida; but there is very little reason to doubt it; seeing that when the break took place, and the whole mass of No. IV was turned up at right angle, it is probable that it was turned up as a solid mass; and that the lower surface of the bottom bed acted as a grinding surface against the edges of the slates. As no verbal description can give a clear idea of this phenomenon the section is presented in the figure cited in the last footnote.

The Schuylkill Water Gap is 50 miles east of the Susquehanna water gap; and in these 50 miles the character of the formation has evidently changed in an extraordinary degree; and this change goes on becoming more and more striking eastward.

No. IV Lehigh Water Gap.

At the Lehigh Water Gap (25 miles east of the Schuylkill Water Gap) Dr. Chance's measured section gives the following details: Upper sandstone rib 85′; upper ferruginous shales 180′; Middle gray sandstone rib 70′; lower ferruginous shales 330′; (total *Medina* 665′;) *Oneida* sandstones, some of them pebble-rocks, 290′; *Oneida* massive conglomerate 170′; (total *Oneida* 460′); total of Formation No. IV, 1125′.

We see that the pebble-rock, which at the Susquehanna gap was less than 100′ thick and at the Schuylkill gap 200′, is at the Lehigh gap nearly 500′; constituting everywhere from the Susquehanna to the Lehigh the central rib of the mountain and sometimes its crest; while the middle and upper sandstone ribs crop out as terraces and benches along the northern slope.*

No. IV at the Delaware Water Gap.

At the Delaware Water Gap (25 miles still further east) the gradual change in the constitution of No. IV produces another feature, namely, the subdivision of the *Oneida* into three, the *Medina* continuing to be sub-divided into four. We now have seven distinct subdivisions of the formation No. IV as follows; *Upper Medina* sandstone rib 200′; upper ferruginous shales with some sandstone beds 530′; *Lower Medina* sandstone rib (here a white conglomerate) 200′; lower ferruginous shales with the sandstone beds 110′; (total *Medina* 1040′); *Upper Oneida* gray sandstone rib 75′; intermediate shales with sandstone beds 240′; *Lower Oneida* white conglomerate rib 210′ (total *Oneida* 525′); total thickness of No. IV, 1564′.†

At the Lehigh Water Gap there is some doubt about the relation of the bottom bed of Oneida to the slates of III on which it rests; but at the Delaware Water Gap there is no confusion or concealment whatever; the under surface of the bottom bed of the lower division of the *Oneida conglomerate* rests quietly and regularly upon the uppermost sandy slates of No. III. And, what is more important

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*At the Lehigh the Upper Medina sandstone makes the crest, but as it is comparatively thin the crest is not sharp; and as it is supported by the second rib, with only 170′ of hard shales between them, the two ribs act like one, and as if 235′ thick, making a very high gently rounded crest. See figure 3, LII, page 554. The south slope of the mountain becomes steeper and steeper across the 330′ of hard shales; and becomes 35° across the 290′ of Oneida sandstone and 170′ of Oneida conglomerate, more than two-thirds of the way down to the foot. Here the slates of III commence, and the slope suddenly becomes gentle. It is a remarkable contour for the mountain of IV, well worthy of careful study. The outcrop which was at the very crest at the Schuylkill is here at the Lehigh nearly at the south foot of the mountain; not on account of dip, but on account of the different arrangement of the rock ribs and parting shales in the body of the mountain.

†Here the Oneida upper sand rock rib, thin as it is, makes the crest, because it is so closely supported (within 110′) by the huge Lower Medina sand rock rib, and by the very sandy character of the Oneida middle shales. The Oneida conglomerate makes precipices along the southern slope half way down the mountain. See cross-section, Pl. LXXX, p. 638.

still, the uppermost beds of No. III are here so sandy as to contain thin beds of sandstone, showing a regular procession of deposits, and a sort of passage from the slaty kind (III) to the coarser sandy and gravelly kind (IV). And yet the transition is in fact instantaneous ; as if a vast quantity of gravel was deposited upon a level sea bottom of dark sandy mud. We are again left in total darkness as to the cause of this remarkable operation. But after all, it is no more extraordinary than the way the May Hill sandstone of England rests upon the shales and limestones of lower Silurian Age.

No. IV in New Jersey.

The Kittatinny mountain (called Shawangunk mountain) after crossing the Delaware river at the Water Gap runs on for 35 miles to the north corner of New Jersey at Port Jervis. *Oneida conglomerate* (*Shawangunk grit*) is described in the Geology of New Jersey (1868, p. 146) as a mass measuring (at Otisville) 800′ or 900′ thick, composed entirely of beds of conglomerate and sandstone. The lower part is a mass of quartz pebbles, from one quarter to three quarters of an inch in diameter, in a light colored quartz cement. In the beds above, the pebbles become smaller ; and near the top they can hardly be distinguished from the paste in which they are imbedded, the whole rock being a massive compact quartzite. No fossil forms have been found. Some of the beds contain crystals of iron pyrites which have yielded to chemical assay as much as $11 of gold to the ton, This occurs at the bottom of the formation next the slates of III. The lead ore veins which traverse the rock will be mentioned directly.

The *Medina beds* outcrop along the northern slope of the mountain descending to the Delaware river. Their estimated thickness where the Erie railroad crosses the mountain east of Port Jervis is 800′. The two formations *Medina* and *Oneida* are here seen to pass into each other by a series of alternations, white and red, the white being *Oneida*, the red *Medina*. These colors strongly contrast and distinguish the two formations. The Indians called the mountain "Shamgum" the white rock. It is evident from the change of color that the sea water at the beginning of *Medina* time, began to receive large accessions of iron; but there was not at any time deposits of iron ore. The red *Medina* sandstones are interstratified with reddish shales; and these are so abundantly traversed by transverse cleavage planes as to give the rock in some places the appearance of a red roofing slate, dipping steeply *across the bed plates* towards the southeast; but the coarser and harder brownish red sandstones do not show this cleavage and exhibit the true northward dip. Occasionally a grayish green shale occurs. The bottom *Medina* beds (next over the *Oneida*) are all sandstone, made up of grains of quartz, some of them containing small pebbles of white quartz, interstratified with soft shales; while the upper *Medina* beds are nearly all reddish shale (much split by cross cleavage) interleaved with thick red and grayish sandstone beds. No fossil of any kind except a sea weed has been found; and this is the more remarkable because, excellently well preserved ripple marks are common, in fact almost universal.

No. IV in New York.

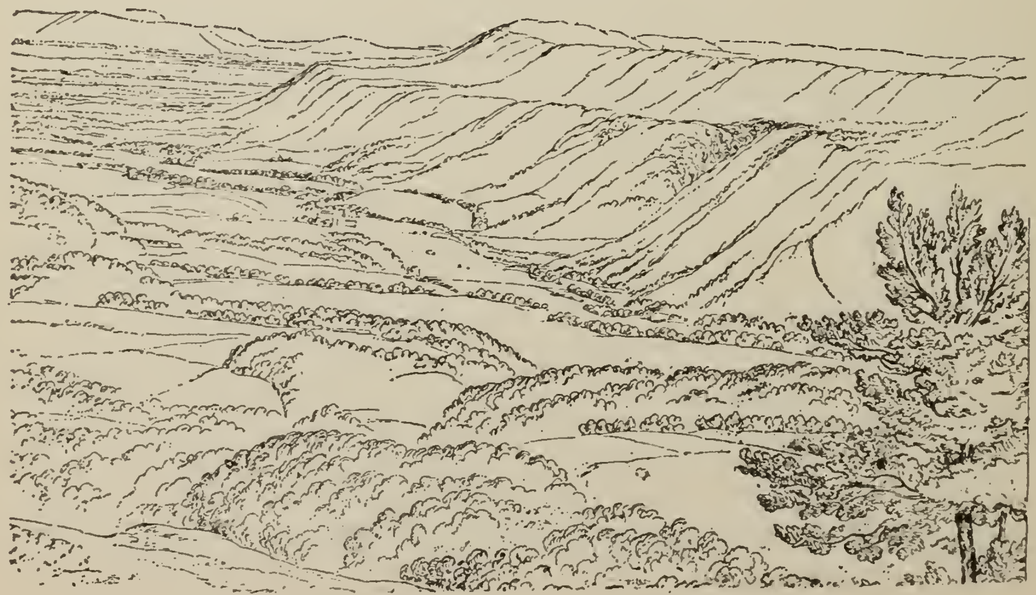
The Shawangunk mountain in New York runs on northeast about 45 miles, to within 10 miles of the Hudson, and abruptly ends at Rosendale where the Rondout and Walkill valleys come together. Leaving New Jersey the mountain has a crest of white *Oneida*, and a northern slope of red *Medina*. But advancing northeastward the *Medina* rocks disappear and at last the mountain consists exclusively of Oneida beds, estimated by Mather at 500′ running down to 150′ and even as thin as 60′. Some red beds at the top would seem to indicate that the *Medina* is slighly represented; but no division between the two formations is possible; and it will be seen hereafter that the next superior formation No. V thins away in the same direction, letting the limestone of No. VI rest upon the beds of No. IV. These details respecting the geology of New Jersey and New York are given here merely for the purpose of showing that the variations in Formation No. IV throughout Pennsylvania are not to be compared for magnitude with its variation in this New York district. The mountain in New York is broken by great cross-faults which traverse also the formations above it and below it. In fact the region bordering the Hudson river valley has been shattered by the earth movements which elevated New England; and probably it is to the greatest of these faults that the mountain owes its sudden termination.

Lead ore veins in No. IV.

The remarkable lead veins which traverse No. IV in New York are among the consequences of the shattered condition of that region. Such lead veins are not to be expected in Pennsylvania where the outcrop mountains of No. IV exhibit few cross fractures. In the early settlement of America, Indians and hunters searched everywhere for galena to furnish themselves with bullets. Hundreds of traditions of Indian lead mines have been handed down, most of which are pure fictions. Indians and hunters certainly did find lead in certain places and carefully concealed their discoveries as long as it was possible to do so; but probably every such actual lead locality is now known, and are few in comparison with the great number of fictitious places. Most, if not all of the actual veins have been repeatedly explored, and some of them mined at considerable cost, none of them to profit. Forty years ago the Ellenville mine at the base of the Shawangunk mountain, the Ulster mine near Red Bridge 600 or 700′ up the side of the mountain, and the Shawangunk mines near Wurtsboro in Sullivan county, N. Y., 600 or 700′ up the mountain, were all in operation. They were all abandoned. In the Ellenville mine some lead and zinc were obtained. In the Ulster mine masses of zinc, lead, copper, and iron pyrites were obtained. In the Shcwangunk mine three masses of lead ore were taken out weighing from 800 to 1400 pounds. But the lead veins were only 2′ or 3′ thick, and the ore very irregular. The abundance of finely formed rock crystals, together with the mixture of ores, show that they were deposited from solution in the cracks which traversed the region after it had been shattered by the great earth movement which took place at the end of the coal age. It is idle to look for such veins in No. IV in middle Pennsylvania. The same may be said of gold. Although the lower beds of the *Oneida* are largely made up of gold-bearing quartz, of course they cannot be considered in any sense ancient glacial placer gravels; and free gold has never been reported. What gold exists is in the quartz pebble itself. It is perfectly certain that no gold mining can be successful in any of the mountains of No. IV in Pennsylvania.

LIII.

The Arch Spring on Sinking Cr. Blair Co.



Canoe Mountain terrace and Sinking valley.

CHAPTER LII.

Topographical features of middle Pennsylvania.

The facts presented in the foregoing chapter introduce the subject of the topography of the central belt of Pennsylvania, especially of that half of it which stretches from the Susquehanna river to the Maryland state line; for this topography has for its most striking features the bold ridge-outcrops of Formation No. IV.

It has already been said that all the Pennsylvania mountains from the North mountain of the Great Valley to the Bald Eagle mountain facing the Allegheny, in the country west of the Susquehanna river (with only three exceptions) are mountains of Formation No. IV*.

The mountains of No. IV may be classified in three groups of zigzags, so complicated in their shape that they can only be described by a map. To the inhabitants of the various counties in which these groups stand they seem like separate mountains, and so each has received some separate local name.

Names of Mountains of IV.

The number of local names is very great; the prominent ends of the zigzags being usually named after some settler, like Parnell's knob and Jordan's knob in Franklin county,

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*Two of these exceptions are in Perry county, namely; Cove mountain, ten miles and Buffalo mountain twenty miles above Harrisburg, which are mountains of No. X, and belong to the anthracite region of eastern Pennsylvania. The third exception is that of Sideling hill and Terrace mountain in Huntingdon county, surrounding the Broad Top coal basin, and continuing under various local names, like Harbor mountain and Town Hill, into Maryland, all mountains of No. X. The Broad Top mountain enclosed by them is made by No. XII capped with coal measures. A fourth exception might be mentioned in the case of Great and Little Savage mountains, in Somerset county, surrounding the Cumberland coal basin in Maryland; but this outcrop of No. X and XII is nothing but a zigzag of the Allegheny mountain and belongs properly to the general bituminous coal region of western Pennsylvania.

Sidney knob in Fulton county, Jacks mountain in Union county, Tussey's mountain, Dunning's mountain and Evitt's mountain in Mifflin, Blair and Bedford counties. Others have been named after the animals that haunted them in early times; Bear Meadow mountain in eastern Huntingdon; the Buffalo mountains in Union; White Deer and Bald Eagle mountains in Lycoming. Tuscarora mountain, ranging through Juniata county, was named after the principal tribe of Indians in middle Pennsylvania. Standing Stone mountain on the borders of Huntingdon and Mifflin, was named after a remarkable monolith or solid stone pillar 70′ high, which once stood on the bank of the Juniata, at the mouth of the creek, near the present town of Huntingdon. Around it the grand council fire of the tribes was lighted. Sometimes a name was repeated; as, for instance, Path Valley mountain, along which the southern county line of Centre runs, which has no connection whatever with the mountains surrounding Path valley in northern Franklin county. Several projecting spurs are called Dividing ridge, or Dividing mountain, because they separate two parts of an enclosed valley. German settlers from the Rhine, familiar with the name Siebengebirge, called the knot of ridges between Kishicoquillas valley and Brush valley the Seven mountains; but their ends toward the Susquehanna, in Snyder and Union, retained their Indian name of the Buffalo mountains; a proof that the bison roamed through Pennsylvania, when the beaver made its dams on many of our streams, and herds of elk ranged through the Allegheny uplands.

Three groups of mountains of IV.

1. The southermost group of mountains of IV lies between the North mountain of Cumberland and Franklin and the Tuscarora mountain which ends at the Juniata at Millerstown. The eastern zigzags are represented in fig. 3, pl. LXXIV, p. 626. They enclose the fertile valleys of Perry county, Greenbrier, Kennedy's, Henry's, Shafer's, Little Illinois, Sherman's, and Horse valleys, with Path valley, Burn's valley, and Amberson valley in Fulton

county, issuing southward upon the Great Valley at Mercersburg. This group is extended southward through Fulton as Sidney knob, Tuscarora mountain, and Cove mountain surrounding McConnellsburg Cove in Fulton county, into Maryland. It includes also the isolated mountain which ends in Parnell's knob ; and the two mountains which project from Maryland toward Mercersburg.

2. The middle group of mountains of IV., is of a peculiar character. It resembles three long narrow canoes moored side by side, but projecting beyond each other ; or rather three canoes floating bottom up, each one with its bottom knocked out. They are in fact the eroded tops of three long closely folded anticlinal arches of No. IV, separated from each other by equally long narrow and closely compressed basins filled with Formation No. V. (*a*)The southern anticlinal, having West Shade mountain for its south dipping and Black Log mountain for its north dipping outcrop,- extends from Fort Littleton on the Fulton county line to within ten miles of the Juniata at Mifflintown. (*b*)The middle anticlinal, called Blue ridge, extends from the Horse Shoe bend of the Juniata at Newton Hamilton to the Juniata river above Mifflintown. (*c*)The third extends from the Juniata river at Lewistown to within 8 miles of Selinsgrove, on the Susquehanna, in Snyder county. The shape and arrangment of these three is shown in the Vignette Map of the State at the beginning of this volume. Nothing in topography is more beautifully symmetrical ; nor can anything illustrate to greater advantage the plication of the formations in middle Pennsylvania.

3. The third group of mountains of No. IV is of so complicated a character as to defy description in words, and is therefore given in outline in the Vignette just mentioned. In this figure a black line represents the Medina white sandstone outcrop which everywhere in this group, extending from the Susquehanna at Muncy in Lycoming county to the Maryland line, makes the mountain crest; while the broken line alongside of it represents the Oneida gray sandstone outcrop which everywhere in this group forms a bold terrace on the mountain flank. The southern

border of this group is the noble ridge of Jack's mountain, which borders the Lewistown valley on the north and for 50 miles, shuts in behind it the fertile Kishicoquillis limestone valley, bordered on the northwest by the Standing Stone mountain, and on the north by the Seven mountains, which spread (northward) as Short mountain, Brush mountain, Nittany mountain, Buffalo, White Deer and Bald Eagle mountains as far as the Williamsport valley. From the western end of the Seven mountains projects Tussey's mountain which runs on uninterruptedly about 100 miles to the Maryland line, shutting in behind it the fertile limestone valleys of Penn's creek, Brush creek, Spruce creek, Canoe valley and Morrison's cove. The Bald Eagle outcrop is the second finest in the State, extending along the West Branch of the Susquehanna for 30 miles, from Muncy to Lock Haven; than onward along the Bald Eagle creek for 50 miles, from Lock Haven to Tyrone City; thence onward along the upper Little Juniata for 15 miles, to Frankstown; then returning to the Little Juniata (13 miles) as Brush mountain ; bending back and running south (20 miles) as Canoe mountain; turning and running north (6 miles) toward Hollidaysburg as Lock mountain; resuming its south course as Dunning's mountain (25 miles) it bends round Dutch corner and runs south (30 miles) as Evitt's mountain into Maryland. Isolated geographically from this outcrop on the west is the anticlinal of Will's mountain and Buffalo Ridge, extending from Bedford (25 miles) to the Maryland line.

This long and perhaps tedious enumeration of the mountains of IV in middle Pennsylvania, west of the Susquehanna river, will interest the people of that part of the State who will now understand the geological identity of the labyrinth of mountain ridges among which they live. But its principal value arises from a single geological idea, namely: that this continuous series of mountain crests and slopes are all made in one and the same way, out of one and the same set of rocks, exhibiting everywhere the same internal constitution and differing only, (1) in the thickness of the beds or groups of beds at one place and another, as has been fully explained in the last chapter; and (2) in the various angles to the horizon, at which their strata have been tilted up.

It now remains to show, first, why these mountains sometimes run in straight lines parallel to each other for many miles; secondly, why these parallel lines sometimes come together at both ends, as do the gunwales of a boat at the prow and stern; thirdly, why in other districts they unite in a series of zigzags; fourthly, why the opposite points of such a series of zigzags have two totally different characters, one long and sloping gradually into the plain, the other high, sharp and abrupt, projecting like a knob into the air; fifthly, why the mountains of the first or southern group have only one crest and two slopes, whereas the mountains of the middle and northern groups have a crest, a long continuous slope on one side, and a bold terrace half way up the slope on the other side; sixthly, why the Bald Eagle mountain in Centre county has two crests of equal height and no terrace; seventhly, why the terraces are cut through at short and regular intervals by double headed ravines; and, eighthly, what all this teaches us respecting the great rock arches which once rose high in the air, but have long since been removed and swept into the Atlantic, furnishing collateral evidence that the surface of Pennsylvania is still being slowly but continuously fretted down toward the level of the sea.

Before taking up these several items it is essential to the understanding of the subject that the reader first imagine Formation No. IV as originally lying in a continuous and nearly horizontal sheet, deeply buried beneath Formations V, VI, VII, VIII, IX, X, XI, XII, and all the coal measures from XIII to XVII. He must then picture to himself this continuous sheet Formation No. IV, with all the formations beneath and above it pressed sideways and folded into arches and troughs also under western and northeastern Pennsylvania, just as we see it at the surface in middle Pennsylvania west of the Susquehanna. Beneath the anthracite coal basins it lies at various depths from 10,000′ to 20,000′; but between the basins the tops of its great arches approach much nearer to the surface; and one of them actually comes to the present surface in Montour's ridge at a single point between Danville and Sunbury, where, in a ravine descending to the North Branch of the Susquehanna, 37′ of its upper beds are actually exposed (See G7, p. 114). The mountainous exhibition of it at the present surface west of the Susquehanna is the consequence of a gradual upward slope of the whole formation from beneath the anthracite country, westward. Going westward the arches rise first, like the backs of whales issuing from the surface of the sea, covered with soft red shales of Formation No. V, and gradually lifting themselves higher and higher into the air. This is why all the eastern ends of all the mountains of IV, facing the Susquehanna valley, have one and the same character of long gently sloping mountain noses.

Parallelism of mountains of IV.

A. *The first point* mentioned above is the parallelism of the mountains of IV. This parallelism is perhaps the most remarkable feature of the topography of middle Pennsylvania. It is a consequence of the extraordinary symmetrical shape of the anticlinal arches, which can be compared to nothing better than the long even folds in heavy woolen carpets when pushed sidewise over a floor. The formations composing each fold may be well explained by the annual layers of wood in a fallen tree trunk which arch over each other, flat along the top, and steeply sloping on the sides. Now let a lumberman adze off the upper part of such a tree trunk, reducing it to a flat surface, he will expose the edges of the wood-layers in two sets of parallel lines, one set to the right and the other to the left; exactly corresponding to each other; the uppermost layers being the farthest apart, and the lowest layers to which his work reaches occupying a middle line over the center line of the log.

This it precisely what nature has done in her carpentry work upon the long prostrate anticlinal folds of the Palæozoic formations; only with a difference of tools. Instead of the carpenter's adze, she has employed frost, the thawing heat of sunshine, and the transporting power of rain water. With these tools everlastingly at work she has planed off all the anticlinal arches of middle Pennsylvania nearly to a common level.

But the difference in the tools employed by the carpenter and by nature makes a signal difference in the neatness of work done in the two cases. The adze and jack plane make no account of variation in hardness or softness of the several layers of wood; the edges are all reduced to the same plane surface; for such tools have no selective power and care nothing for either the resistance or the compliance of the wood which they remove. But the tools of nature exercise a kind of selective judgment; or, rather, they are sensitive to the slightest differences of hardness or softness in the rocks upon which they operate. If we could ascribe intelligence to nature we should be obliged to say, that she has no intention to produce an even smooth topography, that is, to reduce the surface of the State to a perfectly level plane. Her water work has gone further into the softer rocks, leaving the harder outcrops elevated, and the hardest and most massive formations standing out as mountain ridges. But her manner of working has been essentially the same as that adopted by the carpenter who, instead of the rapid action of adze and plane, should content himself with the slow and tedious operation of sandpaper, would himself produce the same variety of parallel ridges separated by creases on his log of wood.

The parallelism of any two mountains of IV on two sides of any anticlinal which extends for many miles teaches us two facts:

1. We learn that to have exact parallelism in long straight outcrops the crest of the anticlinal must be level for a long distance; for it is evident that if the crest of the anticlinal slope upward the opposite outcrops must diverge; if it slope downward they would approach each other. (2) We learn that the characteristic form of our anticlinal arches cannot belong to one formation, but to a whole and very thick series of formations, all folded together. This can

be easily understood by crumpling two substances even as different in thickness as silk and woolen; or by comparing the short irregular angular crimpling of one thin sheet of paper with the ample and regular fold of an entire ream of paper. The Palæozoic formations, lying upon each other like a pile of Canada blankets, could not have been pressed by the earth movement into any arches and troughs not of magnificent length, height and depth, and of beautiful symmetry. Therefore it must be kept in mind that we are dealing not with a few layers of sandstone, but with 40,000′ of superimposed sediments; and that when they were thrust into anticlinals and synclinals they all moved together, yielding and adjusting themselves to each other, especially the softer to the harder, but yielding to the earth movement as if they all constituted one single formation.

Convergence of mountains of IV.

B. *The second point* to be noticed seems at first sight a violation of the principle just stated; for the parallelism is not perfect and universal; it has its variations; but these variations, when explained, will be seen to be essential to the principle. However many miles two mountains of IV may run parallel, they are sure sooner or later to approach and unite at one end or at both ends. If this occurs at both ends it shows that the anticlinal fold dies down in both directions.

The student of our geology must be careful to make a strong distinction in his mind between the end of an anticlinal *mountain* and the end of its anticlinal *fold*. The mountain comes to an end because two parallel outcrop mountains have converged and sink together beneath the present surface. But the anticlinal fold itself keeps on, carrying the formation deeper and deeper In this way one formation disappears in a loop at the surface and is replaced by another further on, also in the shape of a loop. Following the axis of an anticlinal fold we have say first an arch of No II in the valley coming to a point; then, a loop of No. III, filling up the end of the valley; then a loop of No. IV making the end of the double mountain; on the outside nose of which is a loop of No. V settling into the plain; then a loop of the limestone formation No. VI descending beneath a looped ridge of Oriskany sandstone No. VII; which descends beneath a rolling hill country of No. VIII, ending in a grand mountain cove of red sandstone No. IX capped with white sandstone X; sinking as an anticlinal nose into a deep loop valley of the red shales of XI, enclosed between opposite dipping mountains of the Conglomerate XII, separating two coal basins.

This is the rule in all cases where the anticlinals are of the first order of magnitude.

Mountain spurs of No. IV.

C. *A third point* to be explained is the production of groups of mountain zigzags. This requires a little more strenuous effort of the imagination, but it is merely a complicated form of what has just been described. When the earth-movement pressed the whole series of Palæozoic formations into folds it obeyed a thousand variations of local stress and strain, and produced therefore not merely a few grand arches of the first order one or two hundred miles in length, but scores of folds and wrinkles of the second and third order of far inferior height and length. These subordinate folds may properly be considered mere parasites of the great anticlinals; they are, in fact, wrinkles on the descending sides of the grand arches. But these smaller arches bring the outcrop of No. IV to the surface and return it underground in the same way, but more rapidly and locally. They produce the same topography, but on a smaller scale. Each minor fold has its two opposing outcrops of No. IV, coming together in the direction in which the fold dies down. Where there are six such minor folds side by side, all dying down in one direction (say eastward, as in Snyder and Union counties) there are necessarily as many pairs of outcrop mountains of IV one on each side of each fold, producing a group of mountains in zigzag, with six points in one direction, and as many in the other. Perhaps the best way to comprehend this phenomenon, would be to take a sheet of corrugated zinc roofing, and hold it slanting in a basin of water. The edge of the water will make similar zigzags against the surface of the tin. The more erect the zinc plate is held the shorter will be each zizzag. If the plate be held nearly flat, one end scarcely below the water and the other scarcely above it, the zigzags will be long and sharp pointed. By varying the shape of the bends in the tin plate, that is, by representing anticlinals and synclinals of different height, breadth and sharpness, all sorts of variations in the zigzag water line can be got, and all the variations of our No. IV. mountain zigzags may be imitated.

The inelasticity of sand and mud deposits greatly helps us to explain their present folded condition. It cannot be too often repeated, that, when the earth movement took place the whole 40,000′ of Palæozoic formations were still in a moist and plastic state. Had they been of any dry, hard, elastic material they would have been bent into a very few perfectly regular folds, each formation sliding upon the surface of the one beneath it, and none of them wrinkled. But the actual mass of mud and sand deposits being wet and plastic, was necessarily, when thrown into folds as a whole, compressed into ten thousand subordinate folds and wrinkles. The great anticlinals are none of them mathematically perfect vaults. Their opposite sides do not descend in smooth unvarying curves into the synclinal troughs, but wave and halt and pitch irregularly in their descent. In geological language, the dip is constantly changing to steeper or less steep, and is occasionally reversed ; so that on the long slope of a grand anticlinal there are always seen to be one or more subordinate rolls and basins. When the bottom of the long anticlinal slope is at last reached, we are in the middle of a great synclinal basin, and begin to ascend the long wavy slope of the next parallel grand anticlinal. Thus, anticlinals and synclinals virtually occupy the same ground ; each anticlinal measuring in breadth from the center line of one synclinal across the arch to the center line of the next synclinal ; each synclinal measuring in breadth from the crest line of one anticlinal across to the crest line of the next. From the very nature of the curves it is impossible to avoid embarrassment in the use of these terms; and it is unfortunate that the double meaning of the terms employed makes their representation to the mind of the student somewhat vague. If it were possible to assume points *half way down the slope* we might confine the term *anticlinal* to the arch above these lines, and the term *synclinal* to the trough below these lines; but in practice this cannot be done; the reader must exercise his intellect to understand the facts of the case, and keep the distinction between the upward curves or *arches* and the downward curves or *troughs* as distinctly as possible before his mind's eye. Nothing in geology is simple; nothing in any branch of science is easy; to understand the true nature of the commonest fact of the world requires a strenuous endeavor of the judgment and the imagination working harmoniously together. And this is especially true in geology, most of its facts being concealed from the naked eye, and therefore to be mentally conceived, and cautiously reasoned upon.

Illustrations of the complicated character of the anticlinals and synclinals of No. IV are given in fig. 1, pl. LXXIII, p. 624, and fig. 1, pl. XC, p. 660. See also pl. XCV, XCVI, XCVII, p. 670. One of these represents a series of sections at intervals apart of about a mile across the Seven mountains in eastern Huntingdon county. The other represents a series of transverse sections, taken at greater intervals across the main anticlinal of Perry county which crosses the Susquehanna and runs on eastward between the two arms of the Schuylkill county anthracite coal basin—the Dauphin basin on the south and the Wiconisco basin on the north. In the first section the large white band represents the folds of No. IV, mostly along the plane of the present surface. In the second section No. IV is everywhere underground, but waved in the same manner; at the sections on the Juniata and Susquehanna rivers it is covered by 10,000′ or 15,000′ of higher formations.

How is it possible then, it may be asked, to draw correctly the shape of the waves of the deeply buried formation. The answer is, that they can be geometrically constructed on the supposition that the thickness of the overlying formations remain unchanged throughout the region; at least that any irregularities of thickness in each will practically be compensated for in all; and that the dips observed at the surface will give a good practical idea of the basins and arches concealed underground. Nearer than this to the exact truth the geologist cannot come, unless he employs boring tools, which is of course not to be thought of for such great depths. Enough is plainly observable at the surface to make the complicated structure of middle Pennsylvania completely evident. Wherever formation No. IV comes to the surface in mountain ridges a thousand feet high, cut through to their bases by rivers exposing the strata, there the character of the anticlinals of the first order reveals itself with admirable clearness.

The difference between the anticlinal and the synclinal Knobs of IV.

D. *The fourth question* must now be answered; why the opposite points of a series of zigzag mountains of No. IV are so totally different in shape and character?

It must be remembered that zigzags of No. IV are produced only in districts where the plicated formation is descending beneath the surface eastward and consequently rising into the air westward—or *vice versa.* If now we imagine such a set of zigzags pulled out to a straight line—in other words, the formation not waved, but still descending underground in one direction and rising into the air in the other—it is evident that in the descending direction, it will be first thinly veneered and then more and more thickly covered with the next soft red shale formation No. V. In the other direction the bare sand-rock edges will be abruptly broken off in a line of cliffs, from underneath which will crop out the soft dark shales of No. III, making a steep slope from the foot of the cliffs down to the floor of the valley; and in the valley will crop out the limestones of No. II.

Let us now restore the zigzags. The only difference will be, that instead of a long straight range of cliffs at the crest of the mountain there will be as many pointed projections as there are zigzags, each projection being a *peak of cliffs*, around which the slope of underlying slate will bend. Between the peaks, and running up into the zigzags, will be long narrow vales of slate, No. III.

By merely looking from a distance at the shape of the eastern and western ends of a zigzag mountain of IV a geologist can tell with certainty in which direction the anticlinals which make the zigzags are dying down, whether eastward or westward ; for if the anticlinal is rising westward and descending eastward, the east end of the mountains must be a long and gentle slope covered with the red shale of V ; and the west end of the mountain must be a high peak, rocky and precipitious, with a steep slope of slate No. III into a valley of limestone No. II. The geological county maps furnish plenty of examples of both kinds ; that is cases where the rocky point is at the west end and the red shale slope at the east end of the mountain; and cases where the rocky point is at the east end and the red shale slope at the west end of the mountain. To assist the reader some prominent examples may be pointed out.

Taking the southern outcropof No. IV, and following it from the DelawareWater Gap westward, Offset knob appears as a synclinal cliff-tipped projection looking east, while the red shale end of the zigzag sloping to the west is behind the Wind Gap. The zigzags of the little Schuylkill in northern Berks are produced by ten small anticlinals sinking westward ; consequently it is the eastern points of the zigzags which have the Knob cliffs. In Cumberland county the two projections of the North mountain into the Great Valley are towards the west ; their corresponding red shale zigzags pointing east are in Perry county. Parnell's knob and Jordan's knob are similar synclinal end cliffs pointing southward. The mountains of No. IV in Perry county, all end northeastward in long slopes of red shale ; their southwestern ends, projecting into Franklin county, are high and rocky. The triple central anticlinal group of No. IV, in Shade, Blue and Black Log mountains die down *at* *both ends, eastward and westward*, in long red shale slopes. So does Jack's mountain at its southwest end in Huntingdon county, and its northeast end in Snyder county. The Buffalo. White Deer mountains slope their east ends beneath the red shale country of Union county, but project westward into Kishicoquillis, Penn's, Brush and Nittany valleys in long high rocky ridges, with ranges of cliffs on each side and broken off sharply at their western end.*

Let us take the case of the west end of the Nittany mountain in Centre county. Thousands of years ago the mountain did not end where it now does, but extended further west; and ages before that old time it extended still further west, indeed all the way to the Juniata river. In fact, Nittany mountain at that time extended to and was merely an extension of Canoe mountain in Blair county. In like manner Brush mountain once extended westward and united with Tussey mountain. Short mountain once ran past Aaronburg, Millheim and Spring Mills to join Tussey mountain, and Egg hill was part of it. The same is true of the two beautiful mountains which project westward into Kishacoquillis valley. There was once a time when the northern knob was extended to meet the Standing Stone mountain at Milroy; and the southern knob continued on through the center line of the valley towards Reedsville.

The proper way to express the fact, then, is to say that the cliff knobs of No. IV show how far the destruction of the formation by sunshine, frost and rain in the synclinals up to the present time has gone. In each instance a rocky knob marks the exact center line of a synclinal basin ascending into the air; and on the other hand every long sloping red shale nose of a mountain of No. IV marks the exact center line of an anticlinal arch descending into the underground. With this clue in hand the student of our geology

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*The term broken off, is that which an artist would use, or a mere topographer, or railroad engineer; but the student of geology ought not to use it if he can find any substitute for it; for there is no *geological break* at the ends of these craggy mountains. Let this be well remembered and understood, for otherwise the most important geological idea of this subject will be lost.

can find his way through the hilly labyrinth of middle Pennsylvania.

The elaboration of this subject has been intentionally carried to an unusual length and minuteness in the foregoing pages, because the laws of Structure and Erosion, expressed on so grand a scale by the outcrops of IV, hold good in the million details of structure and erosion on a smaller, and on the smallest scale, in all the other Palæozoic formations, whether regarded in mass, in groups of strata, or in one single layer. Therefore further allusion to the subject will not be necessary in other parts of this book beyond occasional references to what has been written in this chapter.

Crests, single and double.

E. *The fifth question* to be answered, namely: Why the southern mountains of No. IV have a single crest and two slopes, while the northern mountains of IV have but one crest and a terrace, and the northermost of all, the Bald Eagle, two crests and no terrace, can be easily answered by merely pointing to the fact, stated in the last chapter, that Formation No. IV is practically *a single* sheet of sandrock at the southern side of the district, and a *double* sheet of sandrock at the northern side of it. To state the fact more precisely:—In the Kittatinny mountain facing the Great Valley the *Onieda conglomerate*, the bottom member of No. IV, is coarser, and more massive, and has resisted erosion best; while the *Medina strata* are not only comparatively thin, but are weakened in their resistance to erosion by large intervals of softer rocks; so that the whole northern slope has been worn down by the weather without leaving any very bold terraces. In Perry, Fulton and Franklin counties the *Oneida* is thin and has a mass of harder massive rocks above it which make the top of the mountain, with a pretty regular slope, showing slight indications of terraces. But in the middle and northern groups of mountains of IV the formation consists of very massive *Oneida* at the bottom, and still more massive *Medina* at the top, the two separated by a thick, soft, red mass. The *Medina* therefore makes the crest of the mountain, protected by the softer but still pretty massive middle division; while the Oneida, undermined by the soft slate ormation of No. III on which it rests, unable to rival the Medina in its resistance to the weather, and therefore in its height, is necessarily left as a bold terrace on the outcrop slope, about two-thirds as high as the crest of the mountain. In the majority of cases the dip of the formation as a whole, whether toward the south or toward the north, ranges between 40° and 60°; so that the *Medina upper* slants upward through the mountain as its central rib or plate from base to crest, its cliffs overhanging the terrace of Oneida below.

Difference in the height of mountains of IV.

F. *The sixth point* of topographical interest to be explained geologically is the fact of the Bald Eagle mountain having two crests of equal height and no terrace; and the additional fact that this mountain with two crests is inferior in height to the opposite Tussey mountain, which has but one crest and a terrace.

In Tussey mountain the *upper Medina* is thick and the *Oneida* thin; whereas in Bald Eagle mountain the upper Medina and the Oneida are of about equal thickness. In Tussey mountain therefore the *upper Medina* makes a high crest and the *Oneida* a terrace: whereas in Bald Eagle mountain each makes a separate crest.

The inferior height of the Bald Eagle mountain is due to the fact that its stratification is vertical.

This leads us to the consideration of another law of topography, namely that (other things being equal) the relative heights of mountains is determined by the angle at which their rocks lie to the horizon; *the flatter the rocks the higher the mountain; the steeper the dip the lower the mountain;* the steepest dip (90°) makes the lowest mountain.

Surface erosion, that is, the gradual destruction of strata at their outcrops, comes about as a double process of undermining, and toppling down. However hard and massive a formation may be, and therefore in itself constituted to resist erosion, its powers of resistance will not avail it, if it lies, at a moderate slope, upon a soft, easily weathering formation underneath. For, as the underlying softer rocks are removed by the weather, the overlying, massive, hard rocks tumble down in blocks separated by the cleavage planes. But if the underlying softer formation has in it numerous interstratified beds of hard rock, its own rate of erosion is made slower thereby, and the overlying formation is less rapidly undermined; consequently its height above the valleys remains always relatively greater.

But when the stratification is vertical, a lower massive formation (like the *Oneida*) can no longer give a protective support to an upper massive formation (like the *upper Medina*). Each must take care of itself separately. It is a case of "divide and conquer." The sunshine, frost and rain have the mountain at a disadvantage, and reduce its relative height to a secondary rank. This interesting law of erosion illustrates itself by producing various features of topography which are inexplicable to minds not familiar with the character of the war which is perpetually waged between the attacking and defending parties, the elements of erosion on the one side, and the rock constituents on the other.

One beautiful illustration of the way in which the rocks support each other against the assault of the weather may be found in the *synclinal knobs;* for, in these knobs two outcrops come together and are therefore united in self-defense. In addition to their union they lie horizontally along the center line of the basin. The anticlinal knobs are still better protected, and are therefore relatively higher than the synclinal knobs, as shown in the sketch of Tussey mountain as seen from the top of Terrace mountain, back of Stonerstown, in Huntingdon county (Fig. 42, p. 143, of Manual of Coal).

Keel mountains of IV.

Before leaving the subject of the crests and terraces of No. IV, the most beautiful phenomenon in the topography of middle Pennsylvania must be mentioned. When two crests converge and become one. projecting as a single high narrow ridge, between two limestone vales, and ending in a synclinal point, their two terraces curve and unite around the end of the point. If the curve be a semi-circle, that shows that the synclinal is rising rapidly into the air. But if the synclinal rises very slowly the combined terraces project miles beyond the end of the crest, and then come to a similar, but lower synclinal point of their own in the limestone valley. This is the case with the two synclinal terraced mountains at the east end of Kishicoquillis valley; and it is the case with Short mountain, Brush mountain and Nittany mountain in Clinton and Centre counties. A spectator regarding these mountains from the floor of the valley, sees them end on in perspective, or as if in section, and is struck with surprise at their symmetrical shape, resembling ships that have been turned over with their keels uppermost (Figs.—). For this reason they received from the geologists of the First Survey the name of *Keel mountains of IV.*

Ravine system of IV.

G. *The seventh and last item* of topographical interest relates to the two entirely different modes in which the two sides of a terraced mountain of IV is drained. Tussey mountain, for example, with rocks dipping south into Huntingdon county, and outcrops overlooking northward the great limestone valley in Centre. On the Huntingdon side there is a long slope of the red rocks of formation No. V, down which the rainfall delivers itself by innumerable rivulets, flowing in straight and shallow channels from crest to base. On the other or Centre county side the uppermost slope next the crest is a sheet of fallen fragments of *upper Medina*, stopped in their descent by the *Oneida terrace*, the rainfall cannot deliver its waters in straight lines to the base of the mountain on account of the massive *Oneida* strata which out-crop along the brow of the terrace. Consequently it cuts deep ravines sideways, right and left, in the soft *lower Medina;* and these ravines meeting in pairs, break out through the *Oneida* terrace and its supporting slates of III, in deep short gorges debouching upon the limestone valley. The regularity of this system of *terrace ravines* is wonderful. The ravines are all alike in depth, narrowness and steepness of sides. The distance from ravine to ravine is almost exactly the same from one end of the mountain to the other. Each ravine has a double head, one to the right the other to the left, its branches being usually of equal length.* It is impossible to repress one's admiration at this flagrant proof, first, of the regularity of the mountain constitution; secondly, of the equal action of the elements upon it at all points; thirdly, at the total absence of violent, paroxysmal or irregular conduct in the processes of nature. In fact it may be said, that a student who wishes to investigate the subject of Erosion, that is, the perpetual destruction of the earth's surface by the surrounding atmosphere, and the ways in which this destruction is accomplished, could not do better than to start his investigation with a close study of the *terrace ravines of No. IV;* for he would find out in his subsequent experience that this special physical phenomenon will suggest the true explanation of every detail of the features of an eroded region.

The Anticlinal vaults restored.

It only remains to say, that when one has familiarized himself with a limestone valley shut in between two mountains of IV, with their even rocky crests, and ravine cut terraces, the strata dipping always away from the valley in both directions, he cannot hesitate to drawing the conclusion, that as the two mountains come together at the two

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*See also the map of the south flank of Jack's mountain in Mifflin county, given on page plates CIV, CV, CVI, CVII in the next volume. These plates present (on a scale of $\frac{1}{2}$) the eastern half of the unpublished MS. map of the south flank of foot hills of Jack's mountain from Logan's Gap west to McVeytown. The map stretches westward to Mount Union and Jack's Narrows, exhibiting similar features. It was one of the earliest pieces of topographical work of the Survey (1874–75), and was intended to illustrate Report F on the fossil ore belts of the Lewistown valley, but was not finished in time for the publication of that Report. It is now used as an illustration in the chapters on the *Clinton formation, No. V.* The terrace ravines are shown in fig. 2, plate XIV, p. 376; in plate XVII, p. 389; plate XXII, p. 400; and especially by the great map sheets of Morrison's Cove, in Report T, Atlas.

Model of surface of IVc under 20000 square miles of middle Pennsylvania. 1886.

ends of the valley, so their strata were formerly united in the air above in an immense arch or vault of unbroken sandstone miles high.

This effect upon the judgment and imagination combined is irresistible in the case of the larger valleys. In the case of a long and narrow anticlinal valley like Black Log, a casual visitor might not be led to this conclusion, but to a very different one. His first impression would probably be that the strip of limestone land along the center line of the valley had been pushed up, splintering asunder the overlying slate and sandstone formations (III and IV), and thrusting the broken edges of the fracture to the right and left. In the beginning of the present century such was the theory of the Swiss geologists, Thurman, Desor, and others, respecting the valley formations of the Jura ; and such was the theory respecting all the mountains of the world entertained by one of the fathers of German geology, Leopold Von Buch. Quite recently has this old and false conception ceased to mingle intimately with correcter views in many minds. The principles enunciated in this chapter nevertheless cannot be called new, for they were fully explained and sufficiently illustrated in my "Manual of Coal and its Topography," published in 1856, and in Professor Rogers' Geology of Pennsylvania published in 1858. But even then they were not new ; for the whole subject of Plication and Erosion was placed permanently on its proper basis of demonstrated theory fifty years ago, by the assistant geologists of the First Survey of Pennsylvania ; and both facts and principles were known and used by Whelpley, Henderson, Jackson and McKinley in their daily field work, and in the construction of the maps and sections with which they illustrated and embellished their reports. It has been recently stated as a new discovery that there is an organic connection between anticlinal folds and down-throw and up-throw faults ; and the credit of this supposed discovery has been given to the able geologists of the United States Survey in the Rocky mountain regions. But like other applications of principle to fact in this whole subject, the passage of arches into faults was so fully explained

Model of upper surface of Medina Sandstone, No. IVc, restored, By J. P. Lesley, in 1886.

by the early surveys of Pennsylvania and Virginia that nothing essentially new or different has in recent years been added to it, except in the one point of the distance to which *Overthrust faults* have been carried horizontally, as in Western Scotland, the Alps, and the Rocky mountains.

Model of the upper surface of the Medina, No. IV, after its plication and before its erosion.

Page plates LVII, LVIII were made from two photographs of the surface of a model constructed by me in 1886, to show the crumpled geology of Middle Pennsylvania, as contrasted with the gently waved structure of the whole country back of the Allegheny mountain (the western and the northern counties) and the almost wholly undisturbed condition of things in the Pocono and Catskill mountain region on both sides of the upper Delaware river.*

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*I planned this model in 1841 while I was drawing the thirteen long sections across the State which Prof. H. D. Rogers published in 1858 along the bottom border of my State Map. But the data obtained by the First Survey did not seem to me sufficiently precise. When the Second Survey was organized in 1874 I waited until the surveys of the middle counties could be mapped, with local sections abundant enough to cover the whole area. By 1886 most of the county maps had been published on a scale of two miles to the inch, with well-defined limits to the formations. In 1885 I published, in Report X, county maps of the whole State on the scale of six miles to an inch. Of these I selected enough to cover a sufficient area, and afford a satisfactory basis for a model.

There are but two methods of making such a model; one is to cut it down to fixed limits; the other is to build it up from a base plane. With hypsometrically surveyed contour line maps of the surface the simplest method is to jig out the contours in paper, card board, or veneer wood; pile them on one another; paste, glue or tack them fast; cover them with wax; tool the whole to a smooth surface; cast a mold; from the mold cast a positive; and finally tool it to satisfaction. In 1856 I made such a model of the Johnstown district in Cambria and Somerset counties, from Edward Smith's contour map of the country for the Pennsylvania railroad. Sheets of paper representing Smith's 10-foot contours were scissored by myself and my wife in the evenings, and the result was a very beautiful model, the photograph of which was made into a relief plate and published in 1877 in Report H2, page 92. But it was a tedious and laborious job.

Most of the models of the Second Survey have been made in this manner, chiefly by Mr. E. B. Harden, topographical assistant of the survey. The process requires nothing but accurate, patient labor.

Another method is to construct cross sections at various intervals across the area to be modeled, and as nearly as possible at right angles to the

The model is limited on the south by the Maryland and W. Virginia state line, from Adams county to Fayette county ; on the southeast by the range of the South mountains, the Reading and Durham hills, and the Highlands of New Jersey and New York : its lower left hand corner is

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strike; draw them on slips of paper, wood, lead, zinc, or block tin; leave the bases of the strips straight cut the upper section surface lines ; arrange the strips on a solid basis at their true geographical distances from one another; fill in the intervals with plaster or wax; and tool the whole model to the upper section lines. This, however, requires the eye and hand of an artist; but it has the advantage of a more delicate and truthful treatment of the intervals between the section slips, governed and guided by the topographical features of the survey map of the region modeled. The geological artist is not encumbered with the solid plates of the first method, and can work freely in correcting and bringing out to clear view the characteristic features of the topography, provided he has studied them himself and appreciates their character. This method can safely be adopted only by the geologist who has done the field work himself, and it cannot be safely delegated to office hands.

I used a modification of this process for a model of Morrison's Cove, in 1853, for the Pennsylvania Railroad Company, to show the iron ore horizons. I took prisms of soft wood 18″ long, 3″ wide and 2″ thick, and drew on their contiguous sides duplicate geological sections; then tooled down the surface of each block. When laid side by side in a series, the surface of the country was exhibited topographically. By separating the blocks the geological structure on the cross lines between block and block could be consulted. The surface of the whole series was painted to show the outcrop belts.

In constructing other local geological models I have found this method much more satisfactory than the method of jigging and building up.

But in making my model of the corrugations of middle Pennsylvania I was compelled to use the method first described, on account of its rapidity of execution, since I accomplished in six weeks what would probably have cost me as many months of labor by the method of cross sections. A description of the details will be useful to geologists who are not familiar with such work.

I first laid the colored geological Hand Atlas county maps together to cover the field. I divided the field into four parts by equal N. W. interval lines to make four models which could afterwards be cast in one. Then I drew on tracing paper the outcrop limits of the formations above and below the Medina. The known thickness of the overlying formations gave the depth of the top of Medina in reference to sea level. Sea level was the normal datum of the model. The *deepest* sea level of the top of the Medina was adopted as the plane base of the model. The contour lines of the top of the Medina were determined by measuring down from the contour limit lines of all the upper formations. Account had to be taken of the known thinning of all the formations northwards and westwards. The columnar sections governed the whole process. When the dips were steeper a reduction for angle had to be made. When the dips were gentle, no such reduction was necessary, as the error would be trivial. In the end I obtained an unin Butler county. The area exhibited is about 230 miles long by 130 broad. The scale adopted was that of the small county maps in the Hand Atlas, Report X, 6 miles to the inch. The photograph plates reduce the scale to about 33 miles to the inch.

It was essential to my design of a true representation of the amount of plication that the vertical scale of relief should be the same as the horizontal geographical scale, a principle which has been kept in view in the construction of all cross sections published in the Reports of the Survey from the beginning. No matter how gentle the gradients they must conform to nature. The human eye is a perfectly competent instrument and may be safely trusted to notice and estimate accidents of relief of the minutest size and most delicate variation from the horizontal. Nothing should be left to the imagination. Science gains nothing and loses much by any exaggeration under any circumstances. There is no such thing as meeting nature halfway. Absolute truth in relationships is as necessary for knowledge as correct understanding of individual things.

For plate LVII the model was photographed upside down, with a slant light from the left (S. E.) to bring out the master feature of the structure, the Nittany Valley or Bald Eagle Mountain Anticlinal, which occupies in crescent shape the center of the area. As its western slope is very steep, in parts vertical, the shadow cast is heavy. The prevalence of steeper western than eastern slopes in the case of most of the other anticlinals is marked on this plate; especially in the case of the three great anticlinals which lap each other and make the southern border of the First Anthracite coal field from Mauch Chunk, Tamaqua and Pottsville to the end of the Dauphin county basin, and so onwards through Perry and Cumberland county into Franklin. The échelon arrangement of this combined over-

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derground contour line map of the top of the Medina approximately correct. It was only necessary afterwards to take the curves of dip in the air to restore the aticlinals destroyed by erosion, and the model was complete. The scale being 6 miles to the inch horizontal and vertical alike, an inch of height represents 31,680 feet.

thrown anticlinal is very remarkable and could be well exhibited only by a model seen under a S. E. slant light.

For Plate LVIII the model was photographed erect under a slant light from the left (N. W.) to bring out other features; especially the Anthracite synclinals and their continuation southwestward into Maryland. The reader will notice that from Carbondale (an inch below the center of the top line of the plate) there is a continuous synclinal trough, much crumpled in the center of the plate (Seven Mountains), with a local deep hole (Broad Top), shallowing into Maryland. It will be noticed that the Nescopec anticlinal of Luzerne county, which separates the Middle and Northern Anthracite basins, keeps on as the anticlinal of Kishicoquillis valley and Jack's mountain, dying down in Bedford county.

The crescent shape of the corrugations of the region is visibly explained by Plate LVII, which brings into relief the great Nittany anticlinal. By taking its crescent as an arc of a great circle, and drawing a radius from its middle and highest point (in Centre county), southeastward towards the head of Chesapeake bay, it will be made evident that along that radius was exerted the maximum force of the horizontal thrust which displaced the formations and piled them together in folds. By laying a string upon the model along this radial line, I found that the forward thrust of the earth crust (so far as the Medina can indicate it) was at least 40 miles. It is worth noting also that the Bald Eagle Mountain and Black Log Mountain faults are southwest of said radius, and have their right hand (N. E.) side walls thrust forward.

Conformity of IV upon III.

I have expressed my opinion on this interesting geological topic in the third report on Lehigh and Northampton Counties, D3, Vol. 1, 1883, pp. 32 to 35.

A non-conformity of the Oneida conglomerate, No. IVa, upon the top of the Hudson river slates, No. III, has frequently been asserted. In Pennsylvania they appear to be quite conformable; no erosion of the uppermost slates of

III previous to the deposit of the conglomerates and sandstones of IV having been noticed.

At the Rondout quarries in New York the Helderberg limestones seem to lie upon the *upturned edges* of the Hudson river slate. At Catskill village they appear to lie directly but *conformably* upon the slate.

Mr. Davis in his recent beautiful memoir (quoted in G^6) states in his text and shows in his sections an apparently *perfect conformability of the Lower Helderberg limestones* (*No. VI*) *upon Hudson river sandstones and slates* (*No. III*) in the vale of the Catskill, a mile or two back from the Hudson river; with an apparent absence of the *Clinton* (*V*) and *Medina and Oneida* (*IV*) which usually intervene.

Although the district of country in which these phenomena present themselves is small, yet, out of these local phenomena an hypothesis has been framed and made to apply to a thousand miles of the continent, viz: that the Hudson river age closed not merely with a disturbance of the relations of land to sea, resulting in the shifting of coasts and the deposit of gravels and sands (which might be easily admitted), but with huge elevations and upturnings of the sea-bed, extensive erosion, and the deposit of horizontal upon vertical strata.*

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*S. A. Miller in his N. A. Geol. and Pal. 1889, p. 48, says: "It always rests unconformably upon the Hudson river group, and bears the internal evidence of having been derived from land immediately north and east, and of having been deposited in shallow water, subject to waves and currents which transported only short distances. The conglomerate indicates a shore-line and rapid deposition, and is *almost non-fossiliferous*, although a few fragments of fucoids and shells, generally too imperfect for definition, have been found in it. The sandstone too bears the evidence of having been deposited near the land in shallow water, not only in wave-lines, rill-marks about shells, and ripple-marked slabs, but in mud-cracks produced by sun-drying. In all these respects it compares with the Potsdam, which separates the Taconic from the Lower Silurian."

Certainly a sand deposit that extended from May Hill in England to Lake Huron and Tennessee in America, must exhibit the character of a shore deposit in some places, but could not possibly have done so everywhere. Certainly in its many hundreds of miles of outcrop in Pennsylvania it shows nothing of that character. The fine grain of almost all of the sandstone layers of its upper and lower divisions and the loamy nature of its whole middle division, is satisfactorily good evidence that the great Medina sea was not shallow, but deep; and the pebbles of its conglomerate beds are so small

To this I object: 1. the almost universal conformability of the *Oneida* upon *Hudson river* formation; 2. the absence of *pre-oneida* plications; 3. the impossibility of obtaining the principal materials of the *Oneida* conglomerate, out of any known *Hudson river* strata; 4. the fact that *Oneida* deposits still remain far south of the *Hudson river* belts (as at Greenwood lake in New Jersey); 5. and above all, the fact that at the Schuylkill Water Gap, where the *Oneida* rests at right angles on the apparently eroded edges of *Hudson river* slate, there is in reality a snapped anticlinal and downthrow of the slates, and no unconformability.

Mr. Davis shows the *Lower Helderberg conformably overlying the Hudson river "sandstones," in a synclinal.*

At first glance this would seem to settle the question of land elevation and subsequent subsidence; and he therefore speaks of *a long interval of time* (Oneida, Medina and Clinton ages) during which no deposits took place.

But a little consideration will serve to show the uncertainty of this kind of evidence. For, during all these ages it no doubt rained as often as it rains now; and if so, all land surfaces must have suffered erosion; and yet the Hudson river slates in his Catskill section *are not eroded;* they could not therefore have been rained on *i. e.*, they could not have been above water.

The alternative is to imagine *a stoppage of deposit without elevation of sea bottom.* This is not impossible, but very improbable. For, the Oneida was heavily deposited a few

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that they could be carried out some hundreds of miles from shore, as Delesse has shown the pebbles of the Loire are now slowly worked along outward over the sloping bed of the Bay of Biscay into the deep Atlantic.

The assertion that it "'*always* rests unconformably on the Hudson river group is unwarranted; because not the thousandth part of the formation is visible at the surface; and because, as I state in the text, an examination of many hundreds of miles of outcrop contact of III and IV at the present surface has shown not non-conformability but conformability. The Water Gaps of middle Pennsylvania furnish abundant evidence of the fact.

A very good evidence of deep sea deposition is the almost total *absence of oblique-bedding* in IV, showing that its sands and muds were not subject to the tidal currents of shore deposits and shallow water. In this respect it is in marked contrast with the Pocono formation No. X, which contains the Tipton Run coal beds and was a shallow water deposit, as will appear in a future chapter.

miles west of Newburg, and from there on for hundreds of miles westward and southwestward.

An easier hypothesis would be to consider the "Hudson river sandstones" which lie beneath the limestones, to be a finer part of the same deposit as the Oneida and Medina conglomerates and sandstones elsewhere.

But there is another alternative, in view of the close proximity of vertical and overturned strata between the quarry and the banks of the Hudson. The crumpling which Mr. Davis so eloquently describes and so artistically portrays has been produced by the sliding down upon itself and mashing together of the still moist formations on the western slope of the Hudson river uplift. Precisely similar crumplings characterize the same limestones all along the north foot of the *Medina-Oneida* mountain range through New York, New Jersey and Pennsylvania. And it is in front of these crumplings at the Schuylkill water gap that the great fault occurs which plunges the edges of the slates underneath the bottom of the conglomerate.

It should be kept in mind that our massive formations (XII, X, IV) act independently of the softer formations between them, preserving their own larger plications intact and for themselves, and compelling subjacent and superjacent formations of inferior tenacity and greater ductility to conform to limited spaces *by crumpling and sliding*. It is quite possible that the faulted edges of the missing rocks may lie deeply buried. At all events, such is not so violent an hypothesis as that the Hudson river slates remained two or three geological ages out of water without suffering the least erosion.

Non-conformity of IV upon III has been argued from the presence of pieces of shale in IV. But there are also distinct bands of intercalated slate between the sandstones. Even supposing fragments of foreign slate, they could not come from neighboring Hudson river outcrops. For, if the Oneida was deposited over the whole region of Northern New Jersey as far south as Greenwood lake, how could any shore produced by an upheaval at the close of the Hudson River age be near enough to furnish such materials as those of which the Oneida is composed; and how could "pieces of Hudson river slate" get into the Oneida?

But the most complete evidence that there was no change in the relations of land to water at the top of the slate formation No. III, and before the deposit of the great sand-rocks of No. IV, comes from the shape of the Kittatinny mountain along its whole line from the Delaware water gap, past the Lehigh water gap, to the Berks county corner, and far beyond. Any erosion of the slate formation previous to the deposit of the Oneida sandstone beds would have made the outcrop of the Oneida beds very irregular. It is on the contrary remarkably regular; and the synclinal sandstone crest in Offset mountain, just east of the Wind Gap, lies quietly in a synclinal of slate; all the rocks dipping in conformity. Any slight difference in angle recorded in the Water Gaps between the sandstone beds above and the slate beds on which they rest must be due either to imperfect instrumentation; or to the concealment of the actual plane of contact; or to the inevitable slip of the upper rigid mass on the lower flexible mass in the process of uplifting the whole 30° or 40° from the horizontal. When this uplifting reached 90° at the Schuylkill water gap, a great fracture took place, and the whole sandstone mass shot upright into the air, grinding the edges of the slate mass, which remained nearly horizontal, to a smooth plane.*

Along the whole range of mountain in Northampton and Lehigh counties, the upper limit of the slates rises to the top of the long slope, to within about 200 feet of the actual crest of the mountain, where the cliffs of Oneida commence.

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* At the Lehigh Water Gap, on the east bank of the river, near the railroad bridge over the wagon road, massive conglomerate strata at the base of IV, ascend at an angle of 30° to the crest of the mountain. This conglomerate consists of white and black pebbles an inch in diameter. Fine grained sandstone beds overlie and underlie the conglomerate. Fifty feet lower than the conglomerate the rocks are concealed for 50 feet, and then underlying sandy slates appear gradually, passing downward into the top slates of III, which soon after turn over an anticlinal and dip south. It looks as if the concealed interval is the plane of a fault, and the north dipping slates a downward brush. But there is no proof of non-conformability, and it is quite possible that the anticlinal arch is unbroken, just as in the case of the anticlinal behind the Hole mountain at the Swatara Water Gap.

Downwards the mountain slope dies away in the slate plain, chiseled by a thousand brooks which collect the rain water and continue the operation of lowering gradually the general level of the slate belt.

Chapter LIII.

The mineral worthlessness of the North Mountain along the Great Valley and of all the other mountains of IV in Middle Pennsylvania.

This is a fixed fact. There is not a valuable mineral of any kind in the Oneida or Medina formations.

In the mountains of IV there is nothing but worthless slate and common coarse and fine sandstones, the outcrops of which make the crest and back slope of the mountains, and the great ribs of rock in the gaps where the rivers break through. Some of the layers yield excellent building stone; but building stone is a drug in the market in Pennsylvania. Almost every citizen of the state can build a stone house or barn by digging a hole on his own farm; so that what is valuable to himself is of no value to his neighbors, much less to commence. The limestone of the valley is a better building material than the sandstone of the mountain, and more easily obtained; therefore the sandstone rocks may be said to be worthless. Occasionally a piece is wanted for the hearth of an iron furnace.

There is no gold,† no silver,‡ no copper, no lead, no tin

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† The latest deception respecting a gold mine in No. IV occurred two years ago in the neighborhood of Jack's Narrows in Huntingdon county, where a company was formed to mine gold in Jack's Mountain west of the Juniata river at Mapleton. What gave rise to it I do not know, but it is probable that a trace of gold was found in some pebbles in the conglomerate, such as is described in the geology of the Schwangunk Mountain in New Jersey. All quartz seems to have a trace of gold in it. But *gold-bearing quartz veins* have no existence in the mountains of No. IV.

‡ Nothing can be more ridiculous than the report of silver veins in any mountain of IV. As gold goes with quartz silver goes with limestone. If there were faults filled with lead ore in the Medina Mountains more or less silver, if only a trace, would be found in the lead ore. But no lead ore vein is known in Pennsylvania in any of its mountains of IV. The lead ore is confined to the limestone valleys.

The remarkable cross fault lead veins of the Schwangunk Mountain of IV east of the Delaware have already been noticed. None such have been in these mountains. All the old Indian stories about lead ore, and all the lying assurances of wandering miners that they have discovered gold and silver ores in the mountain amount to nothing at all.

As for iron ore the only show of it is in the slates just under the sandstone near the summit. These top slates contain enough iron to coat the stones, and to make little iron ore bogs lower down the slope where the springs of water issue. The iron-coated sandstones are of course worthless. The bog ore is good enough, what little there is of it, and mixes nicely with other ores; but the farm clearings where these bogs lie can hardly be said to be a dollar more valuable for them. There is no *iron ore bed* which could be found by searching for it. The iron is distributed through the slate and cannot be mined.*

On the *backside* of the mountains of IV run outcrops of the valuable iron ore beds of the Clinton formation No. V,

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noticed in that mountain from Port Jervis westward in New Jersey, nor in any mountain of IV in Pennsylvania. When I was surveying the Stroudsburg country in 1839, I learned that a geological tramp from Germany had been deluding the people into preposterous mining operations in the Pocono Mountain. There were traditions of sixteen different Indian silver ore veins in the Kittatinny Mountain east and west of the Wind Gap. This impostor told the people that he had found one of these veins, had traced it across the Aquanchicola Creek valley, across Godfrey's ridge, across Broadhead's creek near Stroudsburg, across the Devonian hills to the foot of the Pocono Mountain escarpment and up the escarpment to a place where it could be successfully mined. He collected one or two thousand dollars in small sums from the farmers and village storekeepers, and kept himself and one or two hands at work for eighteen months making a large hole in the face of the mountain, and then disappeared leaving the hole behind him. Such is a history of fraud many times repeated in the last fifty years.

*One remarkable exception to this statement must be noticed. There is a gash fault across Black Log Mountain west of Orbisonia in Huntingdon county, which was filled with limonite iron ore long before the mountain and valley surface of that country was established at the present level. Nothing of that sort escapes the keen eye of the hunters and farmers of any region. The search for iron ore keeps men and boys on the *qui vive*; and this curious and exceptional deposit was exploited by furnace men and exhausted. No other such instance is known in our state, and probably no other exists. It is strictly analogous to the lead veins of the Schawngunk Mountain east of Port Jervis; for the Black Log Mountain is shivered by cross faults in the same manner; as exhibited in the Rock Hill Gap and in the gangways of the fossil ore mine southwest of Orbisonia.

block ore and *fossil ore.* These beds have been foun dand opened here and there along the North Mountain, but without financial success. In 1839 I discovered the *block ore* just behind the mountain on the bank of the Little Schuylkill opposite Port Clinton. Since then the bed has been opened; but the attempt to mine it was abandoned; the ore was poor and the bed thin. And this appears to be the case along the whole line for a hundred miles. Back of Cowan's Gap in Fulton county it was tried. In the Little Cove southwest of Mercersburg it is of little value. But this has nothing to do with the Oneida and Medina.

If any religious mind asks why God made the mountains of IV without a single valuable mineral in it—a question which has been more than once put to me respecting other mountains mineralogically worthless—the answer is a plain one and should be satisfactory to any reasonable man. Mineral value is not the only kind of value. The true worth of mountain land is to cool the air and condense its moisture into rain, to feed the streams which supply the valleys, and to preserve the forests. For such benefits as these the inhabitants of the Great Valley should be ever thankful to the North Mountain—without looking so fine a gift horse in the mouth—or pining for gold or silver mines, which after all are not half so desirable as fertility and water power.

CHAPTER LIV.

Fossils of Oneida and Medina No. IV.

The whole formation is remarkably destitute of remains of animal and vegetable life. The abundance of molluscan and crustacean forms in the preceding Trenton and Hudson River ages seem to have given place to a barrenness of all living existence. Nothing but the stony casts of macerated seaweeds are to be found in the two or three thousand feet of rock strata of Oneida and Medina age in Pennsylvania. These are so abundant in some places as to cover extensive surfaces of the sandstone beds. Their forms are represented on plate CXI, page 716. They are most abundant in the upper division.* This species of seaweed is called *Arthrophycus harlani.* The surfaces of great slabs torn from the Tussey Mountain outcrops on the Juniata and floated by ice down the bed of the river, are completely covered with a network of its stony casts in high relief.

In New York State James Hall describes from the middle division of IV two small lamellibranch shells *Cypricardia orthonota*, and *Modiomorpha alata* (Conrad's *Unio primigenius*), and two small gasteropod shells, *Bellerophon trilobatus* (Conrad's *Planorbis trilobatus*) and *Euomphalus* (*Cyclostoma*, *Pleurotomaria*) *pervetustus*, the earliest known appearance of this kind of shell. Dana says that one of the most common Medina brachiopod shells is the

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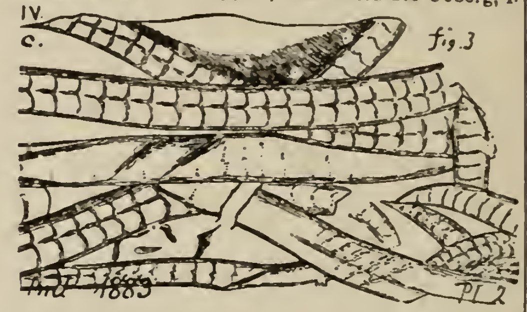
* Prof. W. B. Rogers, Geo. Va., 1884, p. 175, says that "near the upper limits of the group, as well as in the shaly bands beneath, organic impressions are often abundantly discovered. The thin slabs of buff and olive sandstone lying near the top are particularly rich in these remains, among which may be noted as abundant a small globose *terebratula*, and at least two well characterized species of *fucoides* [sea weeds]. Cylindrical markings, similar to those of No. I, are often exhibited in great numbers in the more compact and fine-grained white or pinkish white strata.

CXI.

No. IV, Oneida (a) & Medina (b, c) sandstones.

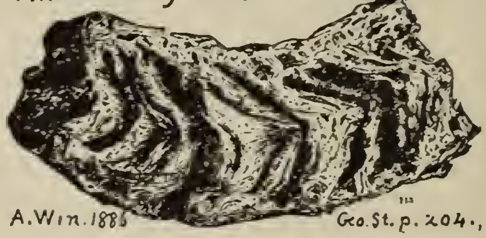
Collected from IVa, at Port Clinton; and from IV b, c, at Greenwood Fur.

Harlania halli. (Goeppert, Foss. Flora des Ueberg, 1.



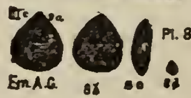
Clisiophyllum oneidense. (Billings Canad.

☞ VIII a. Corniferous limestone.

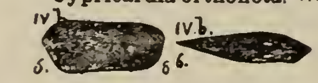


Lingula cuneata, Conrad. (IIc. Trenton in Pa. See Rt T4, p. 424.)

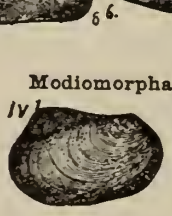
Lingula crassa Omitted from Trenton fossil plates, above.



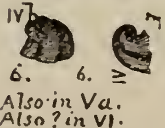
Cypricardia orthonota. Hall.



Modiomorpha alata. Hall. (Cypricardites alata, (Unio primigenius Conrad

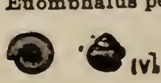


Bellerophon trilobatus (Planorbis trilobat. Conrad.



Also in Va.
Also ? in VI.
Also in VIII g.

Euomphalus pervetustus (Cyclostoma (Pleurotomaria.



wedge-shaped *Lingulella cuneata.*[*] He figures also two lamellibranch shells *Modiolopsis orthonota*, and *Modiolopsis primigenia*, and the two gasterpods *Pleurotomaria litorea*, and *Bucanella trilobata* (Conrad's *Planorbis* above mentioned). He adds that a considerable number of Medina species lived on into Clinton times. In fact the dearth of Medina life in Pennsylvania was due to peculiar circumstances, as the astonishing thickness of the sand deposits sufficiently attest. In other parts of the earth's waters there was an abundance of life. For example, the rocks of this age exposed on the island of Anticosti in the Gulf of St. Lawrence are crowded with fossil forms.[†]

The English May Hill sandstone formation, the representative of our American Oneida-Medina formation, was deposited in waters so full of life that 261 species (of 91 genera) have been found in it, 136 species being peculiar to it. Among them is the oldest known sea urchin, *Palæechinus phillipsi*, Forbes.[‡]

The oldest insect recorded up to 1887, *Palæoblattina douvillei*, was found on a slab of May Hill Sandstone at Turques in Calvados, France, by C. Brongniart. It is one wing of a cockroach, distinguished from all other known cockroach wings, fossil or recent, by the length of its anal vein, and the narrowness of the axillary area.[§]

The abundance of plants and animals of the sea, and the existence of land beetles being demonstrated, it follows as a matter of course that the land surfaces sustained a vegetation of their own. No remains of land plants have been found of the definite Medina age; but a superb fossil fern, *Eopteris morierei*, Saporta, has recently been discovered in

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[*] The figure on Plate CXI, from Hall's Pal. N. Y. Vol. IV, shows three of these little *lingulas* (*lingulellas*) stranded on a beach over which the waves dragged the fine sand into pointed ridges in the wake of the shells. Ripple marks and mud cracks prove that the beds were out of water and exposed to the sunshine, and that the sunshine was as genial then as it is now.

[†] Dana's Manual of Geology, 3d Ed., 1880, p. 223.

[‡] Figured by him in the early Memoirs of the Geol. Sur. G. Brit., Vol. II, plate XXIX, p. 674. Desor's Synopsis des Echinides fossiles, 1856, page 159. Geikie's Text Book, 1882, page 674.

[§] Woodward's paper in Geol. Mag., Feb., 1887, p. 49, quoting Comptes Rendus Acad. d. Sci. Paris, No. 29, Dec. 26, 1884.

the schists of Angiers. These schists are placed by French geologists at or near the base of the Middle Silurian, which, in America, may be assigned to either the upper part of No. III, or the Oneida, No. IVa. It is a pinna (leaf) with large leaflets and a perfectly distinct venation resembling a *Neuopteris* of the Coal Measures. Of this fern, our lamented palæobotanist Leo Lesquereux remarked that "it plainly proves that the land vegetation of that age, including already plants of so advanced types, must have been varied in character. Therefore, according to the law of evolution, it is evidence that a still more ancient *land flora* existed, probably contemporaneous with the first appearance of the vegetable *marine* flora."

Several years ago Lesquereux discovered land plants in the Lower Silurian rocks near Cincinnati, and descanted on their importance. His determinations were at first doubted, but have since been accepted by Saporta and other authorities. The confirmation of Lesquereux's views afforded by the French fern is all the more valuable inasmuch as this fern, which lived in an early Palæozoic age, resembles those which grew in the much later Carboniferous times; and the earth's surface was no doubt clad *locally* with ferns of that type during all the ages intervening; so that Upper Silurian, Devonian and Subcarboniferous Neuropterids may turn up in the future exploration of deposits favorably situated in regard to ancient shore lines, from which soil-laden rivers debouched. Such ferns are therefore no longer to be accounted characteristic of the Coal era; and what is true of ferns must be true of all other kinds of fossil forms. It is the general *facies* or aspect of its flora or fauna which characterizes an age, and not any one species. The identification of the same deposit in two geological regions, far removed from each other, by means of one or two "characteristic forms" must always be done at the risk of making some great mistake certain to be discovered in the further progress of the science.

It should always be kept in view that fossil plants were drifted seaward from the mouths of rivers draining certain kinds of land; delivering therefore certain kinds of mineral matter. The lithology of the rock must be quite as "characteristic" of that special age as its palæobotany. As land surfaces become worn away their river detritus changes character. The same river must make quite different deposits in successive ages. Moreover the drainage system changes; rivers run in other directions and in other volumes; so that the same central forest-covered land district may furnish very different successive deposits with the same kinds of plants. On the other hand changes of vegetation are often rapid; the Delaware and Susquehanna rivers are floating deciduous leaves and twigs *now* into the Atlantic, whither only a century ago they floated coniferous foliage and fruit.

The same is true of animal fossil forms. The stability, the number, size and association of types has always depended upon the lithological output of the land-drainage. This has always been changing in its direction, intensity, extent, and mineral constitution—the changes being brought about slowly or swiftly, and often alternately, not merely by movements of various kinds, but by secular erosion, uncovering deep rocks to the surface, and removing upper rocks from it. Therefore, it is impossible to believe in "characteristic forms," in the dogmatic way in which they have been adopted and applied to stratigraphy.

At the same time all the considerations mentioned above, while throwing doubt on "single characteristic forms,' tend to increase our faith in "characteristic groups," and in their close generic relationship to characteristic lithology.

END OF VOL. I.