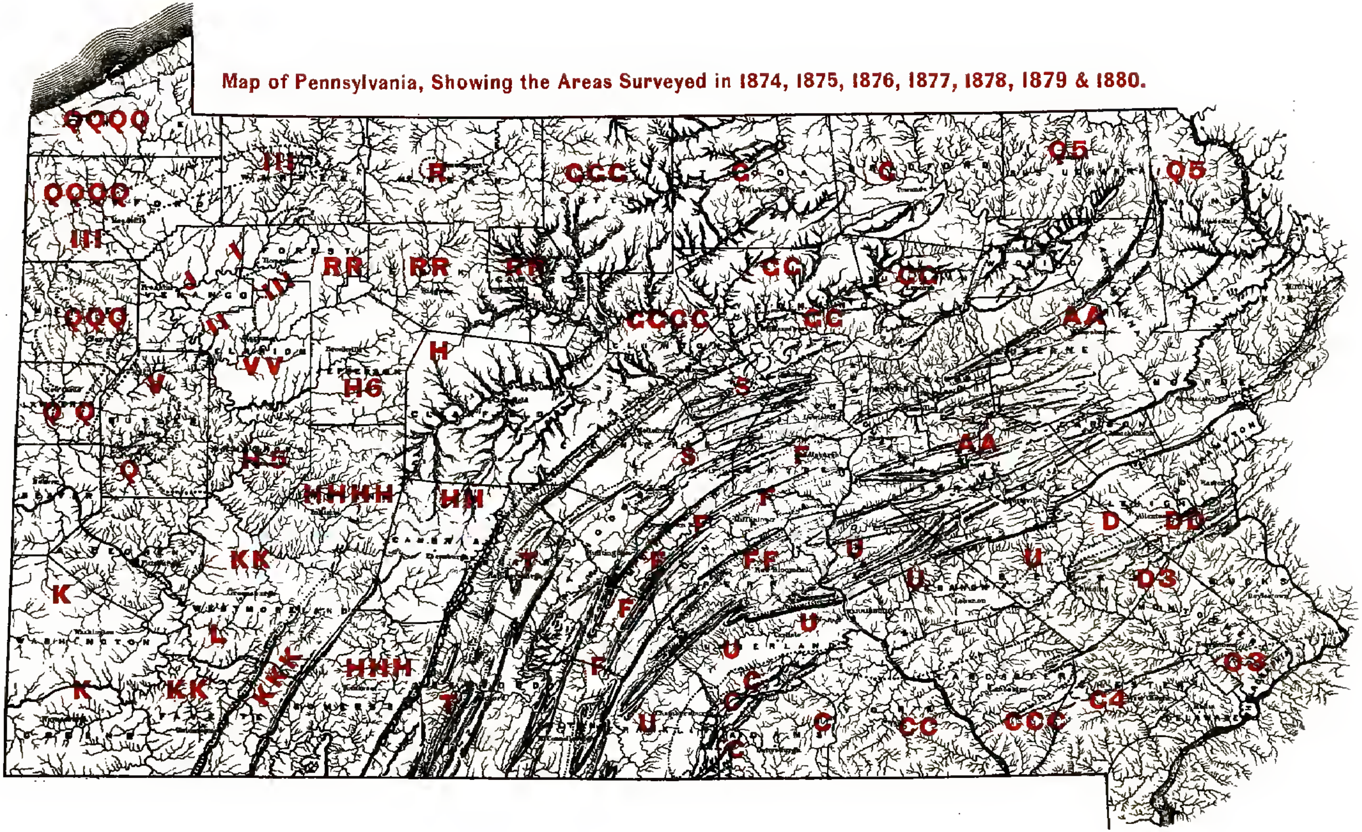
Map of Pennsylvania, Showing the Areas Surveyed in 1874, 1875, 1876, 1877, 1878, 1879 & 1880.



SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA:
C^4.

THE GEOLOGY OF

CHESTER COUNTY,

AFTER

THE SURVEYS OF

HENRY D. ROGERS, PERSIFOR FRAZER, AND CHARLES E. HALL.

Edited by J. P. LESLEY.

WITH A COLORED GEOLOGICAL MAP OF THE COUNTY;
THREE LITHOGRAPHIC PLATES;
AND
MAPS AND SECTIONS IN THE TEXT.

HARRISBURG:
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LETTER OF TRANSMITTAL.

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

SIR: In transmitting this long delayed Report on the Geology of Chester county it is my duty to explain in a few words its character and purport.

The general description of the district in the first chapter, and of its geology in the second chapter, I have written as introductory to Dr. Frazer's detailed report on the several townships in chapter third.

Besides the usual Geographical and Personal Index, I have prepared a *Geological Index*, by which the isolated observations scattered everywhere through the book are brought together and classified under their more important headings.

The thoroughness with which Dr. Frazer has studied the structural geology of Chester county and the judicious manner in which he has reasoned upon its exhibitions, without dogmatizing on its obscurities, can be fully appreciated only by those who will take the trouble to *locate upon the township maps*,* the numerous *dips and strikes* which he has recorded. Only when this is done can an idea of the complicated geological structure of Chester county be obtained. But when this is done, geologists will find that he has given them a sound basis on which to carry forward special local investigations; and the providing of such a basis of investigation is the principal function of a State survey.

The Map.—A colored geological map of Chester county accompanies this report. It was prepared originally by Dr. Frazer to show his views of the limits of the Mesozoic

* The *county* map being on altogether too small a scale for the purpose. I would advise that this *plotting of strikes and dips* commence with those of West and East Marlborough townships.

and Azoic areas; of the extent of the Potsdam sandstone (with the underlying slates) north of the Chester valley; of the probable amount of surface south of the Chester valley now occupied by Potsdam sandstone; and of the probable connection of the limestone and serpentine exposures.

Dr. Frazer thought it inexpedient to offer a hypothetical distinction between the South Valley hill and Octoraro creek region of talc-mica and hydro-mica-schists, and the rest of southern Chester county occupied by mica-schists, schistose gneiss and syenitic rocks, on account of the uncertainties attending the tracing of the limiting lines, and the uncertainties respecting the relations which the rocks bore to each other. Following the example of his Lancaster county map he gave one general color to all these rocks, leaving the distinction to be made hereafter as the local geology of the southern townships became better and better known.

Considering the geological relationship of Delaware and Philadelphia counties with southern Chester, it appeared to me absolutely necessary to separate the gneissic region from the talc-mica slate region by means of their two established colors, pink and grey. This I have done on my own responsibility, and in the rudest manner possible, by a curved line from West Grove to Chrome P. O. It must be understood by those who use this map that this curve of delimitation *has no geological value whatever*, but is merely a temporary expedient, pending future minute local determinations of the belts and patches into which this difficult part of the county map will hereafter be broken up.

The Gneiss areas. On page 33 it is said that two geologically colored maps would illustrate this report: one of Chester county by Dr. Frazer, and another of southern Chester county by Mr. Hall.

I have found it more convenient and equally useful for the end in view to embody on the page plate opposite a reduction of Mr Hall's map of Delaware county, together with a reduction of his map of southern Chester, so connected as to show the extent of the Azoic areas as he understands them.


A Sketch Map
of the
Syenite areas of Delaware & Chester Cos.
with the outcrops of limestone, serpentine & sandstone
as observed by C. E. Hall in his surveys of 1880-'2.
Talc mica slate belt of the South Valley Hill.
Downingtown valley limestone
Penn. railroad.
Potsdam sandstone
Micaceous Gneiss region
Syenite hornblende gneiss &c
Micaceous gneiss region
Delaware River valley gravels & clays
Brandywine Creek
West Chester
Media
Chester

Prof. Rogers' method of defining the shape and extent of the Azoic areas, as he understood them, is exhibited on another page plate, (page 41.)

It is impossible to imagine a greater contrast than between these two illustrations of opposite views. The great regularity of Mr. Rogers' belts, the utter irregularity of Mr. Hall's areas, strikingly exemplify the difference between the conclusions arrived at, in a difficult region like this, by the earlier geologist who made everything bend to his theory of parallel overturned anticlinals and synclinals, and the observations of the later geologist who is fettered by no such theory, but is perhaps quite as strongly influenced by a different sentiment, viz: that the Azoic formations spread out over one another with moderate inclinations unconformably.

Of the *contorted* gneiss so often spoken of by Mr. Hall in his report (the *convoluted* gneiss so called by Dr. Frazer in various places of this report,) a fine artotype picture will be found at the end of this report.

The Potsdam areas. Dr. Frazer divides the Potsdam sandstone formation into an upper and a lower. See his field notes on East Marlborough, p. 307.

The upper, or *Kennett rock* division, he identifies with Mr. Hall's *Edge hill* rock, the *Eurite* of the early Philadelphia geologists, called also *Itacolumite* rock.

The lower, or *Toughkenamon* division, well exposed at Toughkenamon station in southern Chester, he identifies with the pseudo-gneiss and porphyry rocks of northern Chester.

Mr. Hall has recently recognized his *Edgehill* rock in some of the exposures of Dr. Frazer's Mountain Creek series (Potsdam) of the South mountains in Franklin and Cumberland counties. The lower porphyritic division of the Potsdam in Chester county ought therefore to represent the Huronian petro-silex series in the South mountains in western Adams and north-western York counties.

Prof. Rogers sub-divided his Primal formation into upper slates, middle white sandstone, and lower slates, as the

CONTORTED GNEISS OF WISSAHICKON CREEK, NEAR THE PHILADELPHIA & READING RR. BRIDGE.

reader will see in this report; the middle white sandstone being the *Potsdam sandstone* of American geology.

His Primal upper slates are those which underlie the Siluro-cambrian magnesian limestone (No. II) of the great valleys of Pennsylvania; but they may be looked upon as forming the basal division of No. II, being magnesian, and changed to serpentine at Chestnut hill north of Easton.

His Primal lower slates, also magnesian, are the talc-mica schists of the South Valley hill, and of the south-western townships of Chester county.

Beneath the Primal slate lies a micaceous gneiss and coarse mica-schist formation, which occupies much of southern Chester and Delaware counties, reaching the Schuylkill a few miles above Philadelphia.

Beneath the micaceous gneiss formation lie the horneblendic gneiss rocks, the lowest rocks visible along the Schuylkill.

It would be a convenience if we could call the Micaceous gneiss formation *Huronian*, and the Hornblendic gneiss formation *Laurentian*. But such simplicity of classification is not to be thought of in our present state of knowledge; and in fact the chief value of this report on Chester county depends on its showing how confused and sometimes irreconcilable are the natural exhibitions of these formations, by which it may be plainly seen how much is yet to be done before the *systematic geology* of the fundamental rocks of the Atlantic border can be formulated.

The genuineness of the Potsdam sandstone outliers in southern Chester seems to be proven by Dr. Frazer's discovery of numerous casts of the *Scolithus linearis* in its outcrops in London Grove township; see page 333.

Whatever may be thought of the structure of southern Chester county, all the indications point towards a probability that the lowest or *primal* members of the palæozoic system of formations (Siluro-cambrian, Nos. I and II,) once spread over the whole region, and have since been in great part eroded. But if the quartzite (Potsdam proper) of the North Valley hill varies so much as to be absent in the South Valley hill and yet be present in townships to the south, while conformably enclosed between upper and lower primal slates (the latter of great thickness), then we can no longer look upon this semi-metamorphosed sand and gravel bed as the universal shore deposit of the early Palæozoic sea, unconformably resting on the schists and gneisses of preceding Huronian and Laurentian ages. In fact it renders doubtful the existence of such a sea, and rather suggests a number of more or less isolated water basins, which were not combined into an ocean until the opening of the Magnesian Limestone age.

Azoic rocks.—The confusion of our Azoic geology cannot be better indicated than by quoting from a recent memoir of Prof. C. H. Hitchcock* the following paragraphs:

"While the sequence of the Paleozoic column has been satisfactorily worked out in Virginia, little attention has been paid to the order of the crystalline series. First of all, it became clear that Logan's suggestion of the separation of the Eozoic into Laurentian and Huronian was applicable to the east. This was admitted by H. D. Rogers, in 1858, using the terms Hypozoic and Azoic, instead of the geographical terminology. We can now sub-divide these groups still further. The proposed institution of a Labrador or Norian system fails, because the rocks thus distinguished are of eruptive origin. In New Hampshire we find at least four well-marked sub-divisions of the older series; (1,) porphyritic gneiss, (2.) protogène or "Bethlehem" gneiss, (3,) ordinary or Lake Winnipiseogee gneiss, and (4,) the Montalban, [or White Mountain series.]

In the absence of detailed studies of the typical Laurentian areas it is impossible to know whether similar divisions can be recognized in them. From imperfect data we have concluded that the oldest, and possibly the first three, of the New England groups represent the Laurentian of New York and Canada. The Montalban is more evidently an indedendent system.

"The Green Mountain gneisses are related to the second

* On the crystalline rocks of Virginia compared with those of New England. Read at the Washington meeting of the Amer. Inst. Mining Engineers Feb., 1882.

and third of the New Hampshire series. They are repeated by folds in southern Vermont, and overlie the porphyritic gneisses along the western border of New Hampshire, in the Connecticut valley—the older system lying east of the newer one. The same order is perceived along the James River valley, in Virginia. At Balcony Falls and further east, the gneisses are like those of the Green Mountains. Where the Tobacco Row range has been cut through, the porphyritic gneisses show themselves, though not abundantly. Between these ridges an argillitic schist shows itself, which Prof. Campbell regards as a part of the Laurentian. As this kind of rock has not usually shown itself so early I would raise the question whether it will not be found to lie in a synclinal trough—possibly inverted—upon the gneisses, and to be of Huronian or Cambrian age.

"This porphyritic rock is not seen in the next section of the Blue Ridge, along the Norfolk and Western railroad, to the south-west of Lynchburg. Near the dividing ridge the Peaks of Otter show themselves conspicuously. These so closely resemble some of the New England eruptive granite cones as to suggest a like composition and origin. Quite near them on the railroad I observed a coarse syenite which may possibly be connected with their mass.

"The Huronian seems to occur in long narrow strips, enclosed by the gneisses, and possessing a complex synclinal structure. Where the strata are monoclinal they should be regarded as an overturn synclinal. Typical schists of this system, with the included minerals, are repeatedly described in Rogers's reports. At first it was thought that only the "talcose," or soft greenish hydro-mica-schist with the steatite and serpentine should be referred to this system. But later studies and comparisons make it necessary to add great developments of argillitic quartzites and mica-schist, as well as diabases and protogenes to the softer schists both in New England and Virginia. This step will relieve the otherwise excessive reference to the Cambrian of many unfossiliferous terranes. In New England the softer schists are rarely found east of the Connecticut-Merrimack watershed. A similar area is that which is crossed by the Virginia Midland railroad east of Manasses, and to the southwest of Charlottsville. The same or similar rocks are traversed along the Norfolk and Western railroad, between Lynchburg and Thaxton's station. It is also largely developed east of Lynchburg, along the Richmond and Allegheny railroad.

"Another rock, more suggestive of Huronian than any other Eozoic or Paleozoic affinities, occupies the south part of Montgomery county in the gold region of Brush creek, skirting Pilot mountain—the western fork of the Blue Ridge. The rocks are coarse protogenes, cut by large auriferous quartz veins. It is certainly three or four miles wide, with a less dip to the east than the Cambrian quartzite of Pilot mountain. My explorations did not extend far enough to the east to explore the gneissic rocks of the plateau, which are, probably, Montalban, and connected with the lofty Black mountains of western North Carolina.

"Between Pilot mountain and Christiansburg a great thickness of slates and sparry limestones is exposed, which correspond very closely to the Taconic system of Emmons, as developed in eastern New York and western Vermont. They were referred to formation No. I by W. B. Rogers.

"It would seem probable that the broad Huronian belt between Washington and Harper's Ferry, on the Potomac, which continues south-westerly past the James river, according to Professor Fontaine, will still be found to occupy the ground all the way to North Carolina. As the Blue Ridge divides near Roanoke, and the branches extend through North Carolina into Georgia, it will be interesting to know whether the Huronian accompanies the Cambrian slates and quartzites. Inasmuch as copper and gold follow these ranges, the solution of the problem will have important practical bearings, and will also show whether the Montalban is inferior to or superior to the Huronian. Large Laurentian areas may be looked for in the midland Virginia district."

The Huronian System.—On the other hand the geological work which is now so actively carried on by professional geologists in Virginia inspires confidence in the possibility of discovering in future years the true systematic order of the Azoic or fundamental rocks.

The following letter from Prof. Wm. M. Fontaine, of the University of Virginia, is dated January 20, 1883:—

"The Blue Ridge in the northern part of Virginia is, as I take it, much as it is in your South Mountains of York, &c. The Huronian strata hide very largely the Laurentian. On the Potomac the latter does not show at all.

"I find in some places in Virginia the same absence of Huronian over the Laurentian that you mention as occurring in Pennsylvania. I think this is due to several causes. Sometimes it is plainly due to the erosion of the Huronian.

"The Laurentian rises and expands as we go south in Virginia, and often has over it a mere remnant of the Huronian. Thus, in the southern part of Augusta county the Laurentian may be seen with the Potsdam either resting immediately on it, or with a small residue of the greenish *chloritic schists of the Huronian* interposed.

"Another cause of the absence of the Huronian, if we confine that term to the chloritic and epidotic schists, felsites, &c., is the fact that this group of strata does not always maintain the same features. It is apt to graduate into hydro-mica slate, mica-slate, and fine grained mica-schist, so that, traced horizontally, the latter class of rocks may be found superimposed upon the Laurentian. This is the case at the passage of the James river through the Blue Ridge.

"Still further southward, in the counties of Floyd and Carroll, I could find no typical Huronian, such as the chloritic rocks, the felsite, &c.

"A section of 40 miles in length, south-east from the Potsdam, shows a succession of fine grained mica-schists, mica-slates, flaggy hornblendic schists, &c., but no chloritic or epidotic rocks. In the southern extremity of the State, however (in Grayson county) the felsites, chloritic rocks, &c., occur in great force, and make up the mass of the lofty White Top mountain. Here, however, they are intimately associated with the mica-schists and flaggy hornblendic schists, &c., apparently forming one system.

"A section along the Chesapeake and Ohio, from west of the Blue Ridge to Charlottesville, would show the following facts, and this is a type of many in the west part of the State:

"West of the tunnel, the Potsdam is all in place, but forms an overturned (to the north-west) and closed synclinal, faulted against the Azoic of the Blue Ridge and hence dipping south-east apparently under the Azoic. The typical Huronian, viz: the chloritic and other schists, occur here in great force, and form the whole of the mountain, here a single range.

"Coming down the S. E. from the mountain, the strata graduate into hydro-mica slate, and mica slate, with bands of fine grained mica-schist.

"In the chloritic slates, here and elsewhere, there is a *peculiar gneiss* that deserves special notice, for it sometimes might be taken for Laurentian. When least developed, the slate contains nodular particles of feldspar and a waxy, often bluish, quartz. These particles, when the development is carried further, make up most of the rock and are then intermingled in such a manner as to give a grain much like that of some of the Laurentian. Still, a little slaty or serpentinous cementing matter may be detected, and this will always distinguish this gneiss from the true Laurentian rock.

"At the S. E. foot of the mountain a belt about one mile wide of Laurentian is exposed. Then for several miles the Huronian slates, schists, &c., come in again. These graduate into a great series of micaceous rocks that occupy a belt 12 to 15 miles wide, extending to Charlottesville.

"This system includes tender mica-schists, often very flaggy, and mica-schists with small nodular particles of quartz and feldspar, the quartz often bluish and waxy. This is Rogers' gneissoid sandstone, and it has a sandy character on weathering. Some bands of metamorphic diorite occur, and also slates and mica-schists, charged with graphite.

"Just S. E. of Charlottesville the south-west mountains rise. They are the prolongation of the Catoctin range and are formed of typical Huronian strata, epidotic, chloritic, &c. schists. The micaceous series first described modulates into these Huronian strata first by alternations of micaceous rocks and strata of Huronian type, and then by giving way wholly to the chloritic strata.

"On the S. E. side of the mountains the micaceous strata come in again. The dip all the way is S. E. This will show you how intimately the two groups are connected.

"I find in Virginia a valuable guide to the *true base of the Potsdam* in the conglomerates.

"The lowest conglomerate is not always seen. It is often very coarse, with pebbles sometimes 4–5 inches in diameter, and composed of Laurentian or Huronian material, according to the nature of the underlying rock. The matrix is often shaly or slaty.

"It is the conglomerates overlying this stratum that afford the best guide, for they may always be seen.

"They are simply pebble beds in the slate or shale. The pebbles are from the size of a musket bullet down, and usually of quartz, often pink in color. The pebbles look as if they had been scattered over a muddy bottom, forming a very peculiar conglomerate in which all the material except the pebbles is a fine slate or shale. Sometimes some partially decayed feldspathic matter occurs with the pebbles.

"These *shaly conglomerates*, as we may call them, might sometimes be *mistaken for certain amygdaloides of the Huronian* when the latter are weathered, but careful examination will always detect the difference. I have never seen any shaly conglomerate in the Huronian.

"I am now of the opinion that the conglomerates at the R. R. bridge at Harper's Ferry are these lower Potsdam strata, but would require a reëxamination of them before I make up my mind positively. I am also inclined to think that Frazer's Mountain Creek conglomerate is the same.

"Notwithstanding the intimate connection of the Huronian schists and slates with the micaceous system I am not prepared to deny the existence of a mica-schist member and I am still in doubt where to place it if it exists. It seems to be younger than the Huronian."

Gravels. The superficial covering of Chester county has been derived from the immediately underlying rocks; for this part of Pennsylvania lies far south of the region of undisturbed Northern Drift, the southern boundary of which is marked by the great Terminal Moraine extending from the Delaware Water Gap to Olean on the upper Allegheny river, as described by Prof. H. C. Lewis in Report Z.*

On pages 327, '8, 337, however, gravel deposits are mentioned which are not referable to the mother rocks of the locality. One or two such were observed by Dr. Frazer in Lancaster county. Others of considerable size are shown by Mr. Hall on his map of Delaware county (Report C^5) and others on his map of the Philadelphia belt published in Report C^6.

These gravels lie at different heights above tide level. The uppermost or Brynmawr gravel lies at about 400′ A. T. The lower gravels are connected with the brick clay deposits ranging along the right slope of the Delaware river valley.

The whole subject was assigned for special study three years ago to Prof. Lewis, who is preparing his report.

The gravels of the State of Delaware come under the same general head, but differ among themselves as do those in Pennsylvania. An elaborate description of the gravel hills near Newark, by Prof. F. D. Chester, may be found in the American Journal of Science for January, 1883. The gravel there described is the Brynmawr gravel, covering island hills of decomposed gneiss.

"The base of the two hills near Newark is not less than 80′ above tide; one of the hills is 228′ high, and a few of the largest bowlders rest at the summit; i. e., 308′ A. T. The distance back from the river is 10 to 12 miles."

Prof. Wm. M. Fontaine, of the University of Virginia, has thrown new light upon the origin of some of the gravel deposits of the Atlantic seaboard, by finding, on the James river below Richmond, certain beds *underlying the Eocene*

* Nearly ready to go to press.

Tertiary, and containing plants of probable Neocomian or Wealden age, which are made up of stones a foot or more in diameter. Stones lying loose upon the surface of the ground which seem to have come from these beds are sometimes 1½ or 2 feet in diameter. Together with these stones he observed upon the surface of the ground fragments of *Hamilton flags* holding characteristic fossils; but most of the stones seem to be of *Potsdam sandstone*. The *Sub-eocene* or *lowest Cretaceous mother strata*, from which all these surface fragments seem to have come are in some places so completely made up of these large fragments as to appear (in section) like a *cobble stone pavement of a street in Richmond*. Prof. Fontaine is "convinced that much of the gravel that has been deposited in more recent times, e. g. post-Tertiary in E. Virginia, comes from the ruins of these Cretaceous beds." (Letter dated Jan. 17, 1883.)

The specific descriptions of mines in this report seem to demand an apology on account of their age. I must therefore explain that the back history of mining operations is quite as important as their recent history, and the law of the Legislature authorizing the Second Geological survey expressly orders such back history to be inserted in the reports. In the case of the Chester county mines their history in most cases belongs to the past. A large number of them have been abandoned or are now only worked by robbing the pillars. Most of the lead and copper mines stand idle. But the most careful and detailed descriptions of these mines were made by Prof. H. D. Rogers, and are therefore embodied in this report.

To this explanation I must however add that Dr. Frazer's attention being almost exclusively devoted to the study of the *structural geology* of the county, he considered this report only as preliminary to a second detailed report to be prepared from a re-survey of the county in the following year, which however the severance of his connection with the Survey prevented.

Serpentine.—In the Report on Delaware county will be found the map and description of the outcrops between the

Schuylkill river and the eastern line of Chester county, furnished by Mr. Theo. D. Rand. Other data affecting Chester county have been reserved for the same report C^5, on account of their closer geographical connection with the Schuylkill river valley. My intention was to present the two reports together, that they might be included in one volume; but difficulties having arisen in the way of finishing the Delaware county report, it seems undesirable to delay the publication of that of Chester county, which is therefore presented first and alone.

This report is more largely argumentative—more of a scientific memoir—than any of the reports published by the Board, except those of Mr. Carll on the Oil Regions. It is sometimes necessary to mass into one report all the doubts and difficulties which a geological survey encounters—many of which it fails to overcome—along an entire belt of country, upon which several other reports are made.

It has been my duty to exhibit the obstacles which lie in the way of a true understanding of the *structural* geology of the Philadelphia-Baltimore belt; for, what future observers will need to know is not merely what preceding observers have succeeded in proving to be true; but what preceding observers have been led to suppose to be true; the facts as they saw them; the generalizations which they imagined would hold good; the theories which they adopted and used as helps in observation.

Little more can be said than that the First Geological Survey did something to reveal the structural geology of the Philadelphia-Baltimore belt; and that the Second Geological Survey has added its mite to the revelation; but that a great deal more light must be thrown upon it before we can congratulate ourselves upon a proper and satisfactory knowledge of it.

I speak only of the *structural* geology of Delaware and Chester counties. Be it well understood that we have an abundant knowledge of all the kinds of rocks in the region—hornblendic, micaceous and magnesian, the so-called granite beds, the serpentine beds, the crystalline limestones, the quartzite sandstone, the porphyritic schists, talc and mica-schists, steatite, corundum, chrome-iron—*merely as minerals*, massive or distributed. And there is quite as much information respecting their *localities* in Delaware and Chester county as there is respecting the localities of coal in any western county of the State. It would be quite as absurd to ask of the Geological Survey of Pennsylvania to do the work of opening up continuous out-crops of these minerals, as it would be to ask of the Survey to prove by actual diggings the continuous out-crops of the Pittsburgh, or the Upper Freeport, or the Sharon coal beds This is a task for private enterprise ; to be undertaken, executed and paid for from year to year by the business community, not by the State.

What the State provides, through the Geological Survey, is such general investigation of the field, such an examination of localites, as will result in a just and practical understanding of geological structure. When this is published for the benefit of all each citizen can make what use of it his mental intelligence, enterprising spirit and pecuniary means shall prompt and permit.

A general statement of the geological contents of Chester county will be found in this report, together with a detailed account of the *geological structure so far as that could be made out by the visible exposures in every township.*

Certainly all the exposures have not been noted by the reporting geologist. That would be impossible. They number by thousands. No book could contain them. But, as everybody knows, one exposure will stand good for many in a neighborhood where the rocks are regular; a dozen will suffice to track the line of an out-crop across a township; and if a sufficient number of these lines are placed upon a map the structure is bound to appear. But in a contorted and complicated district, like southern Chester for instance, this is a work of time—years in fact will scarcely suffice. One geologist cannot do it. It is a kind of knowledge which grows by the concurrence of many workers. Dr. Frazer's field notes in this report show how it is to be done. He has blocked out the work. The geologists and surveyors of Chester county must complete it;

and every farmer who digs a well can add an important contribution, if he will report the dip and strike of the rock from which he gets his water.

It must be understood that the *structural geology* to be made out relates to the whole county. It cannot be investigated at one locality more than at another. Not until every part of the county is known can the systematic geology of the region be considered fixed. In a single field-season of seven months, a geologist who is to report on a county of 56 townships has just *three days* (on an average) *to each township;* and in a State with 67 counties, all of equal importance to their inhabitants and to practical science, it is evident that a State Survey can only afford one full season to each county, unless its funds be greatly increased, or its duration be indefinitely protracted.

It is equally plain that the geologist who is forced to survey a county in one field-season cannot afford to let the grass grow under his feet; that he must devote his attention exclusively to the observation of out-crops and artificial exposures; that he can neither gratify his own curiosity nor that of others; and that he must in the main do his work undisturbed and alone.

Were the State Survey a permanent establishment and endowed with ample funds much more could be done than merely publishing a *description* of the geology. The work of *exploration* could be taken up and carried forward from year to year in a systematic manner. Questions which a first year's survey raises could be studied along clearly indicated lines, by borings and shaftings, and so find in the end their solution. As it is, we must be content with laying a foundation of knowledge indicating the lines of research to be pursued.

J. P. LESLEY.

1008 CLINTON STREET, PHILADELPHIA,
February 6, 1883.

TABLE OF CONTENTS, C^4.

Chapter III.

List of Illustrations in C, 4.

REPORT OF PROGRESS, C[4].

1880.

REPORT OF A GEOLOGICAL SURVEY

OF

CHESTER COUNTY.

BY

PERSIFOR FRAZER.

CHAPTER I.*

General Description.

Chester county borders on the Maryland and Delaware State lines from Octoraro creek to the Brandywine river, a distance of about 30 miles, (28½ miles in a straight line.)†

Its western boundary, in common with Lancaster county, up the Octoraro, and so on northward to its north-west corner near Waynesburg, has an air-line length of 28 miles.

Its northern border is a nearly straight line (common to Lancaster for 4 miles, and to Berks for 11 miles) 15 miles long to the Schuylkill river two miles above Pottstown.‡

Its north-east border (common to Montgomery) descends the Schuylkill to Valley Forge and is then carried forward by right-angled offsets to the northern corner of Delaware county; the diagonal distance from corner to corner being 21 miles.

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* By J. P. Lesley, October, 1882.

† Mason & Dixon's line. N. lat. 39° 42′. See a full history of this survey in Futhey & Cope's Hist. Chester Co. Phila., 1881, pp. 156-161.

‡ N. Latitude 40° 15. Dr. W. D. Hartman.

Its south-east border (common to Delaware county) very irregular, but with a course generally south-west, measures from corner to corner 18 miles.

The width of Chester county measured along the Pennsylvania railroad is 30 miles; its extreme length north and south 36 miles.*

Its *area*, by the census of 1880, is 760 square miles, or 486,400 acres.†

Its *population* in 1850, was 66,438; in 1860, 74,578; in 1870, 77,805; in 1880, 83,481.

History.—Bucks, Chester and Philadelphia counties were the three original counties established at the first settlement of the Province of Pennsylvania in 1682. Lancaster was set off from Chester in 1729; York from Lancaster in 1749; Cumberland in 1750; Dauphin in 1785; Adams in 1800; Lebanon in 1813; and out of these first sections of old Chester the other counties lying further west were afterwards organized. Chester county is therefore the ancient mother of many noble daughters.

In 1638 the first Swedish colonists of Pennsylvania landed at the mouth of Brandywine and afterwards extended their settlements toward Philadelphia. What is now the city of Chester, they called Upland. In 1642 their seat of government was established on Tinicum island.

In 1655 they were subjected by the Dutch, New Sweden becoming New Netherlands; in 1664 by the English; and in 1672 again by the Dutch, who soon restored it to the English.

In 1681 William Penn received his grant from Charles II, and his deputy William Markham, arriving June, 1681, proclaimed the new government. Penn arrived with a hun-

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* Dr. Hartman places the extreme east and west limiting corners of the county at 55″ and 1° 40′ longitude east from Washington.

† 738 square miles and 423,285 acres, according to Dr. W. D. Hartman's "Report on Chester Co., Pa.," in the Trans. Penn. State Medical Society published separately in a pamphlet of 12 pages, with a geographical colored map, in 1857. The value of this map may be estimated from the fact that it represents the Schuylkill river as sometimes one mile and sometimes two miles wide.

dred emigrants Oct. 27,* 1682; addressed the settlers at New Castle, and proceeded up the river to examine the proposed plan of his commissioners for the site of Philadelphia. He divided his province into three counties, Philadelphia, Chester and Bucks; and divided the State of Delaware into three counties. The first Legislative Assembly, convened Dec. 4, 1862 at Chester, united the States of Pennsylvania and Delaware, naturalized Swedes and other aliens, and established a code of laws. The Provincial Council was organized in Philadelphia, March 10, 1683. The land purchases of 1682, 1736, 1749, 1758, 1768, and 1784 extinguishing the Indian titles to the land, marked the progress of settlement up the Delaware river and westward through Chester county.

Irish Protestants settled the northern and western townships, but were replaced previous to the Revolutionary war by Dutch and Germans. English Quakers settled the southern and middle and Welsh emigrants the eastern townships. The population of the several sections retain the distinctive traits of character of their ancestors to the present day, and are noted for their intelligence, industry and thrift.

The soil of Chester county varies from a stiff to a sandy loam, and is for the most part fertile and highly cultivated, The soil of the valley is a light sandy loam of orange hue, highly fertile.

Wynn's meadows, (in north-western Chester county,) several hundred acres in extent, is the only marsh ground in the county. But many places on the banks of the Schuylkill are low and flat and subject to inundations and to vernal autumnal fevers. The Octoraro, White and Red Clay, Big and Little Elk Creek valleys, bounded by high side hills, have meadow lands subject to occasional inundations, "but from their tillage and perfect drainage, with a few exceptions in the fall of 1855, no malarial diseases have been known to arise in their vicinity for many years."†

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* The Bi-centennial celebration of this event was held on October 24, 1882.

† Hartman's report, 1857.

Delaware and Montgomery Counties.

North Coventry,

Warwick, South Coventry, East Coventry.

West Nantmeal, East Nantmeal, West Vincent, E. Vincent.

Honeybrook, Wallace, Upper Uwchlan, W. Pikeland, E. Pikeland. Schuylkill.

W. Caln, W. Brandywine, E. Brandywine, Lower Uwchlan, Charlestown,

Sadsbury, Valley, Caln, East Caln, West Whiteland, East Whiteland, Tredyffrin.

W. Fallowfield, Highland, E. Fallowfield, W. Bradford, W. Goshen, E. Goshen Willistown, Easttown,

Upper Oxford, Londonderry, W. Marlborough, Newlin, E. Bradford,

Lower Oxford, Penn, Londongrove, E. Marlborough, Pocopson, Westtown, Thornbury.

W. Nottingham, E. Nottingham, New London,—New Garden, Kennett, Pennsbury, Birmingham,

Elk, Franklin, London Britain.

Lancaster County.

The census of 1850 exhibited 333,572 acres of improved land, divided into 4,835 farms, many of them dairy farms with excellent springs.

Fifty-six townships make up the county. Seven range along the Valley; 18 lie north of it; 30 south of it; as shown in the accompanying scheme, page 4.

Nine borough towns were incorporated at the respective dates following:

West Chester, court-house finished in	1786
Oxford, incorporated in	1833
Phœnixville, incorporated in	1849
Hopewell, incorporated in	1853
Kennet Square, incorporated in	1855
Downingtown, (*Milltown, 1784*,) incorporated in	1859
Coatesville, (*Midway*,) incorporated in	1867
Parkesburg, incorporated in	1872

The *roads* of the county are numerous, well laid and kept in good condition.

Four *turnpike roads* traverse it; all of them made by incorporated companies to facilitate the transport of the rich agricultural productions of Lancaster, Lebanon and Dauphin counties to the Philadelphia market.

The *Gap and Newport turnpike* crosses the southern part of the county from north-west to south-east, through Penningtonville and Cochranville.

The *Philadelphia and Lancaster turnpike* crosses the South Valley hill to Downingtown, follows the Valley to Coatesville, and then to the top of the North Valley hill westward.

The *Harrisburg pike* leaves the P. & L. pike at Downingtown and follows the high divide between the Brandywines north-westward to Waynesburg.

The *Conestoga pike* leaves the P. & L. pike west of Paoli, crosses the Valley and North Valley hill, and runs N. N. W. to Springfield, and so into Bucks and Lebanon counties.

Railroads also traverse the county in all directions: The *Pennsylvania RR.* from east to west through the center line;—the *Philadelphia and Baltimore Central RR.* from east to west through the southern townships;—the *Philadelphia and West Chester RR.*;—the *West Chester Branch RR.*;—the *Wilmington and Northern*, from north to south, through the middle of the county;—the *Brandywine and Waynesburg RR.* across the north-western townships;—the *Pennsylvania and Delaware RR.* north and south, through the south-western townships;—the *Pickering Valley RR.*, and the *Valley RR.* in the north-eastern townships. A railroad is in process of construction from West Chester to Phœnixville, and another to Norristown.

Levels along these lines will be given further on, in connection with the description of the different regions of the county.

Five regions of Chester county are distinctly marked:—

I. The southern region of Philadelphia gneiss.

II. The South Valley hill talc-mica or hydro-mica schists.

III. The Downingtown limestone valley.

IV. The northern region of gneiss and Potsdam sandstone.

V. The Schuylkill region of Mesozoic or Triassic (new red) sandstone and shale.

I. The Southern gneiss region.

This beautiful region of the State, over which towns, villages and hamlets are thickly strewn, is a rolling country of hill and dale, highly cultivated, well wooded, well watered, with good roads and public buildings and comfortable dwelling-houses, built of the country stone, and many of them ancient. The streams which descend towards the Delaware furnish water-power, and mills and factories are numerous.

Its general elevation above ocean level is about 400′ below which its streams have cut a thousand tortuous valleys and ravines to a depth of one or two hundred feet, bounded by steep and often rocky slopes, crossed by high railway bridges and embankments.

The Philadelphia and Baltimore Central railroad traverses it from east to west for about 25 miles.* Three other railroads cross it from north to south, viz:—

The *Pennsylvania and Delaware railroad* running from Pomeroy station on the Penn. RR. southward, down Buck run, across Doe run, and down Clay creek into the State of Delaware, near the corner of Maryland;—

The *Wilmington and Northern railroad*, which crosses the Penn. RR. at Coatesville in the Valley, and follows the west branch of Brandywine, south-eastward, into the State of Delaware;—

The *Philadelphia and West Chester railroad*, which branches from the Penn. RR. at Frazer station, and makes a curve through West Chester, and down Chester creek (west branch) into Delaware county and so to Philadelphia.†

Philadelphia and Baltimore Central RR.

	Miles from Phila.	A. T.
Chadd's ford, (Brandywine creek,)	16	129′
Fairville station,	19	255′
Rosedale station,	20	312′
Kennett Square station,	22	260′
Toughkenamon station,	25	283′
Avondale station, (P. & D. RR. crossing,)	26	227′
West Grove station,	29	444′
Penn station,	32	506′
Elkview station,	33	
Lincoln University station,	35	
Oxford, (junction of Peach Bottom RR.,)	38	
Columbia and Penn. D. Junc. Susq. river,	57	

West Chester and Philadelphia RR.

	Dist. from Phila. depot.	Ocean level.
West Chester,	27	406′
Hemphill,	—	318′
Street road,	25	252′

*A branch railroad leaves the line at Oxford, and keeps west through Lancaster county to Peach Bottom.

† This curve however is made by two rival railroads, the termini of which are in West Chester. They are now both owned by the Penn. RR. Co., but are operated separately, giving the people of West Chester a northern and a southern route to Philadelphia. In the table of levels the northern is called the "West Chester railroad" simply.

Cheney,	23	240′
Glen Mill,	22	199′
Darlington,	20	143′
Baltimore Central RR. junction,	19	133′
Lenni,	18	136′
Glen Riddle,	17	160′
Greenwood,	16	218′
Media,	14	210′
Manchester,	—	211.5
Wallingford,	13	168′
Swarthmore,	11	125′
Morton,	10	121.5
Springhill,	9	128′
Clifton,	7	109′
Kellyville,	6	102′
Darby road,	—	103′
Fernwood,	—	90′
Angora,	3	74.5
Woodland street,	—	57′
Philadelphia Depot, 31st and Chestnut street,	0	14′

Wilmington and Northern RR.

Coatesville, (X Penn. RR.,)	30.7*	315′†
Modena,	33.3	278′
Mortonville,	36.1	260′
Laurel,	—	241′
Embreeville,	38.3	231′
Glenhall,	41.4	218′
Northbrook,	—	209′
Seeds,	43.3	195′
Lenape,	45.2	183′
Pecopson,	46	180′
Chadd's Ford,	48	175′
Smith's bridge,	53	209′
Centre,	54.6	263′
Dupont's,	60	282′
Wilmington,	63	12′

Pennsylvania and Delaware RR.

Pomeroy, (junction with Penn. RR.,)	0	483′
Doe run,	6	374′
Pusey's summit,	10	470′
Pennock's summit,	—	463′
Avondale, (X Phil. and Balt. Cent. RR.,)	15	282′
Newark, in Delaware,	26	118′
Delaware City,	38	16′

* From the terminus at Birdsboro' junction.

† 62′ below the Penna. RR. track on the high bridge at Coatesville, (374′.)

The rivers and creeks of this district all flow south-eastward into Delaware bay, apparently without regard to the geological structure beneath the surface ; but it is remarkable that this south-eastward drainage stops at its western border; no streams enter it from the side of Lancaster county. On the contrary, the drainage beyond its western border is westward, into the Octoraro creek, and so southwestward into the head of Chesapeake bay. This fact will be referred to in describing the second region of the county, as it has some geological significance in defining the limit of this gneiss region and of the adjoining talc-mica slate region.

Darby creek heads near Paoli and flows through Easttown into Delaware county.

Crum creek heads west of Paoli and flows through Willistown in the same direction.

Ridley creek heads near Frazer station and flows through East Goshen and Willistown.

Chester creek, east branch, (with its affluent *Catharine* run) heads in West Whiteland and flows south through East Goshen and Westtown into Thornbury, where it joins the *west branch* which heads at West Chester and flows south-east into Delaware county. The Philadelphia and West Chester railroad follows its bed.

These four streams all head along the crest of the South Valley hill, on a straight line about ten miles long.

Brandywine river, *east branch*, after draining the northern region of the county southward across the valley at Downingtown, flows 20° E. past Copesville, Sagerville, and Chadd's Ford, 12 miles to the State line.

Valley creek, flowing west along the Valley to near Garland, turns south and joins the Brandywine a mile above Copesville.

Broad run, instead of flowing east into Chester creek, flows west into Valley creek near Harmony.

Taylor's run flows west into *Blackhorse run*, and this west into the Brandywine at Copesville.

Plum run heads in West Chester borough and flows south-west into the Brandywine at Sagersville.

Radley run does the same, half a mile further south.

Brandywine river, west branch, after cutting across the Valley at Coatesville, flows east south-east 10 miles and joins the East branch between Copesville and Sagersville.

Pocopson creek flows east into the Brandywine a mile below Sagersville.

Ring's run, does the same at Chadd's Ford.

Red clay creeks (east and west branch) drain the Unionville, Taggarts, London Grove, Kennett Square and Norway country (west of the Brandywine) southward into the State of Delaware.

White clay creek, east branch, has its numerous heads at and west of Upland, and flows south past Avondale.

White clay creek, middle branch, heads at Londonderry and flows south south-east, 8 miles, and then with the west branch 2 miles further to join the east branch at the Delaware State line.

White clay creek, west branch, heads at Kelton and flows south and then east.

Elk creek gathers its head waters around Russellville and the Lincoln University, into two main branches (both of which flow south across the P. & B. C. RR.) and then flows south-eastward into Maryland.

Little Elk creek heads at New Prospect and Oxford borough and flows east and south into Maryland.

North east creek heads at Nottingham P. O. and flows south-east and then south into Maryland.

NOTE.—On all the county maps, including those published in the "History of Chester county," 1881, a strange error has been made which a reference to the township map of West Nottingham would have prevented. *North east creek* is made to head in Maryland and flow north and north-westward along the township line into the Octoraro creek. The compilers of the county map have been careless enough to mistake the township line at Nottingham P. O. for a water course. This error has been culpably copied in one of the county maps published with this report; on the other it is corrected.

These are all the streams which properly belong to the gneiss region, although some of them have their upper waters in the talc-mica slate belt of the South Valley hill. *Broad run* flows wholly in the slates.

The descent of Darby, Crum, Ridley and (east branch) Chester creeks from the South Valley hill south-eastward towards tide water is part of the system of drainage of Delaware county, and may possibly be explained in one of two ways:—either, first, the South Valley hill slate belt was always and at all stages of erosion much higher ground than the more decomposible gneiss surface to the south of it; or, secondly, there is a fault along the edge of the Valley limestone, by which the whole district drained by these creeks has been lifted and tilted so as to slope southward. But the grounds for either hypothesis are very obscure, and are rendered more problematical by the line of serpentine and limestone outcrops which passes by West Chester, and which may be a line of fault, and certainly is one of nonconformability.

The branches of the Octoraro will be spoken of directly and the nature of their drainage shown.

West Chester, laid out as county seat in 1786, had a population of 3,173 in 1850; 5,630 in 1870; and of 7,046 in 1880. It stands on high land (about 450′ above ocean level) at the head of the west branch of Chester creek, in the midst of a fertile, wealthy and picturesque belt of country, farmed by a remarkably moral and enlightened population, speaking a traditionally pure English language, and with advanced ideas of civilization.

An Academy of Natural Sciences contains one of the best collections of plants in the State.

The magnesia of the soft decomposed gneissoid strata on which West Chester is built made the well water in the summer months unwholsome, generating diarrhœas, and driving the inhabitants to the use of rain water. Steam power now elevates to a reservoir the water of a large spring which is distributed through iron and lead pipes and is wholesome. (Dr. Hartman in 1857.)

The Legislature having authorized the removal of the seat of justice from Chester to West Chester by the act of March 20, 1780, difficulties arose which were adjusted by the act of September 26, 1789 dividing the county and setting off Delaware county, with Chester as its seat of justice.

The latitude of West Chester is given as 39° 57′ 31″ north; and its longitude as 1° 24′ 57″ east from Washington. The data for this determination, copied from Dr. Hartman's memoir, are presented on page 13.

The *towns and villages* which dot the map along this beautiful belt of country are very numerous. Commencing at the Delaware county line we have—

Leopard, *White Horse*, *Sugartown*, *Goshenville* (on Ridley creek), *Rocky Hill*, *Willistown*, *Milltown* (on E. Br. Chester creek), *Thornbury*, *Dilworthtown*, *Copesville* (on the East Brandywine), *Marshalton*; *Glenhall*, *Northbrook* and *Sagerville* (all three on the West Brandywine); *Locust-Grove*, *Parkerville*, *Red Lion*, *Marlboroughville*, *Unionville*, *Taggerts*, *London Grove*, *Upland* and *Woodville* (all east of the P. & D. RR., and north of the P. & B. Central RR.); *Kennet Square*, *Toughkenamon* and *Avondale* (on the P. & B. C. RR.); *Fairville*, *Norway*, *New Garden*, *Kaolin* and *Landenberg* (between the P. & B. C. RR. and the Delaware State line); *Chesterville*, *Strikerville*, *Kimbleville*, *New London* and *Elkdale* (all between the P. & B. C. RR, and Maryland, east of Elk creek); *Lewisville*, *Peacedale Hickoryhill*, *Chrome*, *Nottingham* and *New Prospect* (all between Elk creek and Maryland, west of Elk creek and south of the P. & B. C. RR.); *Fremont*, *Glenroy*, *Hopewell*, *Oxford*, *Hayesville*, *Lincoln University*, *Russellville*, *Jennerville* and *Londonderry*, (all west and north of the P. & B. C. RR. to the Lancaster county line.)

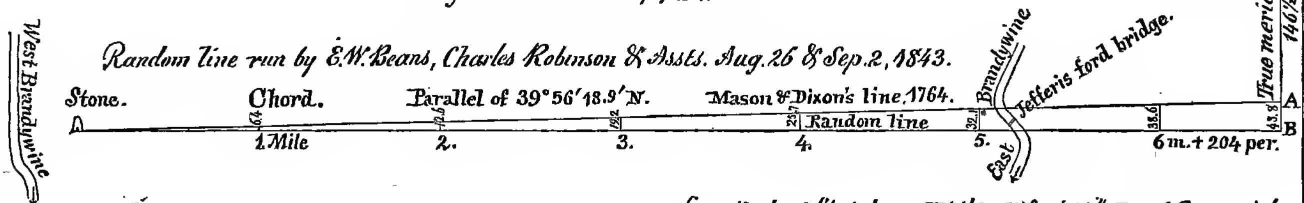
II. Mica-slate region; South Valley Hill.

Bordering the gneiss country on the north and west is a belt of higher ground, which will be geographically described in this report under the name of the *South Valley hill* or *hydro-mica-schist belt*; which traverses the county from east to west with a width of about two miles north of West Chester, four miles south of Coatesville, and then sud-

Determination of the Latitude and Longitude of West Chester.

Mason & Dixon's line of 31 miles west from the Southernmost point of Philadelphia, South St. terminated at this Stone, near the W. Branch of the Brandywine, on Joel Harlan's land, nearly ½ mile above Chester Co. poor-house, in a low situation, surrounded by hills. – The true Meridian line from the Court house steeple was determined by W. Hibbard and E. W. Beans in 1842, by astronomical observations. — A. Mark. Lat. 89°57½. — B. L. 91°11½.

Magnetic declination, 4°2′ West.



Longitude of State house, Phil.ᵃ 75° 9′ 45.″ W. of Greenwich.

Latitude of Stone as determined by M. & D. 1764 & 1776	39°56′18.9″N.
Court house north of this parallel, 146½ perches	1′12.4″
Latitude of Court house at West Chester	39°57′31.3″

Difference of Long. S. H. Phil.ᵃ and southernmost point of Phil.ᵃ	31.9″
Difference of Long. of St. Pt. Phil.ᵃ and C. H. W. Chester, (24 ⁷⁄₈₀ miles on parallel of latitude	27′19.6″
	= W. from Phil.ᵃ 26′47.7″
Long. of C. H. W. Chester f. Greenwich	75°36′32.7′W.
Long. " " " " from Philad.ᵃ	1′ 47″ W
Long. " " " " " Washington	1° 24′57″ E
Long. " " " " " " " "	5′40″ E. in time.

Offsets from the chord to the parallel of latitude, southerly, (too small for the scale of this draft): – 1st m. 3.2 feet; 2d m. 5.4′; 3rd m. 6.4′; 4th m. 6.2′; 5th m 5′; 6th mile 2.8 feet.

Altitude of W. Chester above high tide at Phil.ᵃ	456.4 feet.
" intersection of Pa. & W. C. R.R. (J. P. Bailey)	541.2 feet.

[N.B. This plate is copied from Dr. W. D. Hartman's Top. & Geol. Rept. of Chester Co. Trans. Pa. State Med. Soc. 1857.]

J. P. L.

denly spreads out up and down the Octoraro creek to a breadth of twelve or thirteen miles.

It therefore encloses, as has been already said, the gneiss region on the west as well as on the north; with this difference, that, on the north the separating line is straight and well marked; whereas on the west it is a great curve and very indistinct. This will be dwelt upon hereafter in the geological description.

Topographically it may be described as the high ground which overlooks the limestone valley of Downingtown from the south—and which, after passing the Brandywine west branch, spreads abroad westward and southward into Lancaster county and Maryland.

Its *elevation above tide* is indicated at the east, by the Penn. RR. summit two miles west of Paoli,=550′ A. T;—near West Chester by the Summit level of the West Chester branch RR.=587′ A. T.;—and still further west by Pusey's summit on the Del. & Pa. RR. south of Doe run,=470′ A. T.—the high hill tops ranging about 600′ A. T.

The Pennsylvania railroad runs along the ridge from Radnor to Frazer, about thirteen miles, and then grades down the hill slope into the valley at Downingtown; as shown by the map, and by the following table:—

Pennsylvania railroad.

	Miles from Phila.	*Feet A. T.*
Radnor station in Delaware county,	12	409
Edgewood,	—	401
Wayne,	14	405
Reeseville,	16½	495
Paoli,	19	534
Greentree,	—	543
Summit,	—	550
Malvern,	21	546
Frazer, (junction of W. C. RR.,)	—	490
Glenlock,	25	453
Ship bridge,	—	411
Walkertown,	—	388
Intersection of Waynesburg branch,	—	256
Downingtown,	32	266
Gallagherville,	33	298
Thorndale,	34	313
Caln,	36	359

Coatesville, (X of Wilm. & Northern RR.,) .	38	380
Midway, ...	—	396
Pomeroy, (E. junction of Penna. & Del. RR.,)	42	483
Parkesburg, ...	44	537
Summit west of Parkesburg, ...	—	562
Penningtonville, ...	47	500

West Chester branch, (old line.)*

	Assumed.	*High tide.*	*Ocean.*
Malvern, (old station on W. C. br.,)	232	539	546
Tun road, ...	264	571	578
Summit station, ...	273	580	587
Woodland, ...	264	571	578

West Chester branch, (new line.†)

Frazer, (old station,)	179	484	491
Glen lock road, ...	244	549	556
King road, ...	255	560	567
Woodland station, ...	266	571	578
Kirkland station, (old line,)	230	537	544
Green hill, (Patton's,)	186	493	500
McCall's station, ...	143	450	457
Market St., West Chester, ...	107	414	421

The Brandywine, east branch, cuts down through this highland to and below the level of the valley at Downingtown, 266′, *i. e.* say 300 feet. So does *Valley Creek.*

The Brandywine, west branch, cuts down through it to and below the floor of the valley at Coatesville (315′); at Modeville (Modena) to 260′± *i. e.* say 300 feet.

Back run cuts down into it to and below the level of the valley, but the valley is here much higher than further east; and Back run valley not near so deep as that of the Brandywine. Railroad grade at Pomeroy is 483′, and at Doe run 374′.

Doe run and *Back run* drain Highland township and parts of Londonderry and West Fallowfield, East Fallowfield and West Marlborough eastward into the Brandywine (W. branch) at Mortonville, 6 miles below Coatesville. Doe run however marks about the south limit of the hydro-mica schist belt.

Muddy run heads around Cochranville and flows S. W.

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* Abandoned and rails removed. Station shifted eastward.

† Frazer is the next station west of Malvern on the main line.

7 miles into the Octoraro below Hellbank bridge. Several smaller runs heading at the west limit of the gneiss also drain westward into the Octoraro. One flows north-west from Nottingham P. O. along the township line past Glenroy into the Octoraro above Kirk's bridge. (See *note* on page 10 above.

The geological significance of the fact that all these streams disobey the general law of drainage in Chester county, by heading east along the west border of the gneiss region and flowing westward into and through the hydro-mica schist belt, has already been hinted, and will be hereafter enlarged upon; but it is worthy of remark that it happens only in the western part of the county where the belt expands. In the eastern townships where the belt is straight and narrow the heads of *Chester*, *Ridley*, *Crum and Darby creeks* flow out of the slate belt into the gneiss region. *Broad run* flows lengthwise of the belt; and so do the smaller affluents of *Back and Doe runs.*

The surface land of the hydro-mica schist region is well cultivated, and populated, but there are no large towns.

The *villages* are not numerous. Beginning at the east and going west, they are: *Paoli*, *Grove*, *Harmony Hill*, *Romanville*, *Modeville and Mortonville* (on the West Brandywine); *Youngsburg*, *Doe Run*, *Gum Tree*, *Cochranville*, *Glenville*, *Londonderry*, *Russellville and Haysville* (east of the Octoraro creek); and *Homeville and Steeleville*, close to the Lancaster county pike.

III. The Downingtown valley.

The *Chester valley*, as it is usually called, is the next prominent feature of the county.

Its geology will be described in its proper place; here it is only needful to speak of it as a groove, from 500 to 2000 yards wide, cut straight across Chester county to the depth of from 200 to 400 feet.

The hilly southern region of the county already described ends at the southern edge of the groove; the much more hilly northern region next to be described, begins at the northern edge of the groove. Limestone and marble form the floor of the valley, and rise a short distance up both slopes. The floor is generally level, and the slopes gentle. There are no cliffs or jutting rocks along the sides of the valley; but here and there a small natural output of limestone is seen, or a sinkhole, or an artificial quarry. Rivulets descend the slopes and meander over its floor, some eastward and others westward, to join either the Schuylkill or one of the two branches of the Brandywine.

Three rivers cut across the valley in their way southward to Delaware Bay, and several other smaller streams make *gaps* in its side walls.

Gaps.—The Schuylkill breaks across between Norristown and Conshohocken; East Valley creek (flowing east) breaks out through the North hill into the Schuylkill at Valley Forge; the West Valley creek (flowing west) breaks out through the South hill two miles east of Downingtown; the East Brandywine flows square out of a gap in the North hill, and into a gap in the South hill at Downingtown; the West Brandywine does the same at Coatesville; Buck run at Pomeroy; and the Octoraro creek at the Lancaster county line. Besides these gaps, there is another made through the North hill by a branch of West Valley creek four miles east of Downingtown; and still another in the North hill made by Beaver creek (a branch of Valley run flowing east) two miles west of Downingtown.

Eight gaps therefore exist in the North hill, and six in the South hill, exposing the stratification more or less perfectly.

From Downingtown eastward the old Chester Valley railroad follows the valley to Norristown. From Downingtown westward the Penn. railroad runs along its south side to Caln, crosses to its north side, and gradually rises upon the north slope to "The Gap" in Lancaster county. From Pomeroy the floor of the valley rises rapidly into Lancaster county, but not so fast as the railroad.

Chester Valley railroad.

	Miles.	*A. T.*
Bridgeport, opposite Norristown, ...	0	76′
Shainline's station, ...	—	136
Henderson's station, ...	2	165
King of Prussia station, ...	3½	190
Centreville station, ...	6	202
Garden's station, ...	7	225
Howellville station, ...	8½	221
Paoli road station, ...	9½	238
Cedar Hollow station, ...	10	246
Lee's station, ...	10½	279
Valley Store station, ...	11½	295
Mill Lane station, ...	13	315
White Horse station, (*Summit,*)	14	339
Exton station, ...	16	324
Oakland station, ...	18	301
Baldwin's station, ...	19½	299
Downingtown station, ...	21½	267

(*Pennsylvania railroad—repeated.*)

Gallaherville, ...	22½	298
Thorndale, ...	23½	313
Caln, ...	25½	359
Coatesville,*	27½	380
Midway, ...	—	394
Pomeroy, (eastern junction,)	31½	483
Parkesburg, ...	33½	537
Summit, ...	—	562
Penningtonville, ...	36½	500

Downingtown is a flourishing town, which had a population of 1,077 in 1870, and of 1,480 in 1880.

Belvidere, *Glenlock*, *White Horse*, *Valley Store*, and *New Centreville* are villages between it and the Schuylkill. *Gallagherville*, *Thorndale*, and *Caln* lie west of it.

Coatesville, on the East Brandywine, with its rolling-mills, woolen and paper-mills, had 2,025 in 1870, and 2,766 in 1880.

Pomeroy and *Parkesburg* are important railway stations, the latter with a population of about 500.

The valley was early settled, and shares with the other limestone areas of the State their extraordinary fertility.

* Here the P. RR. has risen on the slope of the north valley hill to a height of 62 feet above the W. & N. RR., which comes beneath it. The valley floor is therefore only about 318′.

It is undermined like them by innumerable natural caverns, the roofs of which have in many places fallen in, leaving funnel-shaped sink-holes, some of which have appeared in recent years.*

The marble quarries are ranged along the foot of the south valley hill. Beds of brown hematite iron ore have been found and worked along the floor of the valley; and in this respect also it resembles the Lancaster county plains, and the southern half of the great Lebanon or Cumberland valley further north.

IV. The northern gneiss region.

Chester county north of the Valley is divisible into two totally different kinds of country, whether considered topographically or geologically, viz: A lower rolling country of much decomposed gneissoid rock, traversed by ridges of sandstone; and a somewhat higher rolling country of red sandstone and shale traversed by ridges of greenstone trap.

French creek, which heads at the Berks county line and flows south-east to enter the Schuylkill at Phœnixville, is for ten or twelve miles the dividing line between these two regions. For the remaining distance of nine miles to Valley Forge the dividing line is marked merely by a change of sôil and a general slope towards the Schuylkill.

The North Valley hill has already been mentioned as the southern edge of this northern region. It will be described hereafter as an outcrop of the Potsdam sandstone formation No. I, of the Palæozoic system.

Welsh mountain extends along the Berks and Lancaster county line from Springfield westward, north of Waynesburg, into Earl township, Lancaster county. It also is of Potsdam sandstone.

Another ridge of Potsdam sandstone runs along the south

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* A thrilling story was told to me when a child by my father, how one dark night the Lancaster stage coach leaders baulked and nó persuasions of the driver could induce them to go forward. Giving the reins to a passenger he advanced with a lantern and discovered a large abyss into which the whole road had sunk, and through which stage, coach and passengers would have been plunged into an underground cavern.

line of Honeybrook township from the pike (above Mackelduff's mill) west, almost to the Lancaster county line.

Copper Mine ridge between the Lancaster road on the north and the Phil. and Lan. pike on the south commences a little west of Waggontown, extends west into Lancaster county, and ends at Big Beaver creek. It also is of Potsdam sandstone.

An isolated hill of Potsdam sandstone is situated in the lower part of Uwchlan township.

The outspread of Potsdam on the underlying surface of the gneiss is shown on the geological map.

The gneiss of northern Chester differs from that of southern Chester in being more uniform, coarsely crystalline, characteristically feldspathic, more hornblendic and less micaceous, than the southern gneiss. (Hartman.)

The highest portion of the region is the north-west corner of the county where its three principal streams, the two branches of the Brandywine and French Creek, have their head-waters close together. The general tendency of the drainage is eastward.

The *West Brandywine* drains three miles of the west line around Waynesburg, carries the collective waters east, past Rockville, and then flows south to Coatesville. All its affluents, *Birch run*, *Rock run*, &c. except one, come from the west.

The *East Brandywine*, drains four miles of the north-west line, and flows south-east, and then south to Downingtown. *Marsh run* and *Perkin's run* are two of its three heads. The two branches of *Indian creek* come in from the west lower down at Springton. *Gulbertson's run* comes from the west lower down near Milford mills. *Beaver creek* drains also from the west, first into the Valley and then to Downingtown. *Marsh creek* with its two main branches, *Lyon run* and *Black Horse run*, flows south to join the E. Brandywine at Dorlan's mills.

French creek drains seven miles of the north-west line with its north and west branches and *Hock run*, and flows east; receiving from the west, a stream at Pughtown, and

Birch run (not the one above mentioned) two miles below Pughville; and enters the Schuylkill at Phœnixville.

Pickering creek, with its branches *Pine run* and *Pigeon run*, also flows east into the Schuylkill a mile or more below Phœnixville.

This eastward direction of the drainage must have some geological significance. A line drawn west from Phœnixville through Waynesburg into Lancaster county represents an ancient mountain range now worn down by acqueous erosion, which no doubt declined in height from west to east. Although its general surface became gradually lower and lower the original eastward flow of its waters remained the same, passing diagonally down its southern slopes and so southward into the Valley. Probably the whole region was once covered by Potsdam sandstone, and by the overlying limestone formation; and if so the original drainage was established upon a dome-shaped surface at least 30 miles long by ten or twelve broad (north and south.)

Probably more than one undulation constituted the general mountain range, broadening it, and separating it into rudely parallel ranges.

The western end of the main line of elevation (that of the Welsh mountain proper) is shown on the geological map of Lancaster county (Report CCC) at Laurel hill, Green Bank and Mt. Airy, where the Potsdam overlying the gneiss is seen to descend beneath the great limestone plain. The line of uplift runs on however due west just north of the borough of Lancaster, and as it approaches the Susquehanna river, brings up the Potsdam again, which appears so grandly in Chickies rock above Columbia. The great fault on the north side of Chickies rock is probably one of the phenomena of this Welsh mountain uplift.

The strong contrast between the west and east borders of the Welsh mountain region of Chester county is very remarkable and furnishes abundant food for geological speculation.

The Lancaster county border shows the gneiss country sinking westward and northward beneath Potsdam sandstone, and this again beneath the limestone. The eastern or Schuylkill valley border, on the contrary, shows the gneiss sinking eastward and northward beneath New Red sandstone, with not a trace of Potsdam or limestone intervening; and that along a distance of 18 miles, from Valley Forge to Berks county. Now it is certain that the sunken floor of the New Red country of the Schuylkill region is limestone, lying upon Potsdam sandstone. Why then do not the eroded edges of these formations appear along the French creek border of the Welsh mountain gneiss region?

Two different answers can be made to the question.

1. Perhaps this part of the Welsh mountain region was never covered by the limestone and sandstone. But if so, then it must have been higher than the western portion, on which large patches of such a covering (at least of sandstone) still remain. But, again, if so, then how could a surface drainage eastward have been originally established?

2. A much simpler answer may be stated thus:—Where ever the New Red exists there has been a great subsidence beneath sea level, and a subsequent reëlevation. It is also evident that the subsidence was profounder in Montgomery and Bucks counties than elsewhere. In other words, the eastern part of the primary region (of which the Welsh mountain is merely a single district remaining exposed to the air in our day) sank deeper than the western or Lancaster county district. Previous to the sinking erosion had been going on, removing the limestone and sandstone formations from off the higher parts of the (gneiss surface on which they had been deposited. When the sinking occurred it carried down all the surface on which the limestone and sandstone now remain, and part of the surface from which they had been removed, leaving a sea shore of gneiss, facing the eastern sea (floored with limestone). New Red strata were then deposited directly upon the gneiss along shore, but upon limestone in deeper water.

But the sinking being thus greater eastward, a general slope was given to the partially eroded and denuded Welsh mountain surface eastward; and this explains the present eastward drainage.

The above remarks are intended, not to give a final answer to a very difficult question, which has too many side relationships with the whole geology of the State to be settled by the study of any one district, but to suggest to the readers of this report the curious and important connections which exists between topography and geology, and how it may be possible to obtain light on a difficult problem of geology, by observing the purely geographical features of a map. (See small drainage map, page 25.)

Levels above tide along the railroads show the depth to which the present drainage waters have cut. (See the following tables.) Those along the ridge-roads show the elevation of the higher land.

The North Valley hill top above Beaver summit on the new Phœnixville and West Chester railroad line rises to 430′ A. T.

The highest place in the notch by which this railroad gets through the North Valley hill at Beaver's summit is 380′ A. T.

The gneiss hills further north are higher.

Byer's summit, the end of the Pickering Valley RR. near Windsor, is 426′ A. T. The railroad descends 104′ in 2 miles; 44′ in the next 2 miles, to Chester springs; 67′ in the next 3 miles (passing over the divide between Pickering and French creeks) to Kimberton station at the edge of the red sandstone; 83′ in the next 2 miles to French creek; 18′ in the next 2 miles to Phœnixville.

Further west the crest of the North Valley hill rises with the rise of the valley.

At Coatesville the Wilmington & N. RR. is 315′ A. T., and in going through the gap in the N. V. hill northwards it ascends the W. branch Brandywine for 3½ miles at the rate of 70′ per mile to Brandywine station (556′ A. T.); then for the next 8½ miles at the rate of 10′ per mile to the upland crossing of the E. B. & W. RR. (647′ A. T.)

Hence northward it is practically level to the Berks county line. At Joanna (627′ A. T.) it begins to descend rapidly to Birdsboro' junction (173′,) 454′ in 10 miles.

At Downingtown the floor of the valley is 256′ A. T. At Shelmire's 246′ A. T. The East Brandywine cuts down so deeply into the upland, that the E. B. & W. RR. rises 115′ in 6½ miles = 17.7′ per mile; thence 380′ in 11½ miles = 33′ per mile, to the end of the old track beyond Waynesburg station, 741′ A. T. On the extension of the railroad into Lancaster county a new start was made at Waynesburg (728′ A. T.) *with some slight difference of datum;* but after descending slightly (say 10′) to Honeybrook, the road ascends to 867′ A. T. at the crossing of the Churchtown road; and this represents the Welsh mountain proper.

The descent from here to New Holland, on the Lancaster plain, 8½ miles, is only (867′—482′=) 385′; and thus it appears that the height of the Welsh mountain is really insignificant. It is merely the higher north-western end of a gentle rise of the whole country from the south and east, towards the north and west.

Wilmington and Northern RR.

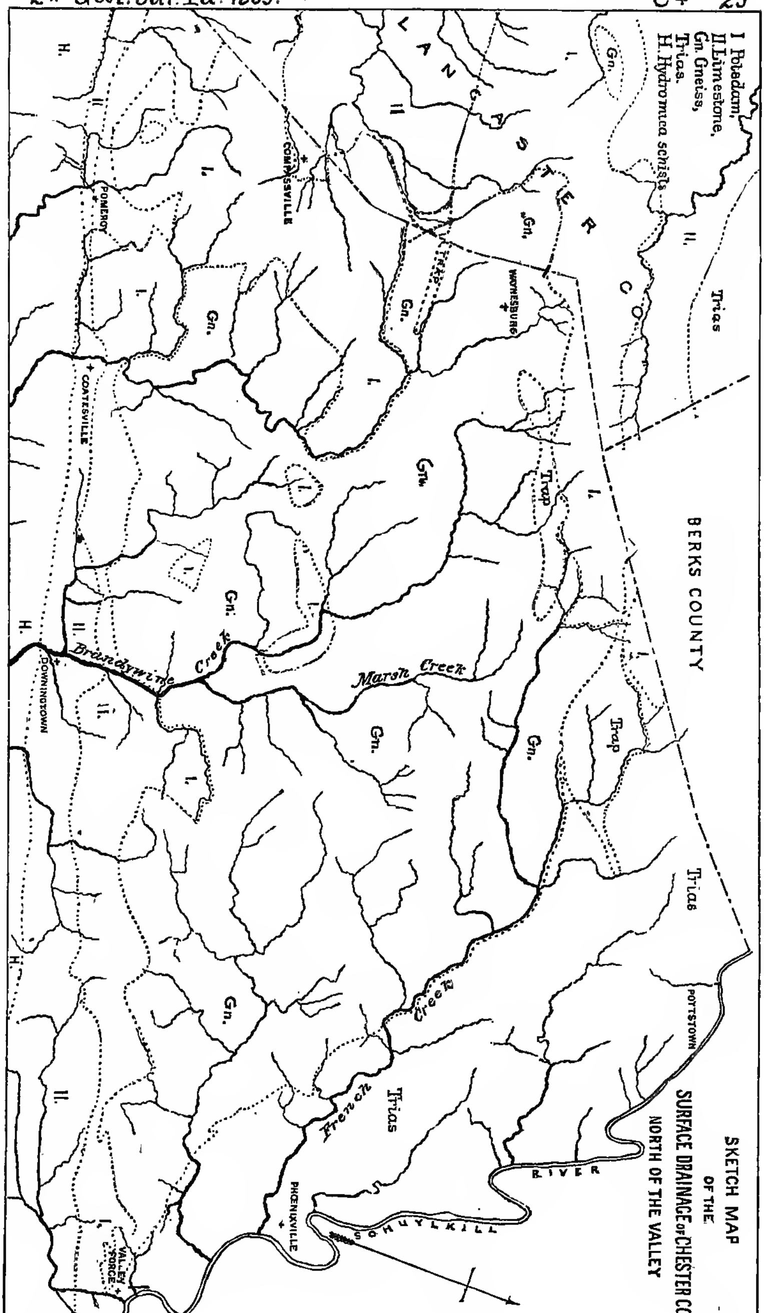
	Miles.	*A. T.*
Birdsboro' junction, in Berks co.,	0	173′
Hampton station, "	2.7	223
White Bear station, "	4.6	349
Geigertown station, "	6.2	432
Cold Run station, "	7.7	525
Joanna station, "	10.2	627
Springfield station, in Chester county,	12.4	645
Conestoga station, "	13.7	647
Isabella station, "	15.7	639
East Brandywine and Waynesburg RR. crossing,	19	647
Beaver Dam station, in Chester county,	21.3	603
Honeybrook station, "	23.1	596
Manor station, "	25.9	572
Hibernia station, "	27	530
Brandywine station, "	27.6	556
Coatesville, in the Valley,	30.7	315

The descent of the last three miles through the gap of the North Valley hill into the valley is 241′= 70′ per mile.

*East Brandywine and Waynesburg RR.**

	Miles.		*A. T.*
New Holland, in Lancaster co.,	28.1	52′	482′
East Earl, "	25.2	80	510

* The station west of Waynesburg not being marked on the profile, the distances were taken from the time-table, and the elevation of each point calculated from the profile. (E. B. Harden, 1882.)


SKETCH MAP
OF THE
SURFACE DRAINAGE OF CHESTER CO.
NORTH OF THE VALLEY
I Potsdam,
II Limestone,
Gn. Gneiss,
Trias.
H. Hydromica schists
LANCASTER CO.
BERKS COUNTY
COMPASSVILLE
POMEROY
COATESVILLE
DOWNINGTOWN
WAYNESBURG
POTTSTOWN
PHOENIXVILLE
VALLEY FORGE
SCHUYLKILL
RIVER
Brandywine Creek
Marsh Creek
French Creek
Trias
Trap

Cedar Lane, in Lancaster co.,	24.6	122	552
Beartown, "	22.0	333	763
Churchtown road, "	20.7	437	867
Honeybrook, in Chester county,	18.1	298	728
End of track in 1877, "	18	—	741
Waynesburg station, "	—	—	728
Lancaster pike, "	—	—	696
Buchanan's station, "	16½	—	672
Wilm. & Read. RR. crossing,	16	—	645
Dampman's station,	15	—	628
Forrest station,	14½	—	576
Cupola station,	14	—	565
Lewis Mills station,	13½	—	542
Barnestown station,	12	—	486
Moorestown station,	9½	—	443
Springton station,	—	—	405
Cornog's station,	7½	—	361
Brooklyn station,	6	—	331
Reed's road station,	4½	—	309
Dorlan's station,	4	—	280
Dowlin's Forge station,	—	—	274
Shelmire's,	1	—	246
Downingtown junction Pennsylvania RR.,	0	—	256

In this case the descent through the gap in the North Valley hill is only 24′ in 4 miles = 6½ feet per mile.

Pickering Valley RR.

	Miles.	*A. T.*
Byer's Eagle summit,	11½′	426′
Cambria station,	9½	322
Chester Springs station,	7½	278
Pikeland station,	7	272
Kimberton station,	4	211
French Creek station,	2	128
Phœnixville station,	0	110

*Phœnixville and W. Chester RR.**

	Above P. RR. datum.†	*Above ocean datum.*
Main St., Phœnixville,	113′	120′
Pickering Valley RR.,	110	117
Nut's road,	136	143
Pothouse road at Harveyville,	194	201
Pickering dam,	135	142
Reese's paper-mill, road at,	252	259

* From the profile in the Pa. RR. office, 1882. (E. B. H.)

† These do not represent the RR. grade where built, but the elevations of points on roads and streams along the located line.

Beaver summit, road at, ...	365	372
Conestoga turnpike, ...	348	355
Chester Valley RR., (top of rail,)	343	350
Frazer, (old station,)	484.140	491
Frazer, (new station,)	483±	490

Waynesburg, in the north-west corner of the county, is the only considerable place in the whole district.

Cambridge, *Martin's Corners*, *Wagontown* and *Sadsburyville*, are villages in the hill country west of the W. Brandywine;—*Rockville*, *Brandywine*, *Corner Ketch* and *Guthrieville* are villages on the old Philadelphia and Lancaster turnpike which passes over the hills between the two Brandywines;—*Cupola*, *Barnestown*, *Isabella* and *Loag's corners* are villages at the heads of E. Brandywine;—*Norwood*, *Wallace* and *Springton* are on the E. Brandywine;—*Milford mills* stands in the forks of E. Brandywine and Marsh creek;—*Lyonville* and *Winsor* on the divide at the head of Pine and Pickering creeks;—*West Vincent* and *Nantmeal* at the heads of *Birch run* and another branch of French creek;—*Springfield* at the head of the south branch of French creek;—*St. Mary's*, *Knauertown* and *Pughtown*, on French creek at the edge of the gneiss and red shale;—*Chesterburg*, *Marisville* and *Charlestown* on Pickering run; and *Kimberton* on the edge of the gneiss three miles west of Phœnixville.

V. The new red sandstone region.

This is a long triangle, one half mile wide at Valley Forge and five miles wide on the Berks county line, bordered on the east by the Schuylkill river and on the west by French creek for nine miles, and by the edge of the gneiss land for the remaining nine miles.

It is everywhere hilly, but elevated nowhere more than about 500′ A. T,

Pigeon creek flows in it and enters the Schuylkill four miles below Pottstown.

Stony run flows in it and enters the Schuylkill just above Phœnixville.

French creek flows between hills of gneiss on the west and hills of red sandstone on the east for nine miles, and then traverses the red sandstone to Phœnixville.

Pickering creek issues from the gneiss country and flows two miles across the red sandstone into the Schuylkill below Phœnixville.

The *Schuylkill river* has in its south-east course three very remarkable closely folded double bends between Pottstown and Phœnixville which well deserve the attention of the hydrologist, illustrating as they do the action of an eroding current upon the bed planes of a formation dipping everywhere up stream. In each case the river recoils from the opposing dip, retreats to the left, and returns to the attack at the next bend. The face of the retreating part of the bend is in each case a cliff.

The fall of the river from Pottstown to Valley Forge is perfectly represented (throwing out the bends) by the grade of the Reading railroad, thus:—

Reading railroad.

	Miles.	*A. T.*
Douglassville,	44½	161′
Pottstown,	40	150
Limerick,	34	138
Royer's Ford,	32	127
Mingo,	30½	116
Phœnixville,	27½	110
Perkiomen Junction,	25	109
Valley Forge,	23½	98
Port Kennedy,	21½	87
Merion,	19	81
Bridgeport, opposite Norristown,	17	76
Philadelphia, Delaware front,	—	28

Phœnixville is the only place of importance in this belt of the county. It is a place of iron furnaces, rolling-mills, and iron bridge building shops, cotton factories, and sash and planing-mill, with a population of 5,292, in 1870, 6,681, in 1880. It is on the Reading railroad, 27½ miles from Philadelphia. Here the railroad passes through a tunnel, and crosses to the east bank of the river. This tunnel revealed the existence of a bed of coal-slates full of plants and animals, which were collected by Mr. C. M. Wheatley; probably the same bed which was pierced in the Gwynedd tunnel on the North Pennsylvania railroad in Montgomery county; and the representative of a plant bed in Frederick county, Md., and of the Triassic deposits of coal in Virginia and North Carolina.

Cedarville, Madison, Frick's locks, Lawrenceville, Springville, Schuylkill and *Valley Forge*, are villages along the west bank of the river;—*Coventry, Vincent, Bucktown* and *Harmony* are others lying back from the river.

The *iron manufacture* of Chester county was begun in 1716, by Thos. Rutter, at Pool forge, three miles above Pottstown. In 1718 Sam. Nutt took out his patents for 400 and 800 acres of iron ore land on French creek; 300 were laid out in Coventry, 1720; 650 were surveyed in 1719 at Warwick furnace and 300 purchased by him in 1721 in Coventry. A forge on French creek was in operation prior to 1720; assessed in Nantmeal township in 1722 and in Coventry in 1724; therefore it must have been on the township line.

In 1726 "Nutt's road" was laid out (through the forest?) from "the iron works on St. Vincent river in the township of Coventry leading to Uwchlan meeting-house," beginning at the forge and at the distance of four miles passing over "Mt. Austrie."

In 1736 S. Nutt & W. Branson (partners since 1728) agree with John Potts to carry on "*Redding furnace*" recently built near Coventry. In a petition for a road it was called "Redding's furnace."

Warwick furnace was soon afterward built by Widow Nutt and her daughter. Another was built by Branson 1½ miles higher up the creek. The interests of all parties were consolidated by Rutter and Potts of the Warwick furnace in 1778 to 1783.

Acrelius writes in 1759: "Friend's (French) creek, in Chester county, near the Schuylkill. The mine is rich and abundant, from ten to twelve feet deep, commencing on the surface."

Crum creek iron-works were established as early as 1742 by John Crosby and Peter Dicks; Thos. Dell complaining to meeting that the dam overflowed his land.

Sarum forge (at Glen mills) on Chester creek, owned by John Taylor in 1742, was certainly worked in 1745, 1746 and 1751.

England protected her own iron works carefully by laying a duty on American iron coming into her ports. In 1743 Thomas Penn endeavored to have this tariff removed. It was in fact diminished. But in 1750 Parliament enacted that "no mill or other engine for slitting or rolling of iron, or any plating forge to work with a tilt hammer, or any furnace for making steel, shall be erected or after such erection continued in any of his Majesty's colonies in America . . . . but be deemed a common nuisance, to be abated, &c."

A call for statistical information being made at that date it appeared that in Chester county only one slitting and rolling-mill existed, viz:—

John Taylor's *plating forge* in Thornbury township.

Redding (now Warwick) *furnace* in E. Nantmeal, after its purchase of Rutter & Potts, fell into ruin; and was replaced by a forge, for which S. Van Leer was assessed in 1788, and which was carried on successfully many years.

In 1786 Jesse Potts was assessed for a *steel furnace* in Coventry; operated in 1787 by Ellis, Jones & Co.; in 1788 by North & Evans.

In 1786 David Moore had a *forge* in W. Nantmeal; in 1788, James Moore.

Vincent forge was frequently advertised in the Philadelphia Weekly Mercury in 1781, 1785, 1788.

Rebecca furnace, built by Mordecai Peirsol about 1764 to smelt the *Jones mine ore*, was owned in 1793 by Vinance, Rutter, May & Potts, and blown out in 1794 for lack of charcoal.

Warwick furnace made cannon for the revolntionary army.

Isabella furnace was built by David Potts, in 1830.

Valley forge was operated by the Potts family in 1757, and destroyed by the English army in 1777. Its pig was hauled from Warwick furnace. After the war it was rebuilt three quarters of a mile further down the Valley creek, and its dam overflowed part of the site of the old Mount Joy forge. A slitting-mill was built. In 1786 Isaac Potts & Co., and afterwards others owned the works; in 1814 Jac. Vogdes sold them to J. Rogers and Josh. Malin, who rebuilt the mill. In 1821 part of the works were converted by Brooke Evans into a gun factory.

Mary Ann forge, on the N. Br. Brandywine two miles above Downingtown, was built in 1785.

Springton forge, five miles above Mary Ann forge was built in 1766.

Hibernia forge, on W. Brandywine, four miles above Coatesville, was built in 1793, and a small rolling-mill added in 1837; abandoned in 1793; dismantled in 1880.

Rokeby rolling-mill, on Buck run, four miles south of Coatesville, was built in 1795.

Brandywine rolling-mill, at Coatesville, was built in 1810.

Sadsbury forges, on the Octoraro creek, near Christiania, were built in 1800 and 1802.

Ringwood forge on the Octoraro, near Christiania, built in 1810, was in operation still in 1856, but afterwards abandoned.

Pinegrove forge, on the Octoraro 16 miles south of Penningtonville, built in 1800; rolling-mill added in 1844; both abandoned.

Pleasant Garden forge, 5 miles S. E. of Oxford, 2 m. S. W. of N. Mondon; built in 1806; abandoned in 1848; rolling-mill built in 1845, also abandoned.

An interesting account of the first attempt to make German steel will be found on page 349 of the History of Chester County, and Swank's History of Iron Manufacture.

Reutgen's works were situated in Pikeland township, and so called.

Lukens (formerly *Brandywine*) *rolling-mills* at Coatesville were established in 1810, and are now owned by Ch. A. F. & C. L. Huston and Ch., Penrose, (Huston, Penrose & Co.)

Phœnix iron works at Phœnixville were a nail works in the last century. Bought in 1828 by Reeves & Whittaker, they have become one of the largest furnace and rolling-mill establishments in America. Two furnaces were built in 1845 and the rail-mill in 1846. The nail-mill was burnt in 1848 and never rebuilt. With a third furnace, they employ 1,500 hands, consume 60,000 tons of ore, 100,000 tons of coal, and convert 30,000 tons of pig iron into shapes, worth $3,000,000 annually. The shapes are adapted to rails, bridges, ribs and decks of iron ships, &c.

Thorndale iron works, erected in 1847 by Forsythe & Sons, owned by J. B. Morehead in 1861 and W. L. Bailey in 1868, now by a company, manufacture plate iron with 80 to 90 hands; 6,500,000 ℔s. of finished iron in 1880.

Valley iron works, at Rock run, one mile above Coatesville, owned by C. E. Pennock & Co., makes plate iron with 200 hands.

Viaduct mill, Coatesville Iron Co., makes pipe and plate iron with 150 hands.

Laurel iron works, at Parkesburg, make skelp and flue iron.

Goodman's forge, on the Octoraro,—

Cornog's forge, on the Brandywine, and

Kauffman's forge on French creek, are all three in operation (1882.)

Chapter II.

Geological description.

Two maps of Chester county, geologically colored, are published with this report:—One prepared by Prof. Frazer, and printed in 1880; the other prepared by Mr. C. E. Hall in 1882.

Prof. Frazer's map gives his interpretation of the outspread of the formations on or immediately beneath the surface; except in one part of it, which will be explained directly.

Mr. Hall's map is the result of his notes of the geological outcrops in the southern townships of Chester, in connection with his survey of the same formations in Delaware county. On this map nothing is laid down which does not actually appear above the soil. No attempt is made to connect such exposures, hypothetically, underground. The indefinite limits of the rock areas are expressed indefinitely; and the reader is allowed to draw his own conclusions.

If these two maps be compared with the geological map of Pennsylvania published with Prof. H. D. Rogers' final report of 1858 many striking differences of detail will be noticed, especially in southern Chester and Delaware counties.

On the State map of 1858 the borders of the formations are long parallel east and west lines, suggesting a simple and regular structure; and the color assigned to the Potsdam of the North Valley hill is assigned to the hydro-mica belt of the South Valley hill, and to much of the region to the south of it which is occupied by gneiss, syenite, &c. Prof. Rogers had a definite theory of the order and superposition of the formations. This theory his map-coloration represents; and it is described in the text of his report, Vol. I, pp. 67 onwards.

Since 1858 the district in question has been closely and repeatedly investigated by Prof. Frazer and Mr. Hall, the one approaching it from the west, the other from the east. They differ radically in their views of the order and superposition of the formations, not only from Prof. Rogers, but from each other; so that this report will leave several points of geology in almost as great obscurity as ever.

A long step has been made in determining the nature, the the areas, and even the structural attitude of these anomalous formations of whose age and deep underground condition we still know so little.

Mr. Frazer's map was constructed, revised and printed under all the difficulties which attend the publication of geological illustrations during the season when the geologist is actively employed in field work, at a distance from both draftsmen and lithographers. Prof. Frazer is dissatisfied with several details of the map, as published; especially with the manner of representing the hydro-mica schist belt south of the Chester valley. Of this he says:—

"The chloritic and hydro-mica schist areas of 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 chloritic and underlying gneisses, though an isolated patch of the former in the latter in 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 partly modified their distinctive character.

"Add to this that a thin unknown series resembling the rotten representatives of all these has since appeared to increase the confusion.

"Nevertheless the 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 or zone.

"The attempt was abandoned, the difficulties were explained to the chief geologist, and the necessity was urged for giving the same general pink color to this area which had been used for the adjoining district of identical rocks in Lancaster county.

"What then was my astonishment and chagrin" &c.

The explanation is simple. Had the pink color of the schist area on the Lancaster county map been given to the schist area of south-west Chester, to make it agree with Lancaster, it would have confused the geology of south-eastern Chester, Delaware, Montgomery and Berks by obliterating the distinction between the different areas of Laurentian (?) syenite, of micaceous gneiss, and of the South Valley hill hydro-mica schists. Prof. Frazer adds:—

"A narrow strike of syenite should pass from near the S. E. corner of the borough of Kennett Square N. E. cutting off the Sharpless quarries from the rest of the limestone to the west.

"About one mile N. W. of Kaoline a small area of Potsdam (yellow) should be traced on the road and on each side of it. All the pink in New Garden and East London Britain should be *light pink* and yellow, if the latter color be used for the entire Potsdam, of which these rocks are the lower members.

"Close against New London P. O. to the N. W. there should be a small area of yellow."

The discordance of the two maps along the Lancaster and Chester county line north of the Chester valley, is due to the usual differences between all the published county maps of the State.

Owing to the obscurity which surrounds the age and order of the formations occupying Chester county, the coloration of the map can hardly be said to have a *geological basis* in the strict sense of that term; each color merely indicates an area of the county over which rocks exhibiting a common *lithological* character prevail, without regard to their relative age in the history of deposits.

One striking contrast is observable between the map of Chester and the map of Lancaster. The wide rich central limestone plain of Lancaster county invades Chester county only for a single mile at Compassville, leaving all the northern part of Chester county an expanse of hills, composed of crystalline or semi-crystalline rocks of inferior fertility.

The general resemblance of the two maps on the other hand is equally striking, and is due to the fact that southern Chester is in a geological sense merely the extension of southern Lancaster eastward.

Mr. Hall's map shows how completely the geology of Delaware county is represented in the southern townships of Chester; but it leaves entirely unexplained the relationships of the syenite or gneiss rocks with the limestone, sandstone, mica-slate and serpentine outcrops which dot the district. In his notes he guardedly expresses some opinions respecting the connection of these dots upon his map, but wisely abstains from dogmatizing on the subject of their age and order in the geological series.

The five regions into which Chester county was conveniently divided in Chapter I, above, will now be taken up in regular order, and their boundaries geologically described; a summary of their leading geological features will be given; and some of the questions stated which may have to wait a long time yet for a final answer.

I. The southern gneiss region.

The northern boundary of this region is a nearly straight E. N. E. line passing by West Chester; a line marked here and there by exposures of serpentine and limestone; and these may be the occasional appearance at the surface of one continuous layer under ground; but the visible thickness is nowhere more than 50 or 60 feet.

North of this line runs the hydro-mica-schist belt to be described further on.

South of this line spreads a country of syenite rocks, feldspathic porphyry rocks, hornblendic gneiss, micaceous schists, chlorite schists and quartzite beds, such as are described minutely by Mr. Hall in his Report of Progress C[6] on the Philadelphia belt; and again in his Report C[5] on Delaware county.

Patches of serpentine and crystalline limestone are dotted over the region, with beds of impure limonite, pure kaoline, and often an abundance of corundum.*

Whatever may be the age of the rocks of this region, they were originally sediments of mud, sand and gravel, for they are everywhere more or less distinctly stratified, although it is sometimes difficult to distinguish their original bed planes from the planes of cleavage which cross them (usually in nearly vertical planes) and in many cases completely mask them. This is especially true of their more massive layers. But the real stratification is visible wherever they are quarried, and pictures of the quarries in Delaware county are given in this volume to illustrate the fact. We owe to Mr. Hall's close and intelligent observation the collection

*A general idea of the distribution of these minerals can be got from the colored map accompanying this report; special note of the localities will be taken in the pages devoted to the several townships.

of a large amount of satisfactory evidence for the general horizontality, or low dip angle, of most of the rocks of this region; whereas hitherto it has been taken for granted that a general steepness of dip prevailed.

Infinitely numerous and rapid variations of constituent character, texture, hue, and crystalline contents make the study of these rocks extremely difficult in a structural sense; there are no key-rocks to mark geological horizons; and so large a proportion of the upland is cultivated, that the exposures along one valley cannot be traced across and identified with those of another valley, only a few miles distant.*

Even were we sure of the relationship of the limestones and serpentines to the schists and gneisses, they could not be quite available as key-rocks, because they seem to be of more or less local origin; and even where they appear to underlie the surface in continuous lines or belts, they are only occasionally visible in or above the soil.

Prof. Rogers in his final report of 1858 divides the region into three belts, with a special structure, viz:

1. A *northern*, anticlinal, hard gneiss belt on which stands West Chester.

2. A *southern*, monoclinal, hard gneiss belt on which stands Philadelphia; and

3. A middle, synclinal, soft gneiss and mica slate belt, separating the other two.

Mr. Hall, in his Report of Progress C[6], also divides that part of the region lying on and east of the Schuylkill into three belts; but in his Report C[5] on Delaware county was unable to recognize the same arrangement in the part of the region lying west of the Schuylkill and across the Brandywine. This is plainly indicated by the coloring of his Delaware county map. He sees however a marked dif-

*"Many differently constituted bands of the crystalline rocks either so fade into each other, or are of such limited length that to trace and map them in detail would be a work of herculean labor. The strata are too generally obscured by a deep covering of loose earth, largely derived from their disintegration, and the rocks themselves are too deeply rotted and softened, to permit . recognizing and picturing . . . their innumerable bands."—*H. D. Rogers, p. 68.*

ference between the kinds of gneiss in northern and southern Delaware county.

Mr. Frazer, in Chester county, gave up in despair the attempt to arrange in definite belts the numerous varieties of crystalline and sub-crystalline rocks of the Chester county part of the region.

H. D. Rogers' three belts.—Mr. Rogers' system has the merit of simplicity; but it is certainly of doubtful value. The facts, however, on which it is based remain to-day as they were when they were observed in 1851, and deserve careful consideration. His classification of the region into belts is a convenience, but his structural explanation of it should be used by local geologists with the greatest circumspection, not only because it has not been satisfactorily proved, but because the more recent surveys have failed to lend it any solid support. It may be thus described:—

1. The West Chester gneiss belt.

The northern margin of his *northern gneiss belt* is thus defined by Mr. Rogers, (page 77:)—

East of the Schuylkill; along the northern brow of Chestnut hill, to just below Spring mill.

West of the Schuylkill; along the brow of the hill overlooking the river, past G. W. Fisher's, P. Pechin's, W. Morgan's (N. E. of Morgan's corner;) half a mile south of the Spread Eagle tavern; on the Paoli-Spread Eagle back road, ⅛ mile E. of × road from Reeseville to Leopard inn;* then, on the Darby road, 1½ m. S. E. of Paoli, or ½ m. W. of Leopard Inn;† then, Crum creek, near Mavis' grist-mill;‡

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* Here a fine bluish trap dyke runs a little north of the contact of the gneiss and slate. The gneiss is here dark bluish grey, feldspathic, micaceous, like that south-east of Spring mill; further east very quartzose and massive, (dip 85° to N. 10° E.;) west of Morgan's corner, in the deepest RR. cut, massive, granitic, with greenish feldspar, white and garnet colored quartz, and brown mica; all these are very different from the kind of gneiss above the line of contact further west.

† Here the gneiss is more hornblendic; and the change from the harder gneiss to the softer talc-mica slate causes a terrace of lower, smoother ground.

‡ Here the gneiss is in contact with the serpentine. The long belt of serpentine starts *in the talc-mica slates* (1 m. S. E. of Paoli) more than 400 yards north of the contact of gneiss and slate.

west of Crum creek *very hornblendic* gneiss is in contact with *serpentine* for 8 miles to Taylor's run, passing 1 m. N. of Sugartown and 1 m. N. of West Chester; then, along the south side of Taylor's run to the Brandywine below Taylor's ford; thence keeping near the road from West Chester to Marshallton.

Here Mr. Rogers describes the northern belt as terminating in three narrow prongs or tongues of gneiss nosing down into and underneath the talc-mica schists.* (See page plate.)

The northern tongue he says ends near Boardsley run, not far from the county poor-house.

The middle tongue crosses the Brandywine, and ends a mile or so west of Embreeville.

The southern tongue, a little wider than the others, runs on to within half mile of Unionville.

A little east of Marshallton these tongues are united into one belt, about four miles wide.

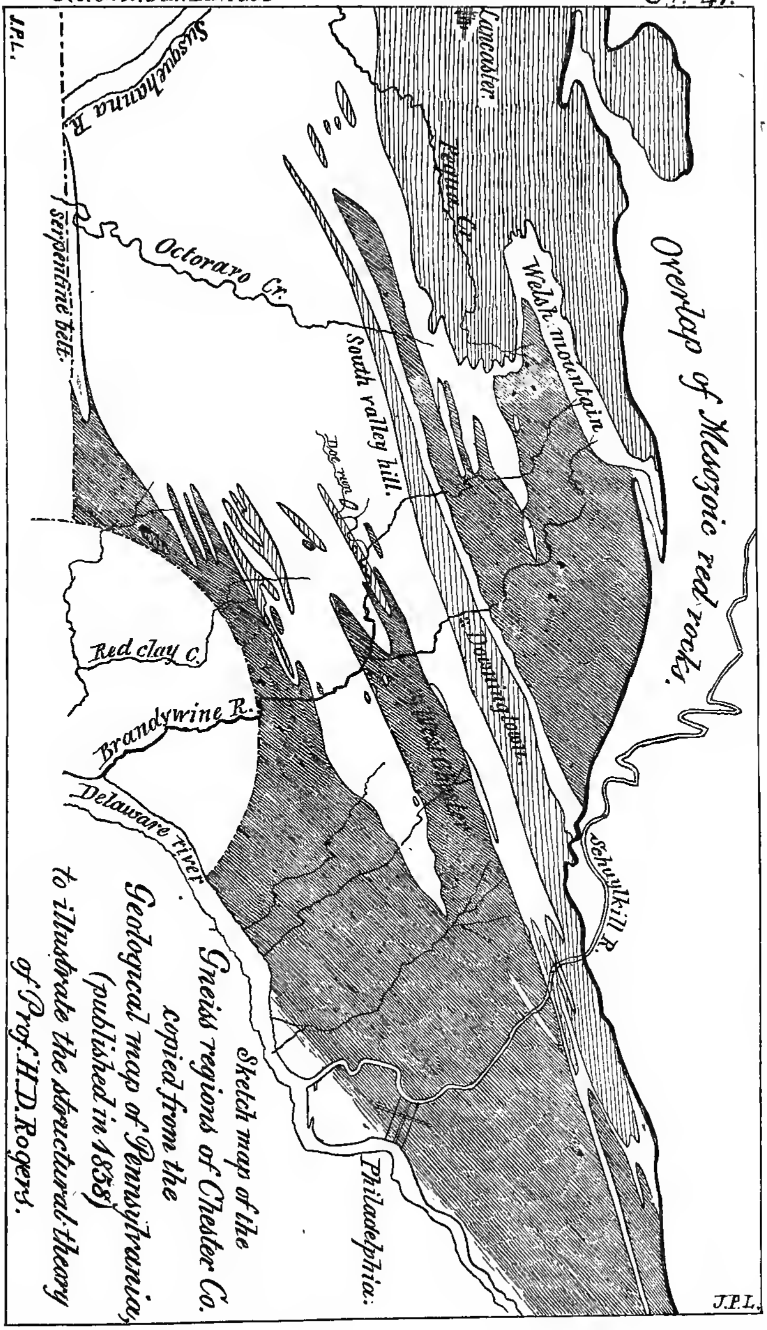
The southern margin of this northern gneiss belt he draws eastward through Yardleyville and Castle rock; crossing the Brandywine somewhere in the mile below the forks; and following the Delaware county line, the lower edge of Newtown, through the eastern corner of Haddon to the Schuylkill, a mile or so south of Spring mill.

If the rocks of this northern belt differ at all from those of the southern Philadelphia belt, Mr. Rogers thinks that they differ: 1, in exhibiting fewer micaceous strata, and including no mica slate layers at all; and 2, in a less complete metamorphism.

Its prevailing varieties of rock are: 1. Massive feldsphatic gneiss, some of it micaceous, some of it like stratified syenite, sometimes porphyroidal, and very much like that at the falls of Schuylkill; 2. Dark, hard, hornblende felspar gneiss, thinly laminated and strongly striped, when viewed in transverse section.

The whole mass shows a great excess of felspar and a comparative lack of quartz, mica and hornblende. Mica is next in abundance and is generally black, and in minute scales. Most of the hornblende appears in the upper beds,

* Geol. Pa., I, page 66, and State map of 1858.



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.

where true hornblendic gneiss beds, micaceous felspathic gneiss beds, and purely felspathic beds alternate. *Garnets are entirely absent.*

Whether influenced by a theory or not, Mr. Rogers thought he could assert that the rocks of this belt were less perfectly metamorphosed than that of the gneissoid country to the south of it (on the Schuylkill at least); their constituent crystals, felspar especially, being less exactly formed, and often in a rounded or lenticular condition. But he went a step further, and thought he noticed a progressively less and less degree of metamorphism as he went up in the order of the beds; the lower beds showing only the felspar and mica segregated, and in laminæ, and the felspar in large crystals; the middle and upper beds showing "finer laminæ and more commingled," the constituent elements less coarsely crystallized, the felspar isolated in lenticular or ovoidal knots.

It would have been impossible to speak of lower and upper beds without some well-defined conception of the structure of the belt. This conception he obtained at the Schuylkill, and it governed his interpretation of the whole belt in its prolongation through Delaware and Chester counties to its western three-pronged end.

Prof. Rogers' theory is a perfectly plain one, and is as evident on his map as in his text.

He sees the Philadelphia rocks dipping northward beneath the Manayunk rocks; these dipping northward beneath those of Sinnaminson run; these dipping northward beneath those of Greentree run; and these again dipping northward beneath the talc-mica strata of the Soapstone quarry locality.

2. He sees then a rise of the Philadelphia gneisses to the surface, an anticlinal, and finally a vertical plunge downward of these gneisses, at Spring mill, beneath the talc-mica belt of the South Valley hill.

Consequently, he regards the exposures on the Schuylkill as forming the cross section of a *synclinal* trough of talc-mica schists (his Lower Primal slates,) contained in a still wider trough of underlying gneiss rising southward at

Philadelphia, and northward at Spring mill; there immediately turning over an *anticlinal* and going down again (northwards) beneath the talc-mica schists of the S. Valley hill.*

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*"A remarkable feature in the structure of the whole southern gneissic district, is the prevalence of a northward dip in the strata. This inclination prevails along the Schuylkill, with very few local and trivial exceptions, throughout all the three great sub-divisions of the zone of gneiss, until we approach the upper or northern side of the third or northern belt. There the rocks for the first time, for any considerable width of outcrop, are contorted, folded, and lifted into a generally almost perpendicular dip. The ordinary or average angle of inclination of the strata may be stated to vary between 30° and 50°, and the prevailing point of the compass to which this dip is directed is somewhere between N. 20° E., and N. 30° E., though occasionally it is nearly N., and in one or two instances it is N. E. From Philadelphia, the whole way to the Wissahickon, there exists no interruption to this general northward dip; and not until we approach the lower edge of Manayunk is it much undulated or contorted: and even there the undulations are within very narrow limits, and produce very little reduction in our estimate of the thickness of the formation. At Fairmount the true dip of the rocks is very steep, approaching indeed to the vertical. The strata there are traversed by numerous conspicuous joints, presenting at a little distance a deceptive appearance of a nearly horizontal stratification, in thick and almost parallel beds; but this is not to be confounded with the genuine stratification or grain of the rock, as marked by the structural distribution of its mica and other minerals.

"Advancing northward, this steep inclination of the strata soon subsides, for along the shore of the river, from Lemon hill to the quarries below the Columbia bridge, the ruling dip is in only one or two local spots steeper than 40°, or even than 30°. In the quarries spoken of, it is in one or two places 50°, and even 70°. From the Columbia bridge to the Wissahickon, and even beyond it, the rocks dip with remarkable steadiness at angles seldom lower than 20°, and seldom higher than 30°. Passing the Wissahickon, they begin to exhibit a series of local contortions, though but few of these contain a dip to the southward for more than a few yards. At two or three spots below Manayunk, the inclination is as steep as 50°, or even 70°, but at the town, and indeed as far up as the Sinnaminson creek, a quite gentle slope prevails, the highest angle not exceeding 20° or 25°, excepting at one locality of very narrow contortions. Above the Sinnaminson, as far as the Greentree run, the dips are a little more variable, and generally steeper, but nearly all are embraced between the angles of 30° and 50°. In this part of the section the strata are more waved in their dip, though never thrown out of their prevailing northward declination. Approaching and passing the Greentree run, we find them through a space of nearly 300 feet in an almost perpendicular attitude; they soon, however, resumo their dominant northward dip; but from this point to the vicinity of the Soapstone quarry, they present, for the first time, a succession of synclinal and anticlinal undulations. In this division of the section, the inclination of the strata—still to a large extent towards the north—is at all angles from 30° up to 70°. It is worthy of note here, that the steatite belt itself gives evidence of containing a synclinal wave in the dip; for the talc-slates and mica-slates to the south of it, for several hundred yards, dip steadily

He applies this theory to his map by bringing the Lancaster county and West Chester county talc-mica region eastward as a long broad (synclinal) tongue, as far as Darby creek, thus separating his northern (anticlinal) belt of Spring mill gneiss, from his southern (monoclinal) belt of Philadelphia gneiss.

But the difficulties of the theory are plainly exhibited on the map ; 1, in that the theory calls for the synclinal talc-mica schist on the Schuylkill, whereas it is stopped at Darby creek ; and, 2, in that had it been prolonged to the Schuylkill it would have placed Manayunk on the axis of the synclinal, whereas the synclinal is at the Soapstone quarry two miles further up the river.

The first objection he would no doubt meet by his views respecting an upper and lower division of the talc-mica schist formation ; the upper reaches only to Darby creek ;

towards the north, at an angle of about 30°, while those of the northern side of the quarry show a steeper inclination to the south. Passing the steatite range, the northward dip is quickly resumed, and in this part of the mica-slate belt, both at the Schuylkill and on the Wissahickon, the slope is steeply towards the north.

"Entering now that division of our section which belongs to the northern belt of harder felspathic gneiss, we encounter the most irregularly dipping or undulating portion of the whole gneissic zone. Approaching the quarries of blue porphyroidal gneiss, at the lower limit of this tract, we meet with a steeply-compressed anticlinal axis in the strata, the line of the axis marked by a strong dyke of syenitic granite. Here the south dips are 70°, and even steeper, while the north ones vary from 45° to 55°. Passing the quarries, we immediately encounter a wide space of more than a fourth of a mile, in which the rocks are almost horizontal, and towards the northern edge of this we perceive an axis or turn in the dip, marking a broad, regular, synclinal trough or basin. From the northern edge of this trough, to the upper limit of the whole gneiss formation, past the William Penn iron furnace, No. 1, the gneiss is closely folded, and compressed into very steep, or nearly perpendicular dips, with numerous short plications.

"If now we review these interesting features in the structure of this broad zone of gneiss, we can hardly resist the conclusion, that in the three belts passed over by our section, there are really but two groups of rocks, a lower and a higher, and that the entire zone, viewed broadly, constitutes but one wide synclinal wave or basin, the harder felspathic and hornblendic gneiss dipping northward, throughout the whole southern belt or outcrop, and reappearing in steep and multiplied contortions on the other side of the trough; and the upper or more micaceous group of rocks filling the synclinal center of the trough, and compressed into the lesser foldings which it exhibits, by the lateral force of the wide crust undulation, within which it has been caught and folded."—*H. D. Rogers, in Geol. Pa., 1858, page 76.*

the lower running on in the trough to and beyond the Schuylkill.—The second objection he might meet by pointing to the supposed complicated structure of the trough east of Darby creek; so that if the upper mica slates had been preserved from erosion they would lie in the deepest and therefore most northern of these complications, viz: at the Soapstone quarry.*

A more serious difficulty arises from the apparently enormous thickness of the north-dipping rocks visible along the river from the mouth of the Schuylkill, past Manayunk to the synclinal at the Soapstone quarry, compared with the comparatively small thickness of the gneisses brought up by the anticlinal between the quarry and Spring Mill; for it is hard to see how the rocks in the axis of the anticlinal can under such circumstances deserve the name of the "lowest rocks;" for they ought to represent rocks far above those at Philadelphia.

It is probable however that Mr. Rogers only applied the term "lowest rocks" locally to his *northern belt*; for, his opinion that the rocks of this northern belt are less metamorphosed than those of the southern belt, and his opinion that there is a kind of obscure approach in character (upwards) of the upper gneisses to the talc-mica schists, both show that he regarded the northern belt as higher in the gneiss series than the southern belt. With this understanding his description of the northern rocks at the anticlinal on the Schuylkill is (condensed) as follows:

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*"Whether the rocks bounding this belt of harder gneiss, W. of the Brandywine, appertain all of them to the ancient gneissic slate formation, or whether they are not in reality the lower Primal slates under a highly metamorphic and crystalline condition, is a question which remains open to future research; but I incline to the belief that, within the general synclinal trough of the micaceous gneiss, where the Brandywine intersects it, we shall ultimately discover smaller synclinal waves, containing unconformable troughs of those older Primal slates. The western general limit of the middle gneissic belt may be vaguely defined, then, as occurring somewhere near the Brandywine, across which it is probable there extend some narrow anticlinal fingers, expiring, like those of the southern harder gneiss, under the overlapping, very undulating, margin of the altered Primal series. Whether, indeed, there may not occur, even in the more central tracts of this micaceous zone, between the Schuylkill and the Brandywine, some small insulated troughs of the Primal older slates, is a point which likewise remains for future investigation." *P. 77.*

An anticlinal axis lifts the lower beds in the bluff near the bend of the Schuylkill 500 yards below Wm. Penn furnace; the axis being cut by a granite vein; then north dips, for 350′, regular at 55°, declining to 40°, N. 20° W.; then 800′ nearly horizontal; then, a synclinal and gradual rise, with increasing dip, for 300′; then several beautiful folds up and down for 600′ (to within 200′ of New W. P. furnace (No. 2;) then for 1400′ nearly vertical (with possibly some folds) nowhere less than 80° N. or S.

The full text of Mr. Roger's description on page 75 of the Geol. Pa., 1858, is as follows:

Commencing at the point below the granite quarry, S. of Spring Mills, at about 100 feet S. of the end of the long tangent in the Norristown railroad, occurs the most northern good exposure on the side of the railroad. It begins with a small injection of pinkish granite composed of feldspar and quartz.

Immediately adjoining the granite on the N. side, we find a variety of massive gneiss, consisting of rather coarsely crystallized felspar, quartz, and hornblende, with some mica. Certain bands of it tend to the porphyroidal structure, from excess of felspar. It is evenly-bedded, and shows the parallel lamination of gneiss, but this is not minute or very continuous. It dips about 80° to N. 20° W. A similar massive gneiss appears to occupy the hill on the opposite side of the river, at the cuts in the Reading railroad.

About 160 feet N. of the first dyke is a second vein of granite, or more properly a syenite, producing, on the gneiss in contact with it and S. of it, a dip of 70°. This syenite is composed, chiefly, of coarsely crystallized felspar, both pinkish and white; it holds a much less proportion of quartz, and a considerable amount of large specks of imperfectly crystallized or finely granular hornblende. The injection is about 10 feet thick.

Succeeding the dyke of syenite, is a repetition of the kind of gneiss occurring to the southward, massively bedded, porphyroidal in many of its layers, of a bluish-grey color, and consisting, for the most part of a triple mixture of felspar, quartz, and mica, and occasionally some hornblende—the felspar frequently appearing in large insulated blotches. This rock is now extensively quarried; it occupies the bold point of the hill, causing a bend in the river. From the vein of syenite, for 250 feet across the strike, it dips very evenly at an angle of 45° or 50° to N. 20° W. But at that distance the dip changes pretty suddenly to a very small angle. On the side towards the syenite it is penetrated by a few injections of granite. It would thus seem that there is here a true anticlinal flexure in the gneiss—a large vein of syenite being protruded very nearly in the axis. The slight northward dip is succeeded at 900 feet from the quarry by a gentle dip to the S.

Some 387 feet N. of the small quarry, at the S. end of the new furnace (William Penn furnace, No. 2), the rock is seen in a cut made for pumps; the dip is almost perpendicular, about 87° S. It is a good exposure of a quite peculiar gneiss, massive, dark-blue, streaked, and lenticularly spotted white. It consists chiefly of felspar and dark-blue mica, in alternate slightly wavy bands or laminæ, with lenticular concretions, or crystallizations of pinkish-white felspar. Some of the beds are porphyroidal, from abundance of lumps of felspar, others minutely or closely laminated in delicate parallel, slightly wavy, bluish-black and pinkish-white streaks, produced by the two predominant minerals. This rock contains some quartz, and occasionally some hornblende. Its vertically dipping beds support the large New Iron furnace, No. 2.

At the N. end of the New furnace is a felspathic micaceous gneiss, somewhat minutely banded, without the lenticular crystallizations of felspar. 266 feet from the N. end of the New furnace is a trap-dyke, very hornblendic, about 8 feet thick.

About 421 feet N. of the north end of the New furnace is the same kind of gneiss, minutely streaked or laminated, some beds still containing lenticular segregations of felspar, but these fewer and smaller, the whole rock more minutely and evenly laminated, and more closely resembling an altered argillaceous sandstone, yet still claiming the appellation of a gneiss. The felspar has a mealy chalky aspect on the weathered surfaces.

About 100 feet N. of the north end of the Old furnace, No. 1, is an exposure of a felspathic micaceous gneiss, which continues for 170 feet. At the north end of this furnace the dip is 60°, but 100 feet further on it is 85.°

Nearly 330 feet N. of the north end of No. 1 furnace, there is a ledge of a somewhat different rock, with almost perpendicular and regular bedding. Decidedly less gneissic in its crystallization, it has lenticular lumps of felspthic mineral, and is finely streaked; the whole has an earthy sedimentary aspect, and the felspathic specks and concretions are rounder than in the true gneiss; the strike of the rock is nearly S. 70° W., or parallel with the prevailing strike of the genuine gneiss; to the southward its course is such as to range straight for the shore of the river at the ferry-house, opposite Spring Mill, and it must range thence along the north base of the belt of hills bounding the river, between the ferry-house and Merion furnace, opposite Conshohocken. This rock has a more earthy and less crystalline aspect. I incline at present to regard it as the lowermost member of our Secondary or Palæozoic system of strata. If it be really such, it is not here locally separated from the gneiss beneath it by any marked unconformity in respect to either their strike or dip, but the two sets of rocks are contrasted in a very marked manner, both in their external aspects and their mineral composition. The passage from one into the other is so abrupt as regards their composition and crystallization, as to require us to place them in wholly different system. The visible thickness of the vertically-dipping beds of this upper doubtful group is about 100 feet. This stratum forms the N. point and face of the hill, immediately S. of the Spring Mill valley.—(*Geology of Pennsylvania, vol. I, page 75.*)

2. *The Philadelphia gneiss belt.*

The *Southern* or *Philadelphia* gneisses are usually gray and bluish, finely laminated, metamorphosed strata of white chalky felspar, white or transparent quartz, and black or dark brown mica in small plates,—occasionally including small scattered garnets.* The next commonest variety is a dark bluish-gray, or greenish-black gneiss; hornblende and quartz, with a little felspar; fine grained;

* *H. D. Rogers*, Geol. Pa., p. 68.

thin bedded; fracture controlled by the prevailing hornblende. A third common variety is a light gray micaceous quartz; some beds so made up of minute quartz grains (with a little disseminated mica) as to be whetstone; but such beds are less frequent than in the middle (mica slate) belt. A fourth variety of coarser gray micaceous gneiss beds, with a preponderance of mica in rather large flakes, and less felspar and quartz, are interstratified with the other varieties, and make a transition between common gneiss and common mica slate. The more micaceous the gneiss, the more garnets it contains. True *mica slate* beds also occur, (as on the Schuylkill above and below the Columbia RR. bridge,) and increase in number going towards the north limit of the belt, *i. e.* towards the middle mica slate belt. There is also a *porphyritic* variety; large insulated segregations of crystalline felspar, having their longer axis parallel with the lamination. Such a band crosses at Falls of Schuylkill just below the quarries, and ranges east to Nicetown and west to the Lancaster pike five mile toll-gate. Another crosses the W. C. plank-road just east of Darby creek.

These rocks are *decomposed* to a considerable depth beneath the surface; the felspar turned into kaolin, and the mica and the hornblende blackened by iron. Hence the great quantity of mica in the soil of Delaware and Chester counties, and the general absence of stones in the fields. The potash of the felspar thus set free has made the soil fertile, and the mica keeps it loose. A sharp sand for mortar is got by sifting the decomposed rock.

Granite veins are numerous; narrow, white dykes branching through and contorting the gneiss, and often expiring within it. They are all alike, coarse mixtures of independent crystals chiefly of white felspar, with quartz, and some mica, the mica often wanting. These veins are also so decomposed as often to be hardly traceable.

Thick *dykes* of *felspathic syenite* occur; others of white coarse-grained *granite* (without mica); others of *greenstone trap;* others of pure quartz; others of chrome-iron ore;

others of *serpentine.** The *syenite* dyke rock is a confused crystalline mixture of smoky felspar and quartz, with sometimes a little mica; more rarely a little hornblende; sometimes almost none of either, and then the felspar crystals are large and perfect. Its imperfect stratification occurs only near the walls. It makes a better, tougher, and more lasting building stone than common gneiss. The largest quarries of it are on Naaman's, Brandywine, and Christiana creeks, in the State of Delaware.

Trap dykes are also numerous. One three miles long crosses the county line at the Danville-Huntingdon road, changing the gneiss into syenite.

The contorted gneiss of the Schuylkill at Philadelphia, has been quarried for many years for rough wall work. Numberless plications show to what pressure the whole mass has been subjected. A universal cleavage masks the stratification, which is only 10″ to 20″ northward.†

The belt of felspathic gneiss is quarried not only at Philadelphia, but on Darby, Crum, Ridley, and Chester creeks, yielding excellent stone.

The *southern hard gneiss belt* is given by Mr. Rogers a northern border line which runs in an uncertain and indefinable way from Manayunk to the Brandywine, "somewhere north of Chadd's Ford. (Page 76.) This lack of precision he ascribes partly to a deficiency of exposures, and partly—"perhaps chiefly—to the existence of a succession of undulations, which may cause a repetition of outcrops, or separate belts of the two divisions of the strata." "It would seem that after crossing the Brandywine, the rocks of this group run forward for several miles into Chester county, and through Delaware into Maryland, in a succession of gradually contracting ranges or *slender fingers*, the more northern of which terminate near Redclay and White-

*Mr. Rogers was convinced that it had at last been settled that *some* serpentines were "unstratified;" the head-line shows that he meant "true igneous rocks."—*Page 69.*

†The quarries at the Falls of Schuylkill expose the thick-bedded, felspar quartz, black mica gneiss, sprinkled with solitary garnets, dipping 15°—20° N. 20° E., and traversed by great N. & S. joints.

clay creeks, while the middle ones . . . cross Little Elk creek . . . south of the great *serpentine*."

"It is very obvious" he says "that the gneiss is here *undulated* in a series of *wide anticlinal waves*," judging not merely from the alternate N. & S. dips along the Brandywine, but from "*synclinal troughs* of palæozoic rocks,* which in the S. E. corner of Chester county, and the N. E. corner of Delaware State, *are folded in between the uplifts of the gneiss*," (page 77.)

The western limit of the belt he more precisely described on page 81, thus:

West of the Brandywine, the southern gneiss belt becomes separated like the northern belt into several anticlinal fingers:

1. One crosses at Chadd's ford and runs two miles towards the western end of Pennsbury township. Its principal variety of rock is a dark blue and speckled hornblendic gneiss. A similar rock appears in the prolongation of the finger, in two or three detached broken ridges, all the way to Pierce's paper-mill on East Red Clay creek.

2. Another projection broader than the first borders on the south edge of the Kennett Square basin of limestone and sandstone. Hornblendic gneiss and common gray felspar-mica rocks (often very micaceous and full of large garnets) both appear.

Approaching East White Clay creek this belt splits into three narrow tapering fingers (anticlinal) ending a little west of Middle Whiteclay creek: *a*, the northern, crosses the creek a little below Moor's grist-mill; *b*, about Wickersham's mill; and *c*, the southern, south of Pennock's factory, extends a mile further west. Hornblendic gneiss prevails in these fingers.

Micaceous and talcose slates, identical with similar rocks further north, fill up the (synclinal) intervals.

South of finger *c*, a broad tract of hornblendic gneiss crosses White Clay creek above its forks, its northern edge

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* Primal and auroral, *i. e.*, the sandstone and limestone rocks which appear upon the map, and which Mr. Rogers considered to be Potsdam and Calciferous, or Trenton.

passing by Chandlerville (on E. White Clay,) its southern edge running in contact with the crystalline limestone basin of Nevin's quarries, and both stretching towards Kemblesville.

The broken outcrop of gneiss may be seen at the main forks of White Clay, and for a half mile up stream, some of the beds being hornblendic. This belt bounds the south side of the limestone, and stretches into Maryland.

3. *The Middle or Micaceous belt.*

Four varieties of rocks are noticeable here:

a. Garnetiferous micaceous gneiss is considered by Mr. Rogers to be the most characteristic variety of rock in this belt on the Schuylkill.

b. Wavy, contorted mica schist is the next commonest variety. In beds of this kind coarsely crystallized mica predominates, flakes of which are often twisted around grains or bunches or lumps of quartz. The planes of crystallization in the whole rock seem to be oblique to those of original deposit. This variety graduates into the common more micaceous sorts of gneiss by the addition of finely granulated crystalline quartz, felspar and hornblende.

c. Hornblendic gneiss beds alternate with beds of varieties *a* and *b* throughout the southern half of the belt on the Schuylkill and Wissahickon; they deserve to be called *hornblende schists.*

d. Whetstone schists make a fourth variety, greatly developed along the northern rim of the belt in the interval between the soapstone and hard felspathic gneiss of the northern belt. This fourth variety is a more schistose, gray, fine-grained mixture of granular quartz and minute mica-scales (the quartz preponderant,) a kind of whetstone, many layers breaking up into long narrow chunks, with smooth sides and very ragged ends like rotten wood.

Towards the middle of the synclinal these whetstone schists are interstratified with more or less frequent and thick bodies of the twisted mica-schists full of garnets.

Towards the northern side they alternate somewhat with greenish talc-slates, *i. e.*, talc replaces mica in some of the layers.

The soapstone (steatite) strata on the Schuylkill are only mica slate beds with the mica wholly replaced by talc ;*

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*Mr. Rogers considers the "infusion of magnesia" to have come from the "dyke of intrusive serpentine which everywhere adjoins" the steatite. (Pages 71, 72.)

His Wissahickon section (page 72), intended to illustrate this "middle belt," is as follows:—

"This section, intended to illustrate the middle belt, commences at the most northern exposure of the mica-slate S. of Thorpe's paper-mill. The rock is a mica-slate, exceedingly full of garnets. Besides the mica, which is the principal constituent, and the garnets, it contains a little minutely disseminated quartz, but not much. The dip is 80° to S. The mica is everywhere more or less minutely wavy, and in the very micaceous kinds it is coarsely crystallized and remarkably waved. It weathers a ferruginous brown.

"The exposure of talc-slate, steatite, and serpentine commences opposite the bridge over Wissahickon creek, near Thorpe's mill. The first rock which here succeeds the garnetiferous mica-slate above described is a stratum of green talcose slate, estimated to be 40 feet thick; this dips about 70° to N., about 20° W. Reposing upon it at the same angle is the steatite group, which is an alternation of talc-slate and talcose steatite; the former material apparently predominating. This occupies an estimated breadth or thickness of 120 to 140 feet. In the northern half of this group the talcose chloritic beds contain numerous octahedral crystals of oxide of iron.

"Next in order N. and adjoining the talc-slate and steatite, is the dyke or bed of mixed serpentine and steatite. The thickness of this is not great, apparently not more than from 12 to 20 feet.

"A steatitic talc-slate adjoins the serpentine on the N., extending for 30 feet.

"Then succeeds a garnetiferous mica-slate, dipping about 85° to N., 20° W., quite garnetiferous, precisely similar to that below this. It dips, as do the others, and extends for 75 feet.

"This is succeeded by a close-grained quartz-slate or scythe-stone, the thickness of which is about 100 feet.

"Following this is the ordinary very garnetiferous mica-slate—mica in large flakes, and crinkled. This bed has a thickness of 50 feet.

"Next in order, extending for 500 feet, is a group of beds composed chiefly of a hard quartzose mica slate, or thin-bedded quartzose gneiss, including alternating thin beds of the ordinary garnetiferous mica-slate.

"This brings us to a bold dyke of bluish-gray granite, from 50 to 60 feet in width.

"Then succeeds a hard blue micaceous quartzose gneiss, or thin-bedded flagstone. This alternates with the more rough mica-slate; it has a thickness of about 200 feet. On the N. edge of the quarry it seems to dip S. 85°, but towards its northern limit its dip is about 85° to N.

"Succeeding this rock is a belt of close hornblendic gneiss and quartzose mica-slate, having a thickness of 200 feet, its northern limit coinciding with a marked depression in the hills. These are the uppermost or terminal beds and their importance at the top of the series (where both Mr. Rogers and Mr. Hall place them) may be estimated from the fact that the belt extends from Chestnut Hill east of the Wissahickon, to Mill creek beyond Merion Square, about five miles.

In Chester county on the Brandywine Mr. Rogers says that all the exposures above Brinton's ford, or between the ford and the main fork, exhibit decomposed micaceous gneiss of the ordinary quartz-felspar-mica kind, with some thin-bedded hornblende gneiss, and numerous beds of very micaceous gneiss full of *large garnets.* Occasionally thin granite-like gneiss beds occur with very parallel bed plains, and square fracture; looking singularly like much altered *Potsdam sandstone.**

The prevailing dip is to the south-east, but there are many plications.

It will be seen from the summary of Prof. H. D. Rogers' observations in 1851, given above, that he was guided everywhere by a theory of parallel *anticlinal folds* in the great Azoic or Hypozoic strata; and of intermediate *synclinal troughs*, some of them wide and deep, others narrow and shallow, but all of them containing preserved remnants of more micaceous strata, of a later age, but probably older than the hydro-mica slates of the South Valley hill.

In no respect however does he settle the great question of what the true relationship may be between the older and newer gneisses,—between the newer gneisses and the talc-mica-schists,—between the talc-mica-schists and the sand-

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of the great gneissic formation. A spring of remarkably pure, well-aerated water occurs in the flagstone group, a little N. of the granite quarry.

"Passing the depression in the hill, we enter immediately upon the primal older slates in their usual metamorphic condition, with characteristic white streaks of imperfectly crystallized felspar and dark hornblendic mineral, and with the roundish specs of semi-crystallized felspar. One band in this formation is excessively hornblendic, very ferruginous, and may possible include some workable iron ore. These rocks possess precisely the type which they exhibit on the Schuylkill. Their thickness on the Wissahickon creek cannot be less than 300 feet; dip about N. 20° W."

*Such beds also occur on the Schuylkill between Fairmount and Manayunk stone (quartzite)—between the quartzite and limestone—between the limestone and serpentine—in the southern townships of Chester county.

After an apparently copious and precise array of facts the geology of the whole district remains as confused and obscure as ever. The section along the Schuylkill is the key to the lock; but the key will not turn in the lock; the door remains closed. The section along the Brandywine is equally illegible and therefore useless. Darby, Crum, Ridley, Chester creeks furnish an abundance of exposures, but nothing clear and certain can be made out of them. We travel to and fro across the hills and find no clue to guide us out the labyrinth of infinitely various and yet strangely similar deposits, the strike and dip of which is everywhere more or less doubtful to the eye and tempting to the imagination.

After giving Mr. Rogers' notes and before giving Mr. Frazer's, the following notes by Mr. Hall will be of some value; they will at least explain the coloring of his Delaware county map as extended tentatively over the southern part of Chester county.

The Southern gneiss of Chester.

*Notes by C. E. Hall.**

On the accompanying map I have not attempted to distinguish the areas of mica-schist from the areas of felspathic micaceous gneiss, or to group these strata in belts as I have done on my map of the Schuylkill river country.

The *serpentine areas* I have defined as closely as the scale of the map would allow, and I feel pretty sure that the rock does not extend beyond the geographical limits which I have assigned to it at the various places where it is marked on the map.

The *hydro-mica slates* (of the South Valley hill belt) spread through the south-west part of Chester county with

*Mr. Hall was directed to extend his gneissic and other areas across the Delaware county line into Chester county in the spring of 1882, and these notes were submitted with his map soon afterwards.

a somewhat indefinite line through Londonderry, Oxford and Lower Oxford for its southern limit; and this indefiniteness, due to a general lack of exposures, is expressed on the map by a dotted line.

The *limestone spots* upon the map merely indicate places where limestone actually shows itself at the surface, and has been quarried. How much beyond and in what direction from any given spot upon the map it may extend can only be conjectured from the soil and contour of the surface.

There can be little doubt that the exposures in E. and W. Bradford township belong to a continuous belt of concealed limestone, which probably extends to and includes an extensive area over which are scattered the quarries in Newlin and W. Marlborough townships; but I have chosen to leave it for those who consult the map to establish the connection by exploration.

The limestone exposures shown on the map in the southern part of E. Marlborough are almost certainly connected together underground, and probably also with the limestone exposures of London Grove township to the west. Eastward this belt of limestone rocks may extend to and beyond the Brandywine, where limestone exposures are marked upon the map.

The limestone exposures of Kennett township are probably part of a third belt running west through New Garden to the Avondale quarries, and connecting in some way, not visible at the surface, with those of London Grove township.

If the county map of Chester showed the topographical features of the surface by contour lines or otherwise, one would be greatly assisted in the effort to establish these connections, and if it could be shown that the numerous exposures of limestones arranged themselves as a whole by continuous or zigzag belts, a long stride would be taken towards a proper understanding of the structure of the country and the order of the formations.

The *sandstone areas* noted on the map are of indefinite extent. The exposures are everywhere slight, uncertain, and disconnected, and nothing can be less satisfactory than our knowledge of the true relationships of these beds to the underlying and surrounding formations.

The *syenite areas*, on the contrary, are generally well defined by steep hillsides or escarpments. The rocks are like those of the same age in Delaware and Montgomery counties; and the syenite country of West Goshen, East Goshen, Willistown, aud Easttown, cut transversely by the upper waters of Chester, Ridley, and Crum creeks, spreads across the county line into Delaware county as far east as Itham creek in Radnor township.

A. Laurentian syenite.

There are three principal well-defined areas of this rock in Chester county south of the Chester valley:

1. The eastern area, which is a continuation of that found in Delaware county, extends through Easttown, Willistown, and East Goshen townships. Its western limit is not sharply defined, but is found in the vicinity of West Chester, in West Goshen township. Its northern boundary is more or less sharply defined by the serpentine belt which crosses the northern portions of the townships above named. Its northern edge is somewhat irregular.

In Easttown township, and near Ridley creek in Willistown township, the syenites extend into Delaware county; but otherwise along the northern margin the rocks of this group are overlaid by decomposed felspathic micaceous and garnetiferous schists.

The principal exposures of rocks are along the branches of Crum creek, and near Ridley creek in Willistown township; in the vicinity of Milltown P. O. on the east branch of Chester creek in East Goshen township; and near the west branch of Chester creek, south of West Chester, in West Goshen township.

2. A small area of syenitic gneiss occurs at the junction of the east and west branches of the Brandywine creek in East Bradford and Pocopson townships, and south-west of West Chester. It is surrounded by mica-schists and micaceous gneisses similar to those along the northern edge of the syenite east of West Chester.

The rocks are exposed on the east side of the east branch of the Brandywine creek at Bower's paper-mill above Maconkey's bridge. North-west of Maconkey's bridge, and between the east and west branches of the Brandywine creek, there are numerous exposures of decomposed syenitic rock.

3. An elliptical area of syenite extends through the central portion of Kennett township into New Garden township south of the P. & B. Central railroad and Kennett Square. At several places along its northern edge are limestone quarries, but decomposed mica-schists are usually found flanking the area. The principal exposures are along the branches of Red Clay creek.

4. A small area of syenitic or granitoid rock borders the Delaware State line in south Kennett township, but I am in doubt whether its rocks belong to the Laurentian syenite series, although they resemble in some respects those of the areas already mentioned. The surface of the country furnishes few exposures, and the rocks are poorly exhibited in a few excavations and along the creeks.

B. Sandstone and Quartzite.

1. A sort of quartzose sandstone is exposed a short distance north of Dilworthtown, along the road leading to Thornbury P. O. It appears to be confined to a limited area in the extreme eastern edge of Birmingham township.

2. A small outcrop of sandstone is found on the Baltimore Central railroad between Norway P. O. and Kennett Square, in Kennett township. The rock is much decomposed, and the exposure consists principally of loose sand of a light yellow color.

3. An apparently narrow belt of quartzose rocks and sandstones extends through East Marlborough township into London Grove and West Marlborough townships, extending from the edge of Pennsburg township, not far from the Red Lion hotel, to the vicinity of London Grove P. O.

Going west this belt of quartzite and sandstone spreads out over the larger part of the north-eastern corner of London Grove township, and northward into the south-eastern quarter of West Marlborough.

Along the southern margin of this whole area of sandstone and quartzite, limestone has been found in a number of places.

Along the northern margin the quartzites and sandstones appear to merge into feldspatic schists and micaceous gneisses.

There are few good exposures of the rock throughout the area. It is occasionally seen near the road leading from the Red Lion hotel in East Marlborough township, to London Grove P. O. In Londongrove township, along the highway south-east of Chatham P. O. ; and also in a few places between Chatham and London Grove P. O. In West Marlborough township quartzite is exposed along the road north of Woodville, and on the State road west of Upland. Near the east township line decomposed quartzite and sandstone, with limonite, is exposed along the road leading from Unionville to Doe Run P. O. Here garnetiferous mica-schists occur in proximity to the sandstone.

C. Limestone.

1. In East Bradford the limestone quarried at Cope's mill, a short distance west of West Chester, is impure, and its extent is apparently not great. It seems to be included between beds of micaceous gneiss.

2. South-west of Cope's mills four limestone quarries are arranged in a line running south-west.

3. There are signs of limestone on the east branch of the Brandywine, a little north of Copesville.

4. In West Bradford, the principal quarry is located on the poor-house property near the west branch of Brandywine.

5. In Newlin township, limestone is found near the Brandywine at Embreeville station.

6. A small quarry is located near the south-west corner of Newlin township near the road leading from Mortonville to Unionville.

7. In West Marlborough there are numerous quarries in the vicinity of Doe Run P. O.

8. A small quarry has been worked, just west of Upland.

9. In London Grove township limestone quarries are worked between Irondale and Chatham, along the steep banks of White Clay creek and its branches.

10. In New Garden township is a small quarry near the west branch of Red Clay creek.

11. Extensive exposures of limestone occur along the northern edge of New Garden township, in the banks of Broad run, a branch of the east branch of White Clay creek, south of Chatham and London Grove.

12. In London Britain township limestone is found near Broad run, and also near White Clay creek, about half way between Landenberg and Strickerville P. O. The exposures lie along a N. E. and S. W. line.

13. In the town of Kennett Square, limestone appears on the south side of the P. & B. C. railroad.

14. Also on a tributary of the east branch of Red Clay creek (near the railroad) about half way between Norway P. O. and Kennett.

15. Through East Marlborough township limestone is found in several places south of the road leading from the Red Lion hotel to London Grove P. O., and apparently in continuation of No. 12.

16. In Pennsburg township limestone occurs at Brinton's bridge on the Brandywine creek, which may be a continuation of No. 12 and No. 15.

17. At the western end of Thornbury township, northwest of Dilworthtown, limestone appears.

The limestone exposures in East and West Bradford, Newlin, and West Marlborough townships are no doubt outcrops of a more or less continuous belt. Those of East Marlborough township no doubt extend into London Grove township. Those of Kennett and the north-eastern edge of New Garden township no doubt extend to and are continuous with the deposits at Avondale.

The dip at all localities appears to be southward and southeastward.

The overlying rocks are commonly of a fine-grained garnetiferous shaly mica-schist, which decomposes rapidly at the surface.

D. Hydromica-schists.

The southern margin of the mica-schists belt is pretty well defined from the Delaware county line to Brandywine creek, but from the Brandywine to the Lancaster county line, (Octorora creek,) it is somewhat indefinite.

The range of serpentine and limestone exposures limit it through Easttown, Willistown, East Goshen, and West Goshen; the range of limestone quarries defines it through West Bradford, but 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.

The general tint of the hydromica-slate 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 in Willistown and East Goshen townships turn into a true garnetiferous schist.

The presence of the prevailing rock is indicated on almost all the roads which traverse the belt, but the principal good exposures are along the Brandywine and its tributaries, and in the cuttings of the Pennsylvania railroad, where it is descending into Chester valley.

E. Mica-schist.

I found no way to distinguish into groups the mica-schist and micaceous gneiss rocks which spread extensively over southern Chester county. They are usually much decomposed at the surface of the country, and exposures are very unsatisfactory. All I can say is, that the mica-schists of the country west of the Brandywine are more felspathic than those further east.

As to structure, I found it impossible to reconcile the stratigraphy of this part of Chester county with that of Delaware county, by means of the numerous outcrops of rocks along nearly all the roads which cross the schist belt (if it be a belt), nor by means of the larger streams.

At a few places the rocks look to be identical with rocks seen nearer the Schuylkill river.

1. The rocks exposed on Big Elk creek, in Elk and New London townships, are to all appearances identical with the micaceous gneisses of the Philadelphia belt exposed along the Schuylkill river. (Report C⁶.)

2. In the vicinity of Copesville, East Bradford township, the rocks exposed along the east branch of the Brandywine creek are a coarse micaceous gneiss identical with those on the southern edge of Delaware county. Syenite is found in large quantities in the micaceous gneiss at and north of Copesville. Its occurrence is similar to that as found in the vicinity of the White Horse tavern in Ridley township, Delaware county.

3. In Birmingham, Westtown and Thornbury townships flaggy micaceous felspathic gneiss is found which resembles that along the Schuylkill river above Manayunk and on Mill creek.

4. In the southern portion of Pennsbury township the rock is usually a garnetiferous mica schist and gneiss.

5. Along the east branch of White Clay creek extensive exposures of mica schist and micaceous gneiss occur.

6. The most extensive exposures are in New Garden township, north of Landenburg. Large quarries are in operation in the vicinity of Avondale.

7. Large deposits of kaolin are found in the southern portion of New Garden township at the head of Broad run. The gneiss exposed in the vicinity of the kaolin is light colored and very felspathic.

8. Throughout London Britain, Franklin, London Grove, Penn and New London townships the rock exposed is usually light-colored felspathic mica-schist and gneiss. In the northern edge of Newlin and West Marlborough townships coarse felspathic micaceous gneiss is exposed in the vicinity of Buck and Doe run.

9. Throughout Lower Oxford and East Nottingham townships there are few exposures and the surface is usually covered with a thick deposit of soil probably in part derived from the decomposition of the felspathic gneisses. There are a few exposures along the escarpments of Big Elk creek.

F. Serpentine.

Serpentine is found in a large number of places, but the deposits near the south-eastern edge of the county are usually in small patches; but there is a very extensive area of it in the south-western corner of the county, covering much of Nottingham and passing over eastward into Elk.

1. In Easttown small and unsatisfactory exposures of serpentine are found along the southern edge of the hydro-mica slate belt; one of them is not far from Eagle Station, close to the edge of Tredyffrin township.

2. An unbroken strip of serpentine extends completely across Willistown and East Goshen townships along the south side of the hydro-mica slate belt.

3. Three miles south of this strip, and near the south-west corner of Willistown township, is a small patch of serpentine, principally exposed along the Philadelphia and West Chester turnpike, a short distance west of Ridley creek.

4. In continuation of the line of No. 2, and a mile north of the town of West Chester, runs a prominent ridge of serpentine between the hydro-mica slate belt on the north and the felspathic micaceous gneiss belt on the south.

The rock is exposed on the West Chester Branch of the Pennsylvania railroad between McCall's and Patton Stations. There are also extensive quarries near Taylor run, west of the railroad.

5. On the same line further west between the two branches of the Brandywine serpentine occurs on the East and West Bradford township line near Copesville.

6. Serpentine occurs at Strode's mill close to the south line of E. Bradford township between Lenape P. O. and West Chester.

7. Serpentine is visible in the road near Strode's mill, in the angle of the north corner of Birmingham township.

8. The extensive serpentine quarry of J. Brinton's, on Ridley run, in the south-west corner of Westtown township, exhibits the rock finely, (see plates 13 and 14;) but I was not able to convince myself of the true character of the de-

posit. It has the appearance of lying in a shallow synclinal basin. The area of serpentine is small. A large vein of light-colored granite (shown at the right in one of the plates) crosses the edge of the quarry.

9. A small deposit of serpentine occurs in the eastern edge of Westtown township south of the Philadelphia and West Chester pike.

10. Serpentine is found close to the west branch Brandywine in the southern edge of West Bradford township.

11. Two small serpentine areas occur in Pocopson township a short distance south of the North Brook P. O. The rock is exposed on the slate road which leads from West Chester to Unionville.

12. In the south-eastern portion of Newlin township serpentine is found over a considerable area. The rock is exposed along the road leading from Embreeville to Marlboroughville. *Corundum* has been mined here in considerable quantity.

13. The Elk and West Nottingham townships serpentine area is not sharply defined. Serpentine and its associated rocks cover all that portion of Elk township lying south of of Barren Branch, a tributary of Little Elk creek. The exposures are numerous along roads crossing the area.

Throughout West Nottingham the exposures of serpentine and débris derived from the decomposed serpentine extend over a greater portion of the surface of the township. Numerous *chrome* mines have been opened south of Nottingham township, east of the Philadelphia and Baltimore Central railroad; and also near the Maryland State line south-west of Freemont P. O.

Brinton's serpentine quarry.—The following notes were furnished by the Census Bureau:—

The quarry of Joseph H. Brinton, at Avondale, three (3) miles south of West Chester, was first opened in 1730.

Estimated quantity of green serpentine quarried since that date 500,000 cubic yards.

Largest block ever taken out, 3 feet square section and 16 feet long. No larger can be obtained.

Rock "not stratified;" splits in rhombic forms; texture fine; used to a limited extent for ornamental purposes; chiefly as building stone."

Principal markets, Philadelphia, New York, Washington, Baltimore, and Chicago.

Prominent structures built of it, the University of Pennsylvania, the Academy of Natural Sciences, both in Philadelphia; about twenty churches in Philadelphia; and the court-house at Wilmington in Delaware.

Transport, 3 miles by wagon to railways.

In 1880, 6,000 cubic feet of rock were moved, valued at $10,000. But Mr. Brinton reported that 1880 was not an average so far as production was concerned. He has sold some years $30,000 worth of stone. The capital is $25,000.

Three grades of materials produced.

Price of building stone undressed at the quarry, $0.20 per cubic foot; of stone for free work, $0.40; of stone cut to size for base courses, &c., $1.00. Some of the rock is dressed at the quarry: cost of dressing averages 10 cts.; of pointing 10 cts.; ax-hammered, 5 cts; bush hammered or chiseled, 15 cts. It can be sawn.

Discoloration penetrating from joints not perceptible.

Depth of cap or worthless rock at the surface to be stripped, 15 feet. No water in the quarry.

Hand and horse power, with derricks, is alone used. Two steam engines for sawing are not now in use. Only $50 worth of powder was used in 1880; full time, for 8 months from November to May; the remaining 4 months the quarry was idle; 10 hours a day's work; 40 hands the most employed at any one time between 1870 and 1880; 14 in 1880, 10 of whom were employed in quarrying and four in dressing; with 12 horses, 3 wagons, and 2 vessels. Average wages of skilled mechanic $2.50; of day laborer $1.50.

Carter and Reynold's serpentine quarry; P. O. near Rising Sun, Md., but the quarry in Chester county, Pa.

Opened in 1875; largest block, 2 tons. Stratified, rhombic, fine-grained, homogeneous building stone (used also for ornametal purposes) in Philadelphia and Baltimore ; Laboratory of the University and other buildings.

Two grades of stone ; price of undressed stone in quarry, $2.85 per perch, for broken range work ; $2.40 for rubble facing. No discoloration from joints inward. Can be sawed.

Stripping 4 feet ; quarry naturally drained ; power hand and horse, with derricks, and gunpowder ; stone wagoned ¾ mile to railroad. Worked nine months on three quarter time ; 10 hours a day, from November to May.

Dunlap and Martin's serpentine quarry, near the last, has not been worked to any extent for several years.

Crump's serpentine quarry, near Media in Delaware county has not been operated for some years. Some of the stone for building the University of Pennsylvania in 1870, '71 and '72 was got here.

On the limestone outcrops of southern Chester Co.

*Prof. H. D. Rogers' notes.**

Before leaving the southern gneissic region to take up the description of the talc-mica belt of the South Valley hill, lying north of it, I will now give the notes which Mr. Rogers took of the various limestone outcrops in the southern townships of Chester county ; not only for their intrinsic merit as careful observations of what could be seen at that time in the limestone quarries, some of which have changed since then ; but in further illustration of his structural theory of the region. On page 224, he thus writes :—

"It will be seen, I think, that by far the greater number of these insulated outcrops and small basins of limestone, *though probably not the whole of them*, are, with whatever rocks they are in contact, only outlying patches of the great auroral limestone of Southern Pennsylvania, folded, metamorphosed, disguised, and mineralized by intense igneous action, or that trasforming agency which invaded all the older formations of the district in which they

* Geol. of Penn., 1858, Vol. 1, pages 225 to 231.

occur. Many of the lesser and more insulated of these outcrops of limestone show themselves only in solitary quarries; but even in the great majority of such instances the topographical and geological structure of the adjoining ground strongly imply the existence of smaller or larger basins, or true *synclinal troughs*, resting sometimes on the gneiss, but in most cases embraced as folds within the talcose micaceous slates, which, upon the view I have adopted of the metamorphism of our rocks, are only the upper and lower primal slates of the base of the palæozoic system altered and crystallized. The limestone of these tracts exhibits all gradations of metamorphism, from the first change from earthy limestone to compact crystalline clouded marble, on to granular limestone and dolomite, and even to the most coarsely crystallized calc-spar, with segregated crystalline graphite. In some cases the rock is almost pure carbonate of lime; in others, it is a true dolomite, or double carbonate of lime and magnesia. In some instances, again, it is free from any foreign minerals; while in sundry other cases there abound numerous mineral species in all stages of segregation or development, from the most vaguely-formed crystalline nuclei to the most perfectly definite crystals. In certain examples we may distinctly trace the minerals through all these gradations of evolution, while in other instances we can ascribe their presence only to intrusive veins of true igneous or volcanic matter, bringing the foreign substances into the limestone, or commingling them with it."

Mr. Rogers arranges the exposures of limestone in six lines,† each of which he believes to be a separate parallel synclinal trough.

In adopting this theory he was influenced by a conviction that these limestones are outlying remnants of the *Valley limestone formation*, which once overspread the whole

† He calls them "belts," a term which I will not use here, because it has been used so much in describing the areas of gneissic rocks. I have also transposed the order of his belts; he begins at the south with *belt 1*, and ends at the north with *belt 6*. I shall extract his description of the northern belt first, and the others in order southward,—the order adopted in the preceding pages.

country, superposed upon the *South Valley hill talc-mica-schist formation* (in the absence of the intervening *Potsdam sandstone*,*) —remnants left in some of the deeper of those folds which may be imagined to exist everywhere, and in imagining them to exist here he may be right.

But in adopting this theory, he necessarily subordinates the possibility of at least some of these limestones (the crystalline, if not the granular) being of an older date than the *Valley limestone*, and belonging to the gneissic system at the present eroded surface of which these limestones appear. On Mr. Rogers' theory it becomes very difficult to imagine any of these limestone outcrops to be *anticlinal* exposures, coming up from below; or to imagine any of them imbedded in the gneiss.

I will have to mention hereafter the (apparent) *anticlinal* structure of the limestone quarry near Chadd's ford; and Mr. Rogers himself gives instances of the (apparent) *interstratification* of these limestones with gneiss.

An admission is made by Mr. Rogers (on page 231) which would have been most extraordinary (because subversive of his whole theory) had he known in 1858 (when these notes were published) what is now known, viz: the existence of *Hudson river fossils* in the roofing slates of York county. He writes, after describing the northernmost line of limestone exposures west of West Chester, thus :—

"No true gneiss shows itself N. of the poor-house chain of quarries; but all the strata embraced between that long synclinal line and the great limestone valley of Chester

* In explanation of this absence Mr. Rogers writes, on page 231, thus :—

"The comparatively rare occurrence of white primal sandstone outcropping from beneath these lower beds of the auroral magnesian limestone, which have just been described, should not surprise us when we reflect that that rock is extremely thin, and is sometimes altogether wanting along the southern margin of the deeper and more continuous limestone trough of the main Chester county valley; and when we also remember that this formation, nowhere very constant in thickness over wide districts of country in the Middle States, exhibits in Chester county a progressive general increase of its mass as we advance to the northward. This fact alone makes it very probable that the non-appearance of the sandstone round some of these southern basins results from their lying outside of its continuous area, and it may serve furthermore to explain the absence of its characteristic fossil the scolithus, even where the rock itself occurs."

county pertain to the primal series. This series is here evidently of great thickness; it is made up of micaceous and talcose slates, embracing a large proportion of fissile clay-slate of the nature of *roofing-slate*, and *it apparently belongs to the same place in the formation which embraces the Susquehanna zone of roofing-slate* making so conspicuous a feature near the State line."

Whether Mr. Rogers would have accepted Mr. Hall's theory of the *Hudson river age* of the slate belt after the discovery of the Peach Bottom fossils the lamented death of the great American geologist prevents us from knowing; but certainly Mr. Hall's theory could desire no stronger backing than that afforded it by the opinion of Mr. Rogers that the Peach Bottom roofing-slates of York county were identical with these roofing-slates of Chester county.

In describing the Street road limestone range of quarries (page 228) under the head of "*granite dykes*" (see below) Professor Rogers uses the following language:—

"This protrusion of the ancient gneiss rocks in anticlinal undulations through the overlying limestone, sometimes with traces of the primal white sandstone and primal micaceous crystalline slates, some times without any vestiges of them, is a feature confirming the evidence derived from various other phenomena, of the original unconformity in deposition of the primal and auroral strata upon the gneissic rocks.

Further on he continues thus:—

"It is not practicable to make out in strictly correct sections the undulations and dips of the strata, either in this or any other of the more complicated of these limestone troughs; but their structure is evidently identical with that of the Appalachian basins generally. The inclination of the rocks on the S. or S. E. side is either steep or inverted, unless where an actual dislocation forces the approximately level limestone to abut against uplifted walls of older gneiss or granite, while the dip on the N. or N. W. side is almost universally southward at a gentle angle.*

[* The reader must be warned again that these positive statements are not supported by instrumentally studied cross-sections, borings, extensive quar

Again he says:—

"An interesting geological feature connected with this long and shallow trough of auroral limestone, is the marginal outcrop of *primal white sandstone*, and *primal crystalline slate*, which almost everywhere borders it. These rocks are best seen along the old street road, and the lanes leading out from it, upon the northern side of the basin. The conformable dip of the sandstone under the edge of the limestone, or towards the center of the basin, is well exhibited at the street road opposite Joel Bailey's, and again at Taggart's cross-roads further east.*

"In some of the quarries the limestone, especially near the southern margins of the trough and its branches, is *overlaid by* micaceous and other crystalline slates, identical almost in composition with the micaceous *crystalline schists* of the primal series. These are evidently but the intercalated argillaceous beds which almost everywhere belong to the lower part of the auroral limestone formation. In truth, it would seem as if nearly all the limestone of this and the other small valleys of the district belonged to the very *base of the formation*, or that portion which presents a type of passage from the primal or schistose into the auroral or magnesian limestone series; and this view is in consonance with the *obvious shallowness* of all the limestone masses embraced within these troughs.

With regard to *fossils* he says:—

"Neither in this nor in any other of these local isolated tracts of auroral limestone and primal white sandstone, do we meet with these rocks under a fossiliferous type. Obscure traces of the *Scolithus*, the sole fossil of the primal white sandstone yet discovered in Pennsylvania, have been once or twice met with upon loose fragments of the rock; but

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ryings, long-cuttings, or strongly marked and easily understood topographical features. They are merely interpretations of isolated exposures in accordance with a general theory, and need thorough verification before being accepted as authoritative statements of proved facts.]

[*This is an important locality for the support of Mr. Roger's general theory and deserves all the consideration which can be bestowed upon it. Another important locality is given below in the last paragraph of the description of Kennet Square limestone range.]

this is the only instance of organic remains yet discovered. But this absence of fossils from these the most ancient of all the Palæzoic deposits of our county, need not at all surprise us, since their occurrence is extremely rare even in those basins of the same formations further N., where the strata are much less altered and crystalline. Indeed, we know of no discovery of organic remains in the lowest beds of the auroral limestone equivalent to the rock of these valleys in any part of the middle states."

1. Doe run limestone.—"The shortest of all the synclinal tracts of the crystalline magnesian limestone south of the Valley of Chester county, is that in the vicinity of Doe Run village. This extends for rather more than a mile in a S. W. direction, parallel to the valley of Doe run, from near the village to the vicinity of Passmore's mill. Near the first-named locality the limestone is exposed in a quarry owned by a Mr. Hayes, and it is again developed south of the Doe run, near the south-western end of belt, in quarries owned by Hoopes and Jones.

2. Boardley Run limestone line.—"The next and most northern principal belt of the crystalline auroral limestone occupies a long and narrow trough in the strata extendingfrom Boardley run, one mile west of Marshalltown, to near the south-west corner of West Marlborough, a distance of about nine miles. It is not certain that we have here a simple continuous synclinal trough ; for though the natural exposures and quarries of the limestone all lie in one very straight and narrow line, parallel with the other basins, and with the general strike of the strata of the country, yet these developments are too far asunder, and the topographical features of the belt are too irregular to allow us to assert positively that the limestone is strictly connected along this whole tract. The probabilities are great, however, that it is.

"Commencing with the most eastern exposure, we meet the rock first in *Moses Bailey's quarry*, on the east side of Boardley run. The rock here yields a tolerably good lime for agricultural uses.

"The next opening is in the *Chester county poor-house* *quarry*, about one mile further south-west. The rock is a highly crystalline dolomitic limestone, containing in some, especially the upper layers, much segregated brown mica; in fact, certain of the upper beds include so much mica and quartz as to be entitled, from their composition, to be called *calcareous gneiss*. These upper beds are regularly *interstratified* with a micaceous gneiss-like rock; and even between the more massive beds of the true magnesian limestone, the parting layers are almost invariably either pure mica and talc, or a mixture of these with quartz, entitling them also to the name of *gneiss*. The whole mass dips 35° to 45° to S. 20° E. Much as these overlying strata resemble genuine gneiss of the micaceous-slate variety it is difficult, from the analogy of the limestone to that of other localities unquestionably *superposed upon* the primal crystalline rocks, to regard it as a merely intercalated mass between the strata of the genuine old gneiss formation; it is more in accordance with all the results of our researches, to view this limestone and the associated gneiss-like beds as the passage rocks between the primal and auroral series, and to conceive that they hold their existing position either from an *inversion* of the strata, or from a *dislocation* of the south side of the limestone valley of the poor-house farm, causing them to dip south-eastward against the uplifted older rocks which border them in that quarter.*

"In this quarry occur several interesting minerals, the most remarkable being the chesterlite, once regarded as a variety of felspar; also rutile and feathery talc.

"Next in order south-westward, among the quarries belonging to this belt of limestone, is that near *Hoopes' grist-mill*, in an ox-bow bend of the Brandywine, in Newlin township.

"Nearly two miles to the S. W. of this locality occur the quarries of *Pierce and Edwards*; these are about two miles

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[* Nothing could more plainly show the unsatisfactory state of our knowledge respecting these formations than this whole paragraph; or better illustrate the various methods which a general theory has at command for extricating itself from embarrassments produced by unexpected local phenomena.]

north-west of Unionville, on the road from Embreville to Doe Run village.

"One mile and a half further south-west, and in the same exact line, is *Connor's quarry*, on the road from Unionville to Doe Run. These three last-named quarries yield an excellent lime. The rock is very crystalline, and more or less dolomitic. In Connor's quarry the strata dip at a moderate inclination to the S. E.; and north of the quarry there is a band of south-east dipping primal white sandstone; and still further north are the older primal slates in the condition of quartzose mica-slate, likewise dipping to the S. E., or beneath the primal sandstone, at an angle of 45°. Micaceous sandstone, and occasionally primal white sandstone, border its synclinal valley on the north throughout its whole length; but the white sandstone is detected only occasionally. The older primalslates, highly crystalline in their structure, likewise bound the valley on the south; but in some of the exposures of the limestone we are at a loss to determine whether the rocks of this character, leaning upon the dolomite, are the true primal slates *inverted* upon the limestone, or overlying schistose beds belonging to the alternating portion or base of the auroral limestone series. It is pretty evident that these rocks, as they occur on the south side of the limestone at Connor's quarry, are really the primal slates *inverted* against the limestone.

"The furthest opening in the limestone in this synclinal is that of *Baker's quarry*, half a mile east of the west line of West Marlborough township.

"It is more than probable, from the remoteness of the localities at which the limestone has been discovered, and from the irregular features in the topography of this belt interrupting the continuity of the valley that limestone does not occur in one unbroken trough, but has been lifted and washed out of the shallow basin in several sections of its length; and it is indeed natural to suppose that the synclinal structure itself is not perfectly regular; the more probable view being that the whole tract is *a chain of short* *and narrow basins*, rather than one long, continuous, straight trough.

"About two miles N. W. of West Chester, in the valley of Taylor's run, and therefore east of the Brandywine, is a small outcrop of limestone on land belonging to *Caleb Cope*. This is so nearly in the line of the long chain of quarries of the poor-house synclinal, that we are almost induced to conjecture that it may belong to the same trough with them, and that it is an outstanding remnant of the auroral rocks preserved from denudation.

3. West Marlborough Inn limestone line.—"This narrow belt, marked by a narrow irregular valley, extends for about three miles from near the Drover's Inn (west of Unionville) to nearly the north line of London Grove township, and passes less than half a mile to the north of West Marlborough Inn. In this vicinity, and likewise nearer to the Drover's Inn at *Logan's quarry*, the limestone has been quarried to some extent. The most western quarry of this tract is *J. C. Bailey*, situated about one mile S. of W. from the West Marlborough Inn; but the features of the country and the soil indicate that the limestone belt is prolonged cousiderably further south-westward in the direction of Cook's grist-mill, though the rock has nowhere been opened.

"Traces of the primal white sandstone are to be met with on the margin of this small trough. Between West Marlborough Inn and London Grove post office, and even further to the south, the older primal rocks, in the condition of true micaceous slates, occupy a broad anticlinal belt, their south dip towards the street road limestone basin being obvious in all the neighborhood around London Grove meeting-house and post-office. Between the Friends' little meeting-house and Pusey's grist-mill we pass over the south-east dipping outcrop of this primal sandstone, the same which forms the northern boundary of the street road basin.

"In Eli Logan's quarries, about one mile W. of Unionville, the limestone dips to the S. E. about 30°, but irregularly, and with some remarkable folds. Resting apparently *upon the limestone*, there is a white *gneissoid* rock, possibly only a highly altered or crystalline form of the upper primal slates, in alternation with the limestone.

"It is a conceivable supposition, however, that this rock pertains to the true gneiss formation, and that all the strata in this quarry are *inverted*."*

"In the anticlinal belt which separates the street road trough of limestone from that of West Marlborough Inn, there would seem to be very little or no genuine gneiss west of the meridian of Unionville; but between the Brandywine and Unionville, that rock does appear in occasional narrow uplifts. What seems to be genuine hornblende gneiss occurs near the Marlborough meeting-house, some two miles E. of Unionville. The rock here contains some epidote.

4. Street Road limestone line.—"This is the longest and most continuous of all these limestone troughs. It commences on the east, near the Red Lion inn, on the old street road half a mile west of the east boundary of East Marlborough, and it ranges, curving gently southward a distance of about nine miles, nearly to the middle branch of White Clay creek; the trough is broadest between the west branch of Red Clay creek and the east branch of White Clay creek, having there an average breadth of more than half a mile. The western half of the whole basin is subdivided into *three subordinate narrower valleys*, all of them containing the limestone more or less continuously, and all of them ending westward in the vicinity of West Grove Friends' meeting-house.

"The main or northern fork of the basin stretching toward the middle branch of White Clay creek approaches to within half a mile of Kuisey's clover-mill. Between the east branch of White Clay and the western end it contains three or four considerable quarries of the crystalline lime-

[*This is a remarkable instance of the influence which a general theory exerts over special observations. The only ground for the suggestion of an *inverted* structure here is, of course, the theory that none of the limestones along this belt *can be beneath gneiss*, or *gneissoid rocks*. The suggestion that the gneiss here may be metamorphosed talc-mica slate rock is only another desperate way to escape from the difficulty.]

stone. The chief of these are known as Bailey's and Philips'. This last-named quarry, being situated furthest to the south-west of all the limestone deposits in this part of Chester county, supplies stone and lime for agricultural uses to a circle of country south and west, extending to twelve or even twenty miles. Though it is evident from the topographical features of the whole limestone trough from the Red Lion inn on the east to Philips' quarry on the west, that it is a true basin, yet, from *the appearance in its more central parts* of occasional exposures of *the upper primal slates*, and *even of the subjacent gneiss rocks*, it is probable that the bed of the valley is more or less undulating, and that the limestone is not everywhere absolutely continuous.

"The middle trough of limestone throws off another and shorter branch, diverging from the southern side at a point between the two branches of the East White Clay creek, not far W. of Hicks' grist-mill. This smaller valley runs for about one mile and a half to a little north of West Grove meeting-house. The limestone has, as yet, been very little opened, or quarried in this smallest branch of the general basin. Though the limestone of this branch basin, N. of Pleasant Valley, ranges apparently in a continuous belt, it has been quarried hitherto at only two points: the most eastern one is where it was wrought some years ago by Robert Michener; and the more western, at present wrought by Henry Story, is one fourth of a mile north of West Grove meeting-house.

"The southern branch leaves the main basin about midway between the west branch of the Red Clay and east branch of White Clay, and runs as a narrow, somewhat irregular trough for more than three miles, to a point a little E. of West Grove Friends' meeting-house. There are several quarries of good crystalline limestone included in this lateral valley. One of these is near Hume's grist-mill on White Clay creek, and two others are at William Jackson's, toward the western end of the trough. The point of junction of this small valley (sometimes called Pleasant Valley) with the main basin is in the neighborhood of Joshua Pusey's mill.

"The furthest westward point at which limestone has been detected in this narrow belt is a little S. of West Grove meeting-house, where a tradition of the neighborhood alleges it was met with many years ago in a well, and the topography seems to testify that the rock may prolong itself thus far.

"Excellent crystalline limestone, well adapted for agricultural and other uses, is quarried at William Jackson's; some of the beds being pure white carbonate of lime, while others consist more or less of dolomite.

"Brownish mica occurs in these beds, as in nearly all the limestone quarries of this class throughout the county.

"Adjacent to this quarry there occur scattered chunks of altered white primal sandstone imbedding small crystals of *rutile.*

"In the mica slate bordering the limestone of Pleasant Valley, there have occasionally been found segregated nodules containing a compact kyanite.

"Iron ore, but apparently not in large deposits, occurs S. of West Grove meeting-house.

"A tooth of *mastodon giganteus*, apparently the fifth molar, was found some years ago in Pleasant Valley, about one mile E. of William Jackson's on the east branch of White Clay creek.

"*Uplifts of gneiss and dykes of granite.*—In fact, there seems to extend an anticlinal axis of gneiss parallel with the southern margin of the trough, the whole way from Joel Bailey's, a little west from the west branch of Red Clay, to Hicks' grist-mill on the east branch of White Clay, a distance of more than three miles. Connected with this line of uplift we may occasionally detect an obscure outburst of granite. The gneiss is itself massive and granitic. The anticlinal structure of this narrow protruded belt of older rock is well seen on the farm of Joel Bailey. Fig. 30 exhibits its features as exposed near his house. This anticlinal is said to range for nearly two miles to the eastward, and to approach the east branch of Red Clay; but I have not traced it there.

"*Granite dykes*—Just north of Hicks' grist-mill white granite shows itself in a low ridge, with contorted materials of the primal white sandstone, borne through the limestone apparently by the intrusion of the granite.

"There is a third dyke of granite, possibly a branch of that which ranges by Hicks' grist-mill, which passes S. on the south side of Baker's quarry, between the branch basin containing this quarry and that at William Jackson's. This dyke extends from near Baker's quarry to a point about one fourth of a mile N. of West Grove meeting-house.

"Another but shorter anticlinal uplift of granitic gneiss passes through the farm of William Jackson in Pleasant Valley, and appears to range for a mile or more north-eastward, passing under the knoll upon which the Locust Grove school-house stands.

"Besides the quarries already enumerated, there are two or three good ones in the vicinity of Joel Bailey's. In all of these artificial exposures the general character of the limestone is very similar. It is generally a *crystalline dolomitic limestone*, sometimes very granular, disposed in massive beds, and contains, for the most part, more or less *segregated mica*, talc, and other minerals, the mica being rarely absent. In consequence of these extraneous substances, it seldom yields, when burnt, a perfectly white lime, though in nearly all the quarries some layers may be found so free from these foreign minerals as to produce, if care be observed in quarrying it, a stone convertible to lime of the very finest quality.

"Between the southern border of this Street Road basin and the northern edge of the Kennett Square limestone trough, or that bounded by the Toughkenamon ridge, extremely little genuine gneiss shows itself at the surface, and that which does appear is the hornblende variety. It is obvious that the anticlinal belt which divides these two zones of auroral limestone is here composed mainly of the *older primal slates*, under the highly crystalline micaceous type, which they wear so generally throughout all the southern district of Pennsylvania. The true gneissic or genuine hypozoic metamorphic rocks, elevated only in narrow and broken fingers to the westward of the Brandywine, here hardly lift themselves to the surface. The primal white sandstone on both the N. and S. sides of the Street Road limestone basin, possesses all the features distinctive of this rock under its most metamorphosed form. Thus, where it dips gently southward under the limestone on the north side of the valley near the Red Lion inn it contains the same minute broken crystals of *schorl*, the same thin partings of highly crystalline *talc*, and wears the same felspathic and semi-vitreous aspect which so strongly characterize it throughout all its outcrops bordering the great limestone valley of Montgomery and Chester counties.

"Both in Baker's quarry in the middle branch of the Street Road basin, and at Jackson's in the southern branch, the dip of the limestone is for the most part very gentle; that at Baker's flatly undulating, while that at Jackson's is at the low angle of 20° southward into the base of the hill which bounds it.

"In William Jackson's quarry well-developed crystals of phosphate of lime have occasionally been found; and the same mineral has been met with one mile south-west of Chatham in a soil derived from the primal mica-slate.

"Asbestos, in flexible sheets like paper, has also been found in Jackson's quarry.

"Nearly in a line prolonged eastward from the Street Road basin, but some three and a half miles eastward from its eastern termination at the Red Lion Inn, there is an insulated outcrop of both the auroral limestone and the primal white sandstone just W. of the Brandywine a little below Brinton's ford. This is at *Goodwood's quarry* (formerly Harvey's.) The quarry has not been wrought for several years. The limestone is for the most part sandy. Sandstone is scattered on the surface in the immediate vicinity of the limestone, but does not exhibit itself in place. Very probably this patch of limestone is an outstanding remnant of a more continuous belt which may once have connected it with that of the Street Road basin, for it seems to lie in the same general synclinal wave in the older strata. In like manner there can be very little doubt that the eastern prong of the Kennett Square basin, now embracing the detached quarries of Passmore, Mendon Hall, and Nichol's, was once prolonged across the Brandywine at Chadd's ford; for we have the plainest proofs in the synclinal dipping of the hornblende gneiss of that vicinity, that a great natural trough or basin, competent to contain, until denuded, a belt of primal and auroral rocks, does here exist.

5. *Kennett Square limestone.*—"A line of detached limestone quarries extends from a point one mile S. W. of Chadd's Ford, on the Brandywine, to the east branch of White Clay creek, near Avondale post-office. A branch of this trough, apparently a narrow or compressed fold in the strata, commences at *Nickle's quarry*, includes *Mendenhall's*, which is likewise in Pennsburg township, and embraces *Goss's quarries* near Red Clay creek. It passes or unites with the southern side of the main Kennett Square basin in the vicinity of Pierce's paper-mill. In the quarry of Mr. Mendenhall the limestone is scarcely at all exposed, for, as Mr. Mendenhall alleges, it lies very deep. It is overlaid by sandstone, which exhibits an apparent dip of 35° to the S. on the south side of the quarry.

"The main Kennett Square limestone-basin, divided from the foregoing narrow trough by a ridge of dark hornblende gneiss, extends from a point nearly north of Goss's, to the east branch of White Clay creek, near the Avondale post-office, as above mentioned. This trough is itself divided at its eastern end by a wide low anticlinal hill of the primal white sandstone, upon which the village of Kennett Square is seated, separating it into two branches or subordinate shallow basins. These coalesce into one wide basin a little west of Kennett Square at the west branch of Red Clay creek. Here the valley has a width of more than three fourths of a mile, but the limestone does not apparently everywhere underlie it. This rock is quarried at *Hoope's*, near the creek. From this neighborhood the belt steadily contracts to its western termination beyond the east branch of White Clay. The trough is bounded south by hornblende gneiss towards its eastern end, and by the lower primal slates in the condition of micaceous and talcose slate towards its western. On its northern side the *primal white sandstone*, underlaid by highly-crystalline primal slate, everywhere borders the limestone at the foot of the Toughkenamon hill.

Type locality.—"The unconformable relation of the primal rocks and limestone to the gneiss is nowhere better shown than along the southern side of this basin in the vicinity of Red Clay creek, and nowhere have we more convincing proof that the white sandstone and micaceous slates associated with it, bordering this trough, are of the true primal series; for here they not only dip beneath the limestone all along its northern margin, but rise in regular anticlinal saddle through the limestone to divide the basin into two regular troughs.

"Throughout this belt the limestone, wherever it is exposed, has a highly crystalline structure, and the greater part of it is more or less magnesian or dolomitic.

"The branch basin south of Kennett Square exhibits a deep deposit of sand in the bed of the valley, extensively concealing the limestone. As already stated, the village of Kennett Square itself rests on primal white sandstone."

6. *White Clay creek limestones.*—These are:—

Brown's quarry.—"The most southern of these within the State is a narrow trough ranging S. W. a length of more than two miles, from near the Delaware state line to near the forks of Whitely, or White Clay creek. This narrow belt is bordered on both sides by gneiss, chiefly of the hornblende kind. Three principal quarries occur in the tract. The first encountered, going west, is Brown's limestone quarry, on a tributary of the east branch of Whitely, near the Delaware line. It contains but little of the pure white limestone, the rock being much metamorphosed, and rather full of mica. It is, however, regularly stratified, and the lime furnished is well adapted for agriculture.

D. Nevins's quarry.—"This is situated to the west of the preceding about three fourths of a mile, being on the east side of the east branch of Whitely creek. The strata dip at a gentle angle south-eastward, and a low anticlinal undulation or saddle lifts the talcose slates underlying the limestone to the level of the bed of the quarry, proving the total thickness of the limestone not to exceed 40 or 50 feet.*

"This quarry also contains a small amount of white limestone, much brown mica occurring throughout the upper beds. It yields, however, a pretty good lime. The limestone is overlaid by the ordinary very micaceous rock, dipping on south side of quarry gently south, and there is a dyke of granite at the south margin.

J. Nevins's quarry.—This is the furthest opening south-westward within this belt, and seems to be near its termination. It is between the two branches of Whitely creek, one mile above their junction. It has been wrought for 30 years by Mr. J. Nevins, and includes both the blue and white varieties of the crystalline limestone. The white variety is a coarsely crystallized dolomite, producing an excellent lime for building. This occurs in massive beds in the lower part of the quarry, through a thickness of 20 feet. Above it there lies, in equally massive layers, a variety streaked with bluish and brownish bands, deriving its colors from the presence of an abundance of bronze-colored mica. This colored rock produces a grey lime. An anticlinal axis or saddle runs longitudinally through the quarry in a direction about N. 60° E., (see Fig. 29.)

On the north side of this saddle the dip is about 45°, *under* a micaceous gneissic-looking rock. The dip on the south side of the quarry is to the S. about 30°. A contortion along the southern edge of the quarry, and in the gneiss-like rocks which border it, presents an unequivocal indication of an *inversion* or fold by which the gneissic rock is brought to lean over or rest upon the limestone which it elsewhere supports.

"Fragments of altered white sandstone occur in the vicinity of the quarry, to intimate that this is really a compressed trough of the primal and first lowest beds of the

[* This is one of Mr. Rogers' important observations and has a considerable bearing upon the identity of this limestone with that of the Downingtown valley.]

Auroral strata. The whole breadth of the valley embracing the trough of calcareous rocks is not more than 200 yards.

"There is a quarry of limestone in the State of Delaware, about three miles S. of the state line, distant about four miles from the above-described one of J. Nevins, in a a direction not far from S. 30° E."

*Similar outlying limestones in northern Chester County. H. D. Rogers' notes continued.**

The gneissic region of the townships lying north of the Downingtown limestone valley will be described further on; but it will serve a good purpose to give here Mr. Rogers' notes respecting exposures of limestone which occur in it, because they suggest the idea that the gneiss formation itself contains limestone beds, rather than the idea that all the limestones of Chester county must needs be referred to the *valley limestone formation.* It will be noticed in reading his notes, that Prof. Rogers carefully abstains from his *synclinal outlier* theory, and ascribes these limestones, very doubtfully indeed, to a plutonic origin. In the present state of science such a suggestion is inadmissable.

"1. We meet with is a small outcrop about three fourths of a mile W. of the village of Charlestown, and a little north of Pickering creek, near Clevenstine's foundry. The bed or mass appears to be but a few feet in thickness, and resembles more *a layer in gneissoid micaceous rocks*, or even an intrusive vein of impure calcareous spar, than a folded bed of limestone at the passage of the primal and auroral series. It was at one time quarried to a small extent, and burned in a limekiln, but the lime was dark and impure.

"2. The next outcrop of limestone occurs near the village of Kimberton. This is a small bed of altered crystalline limestone, chiefly in the condition of calcareous spar, with scattered crystals of plumbago, epidote, and two or three other minerals. It occurs very near the contact of gneissic rocks and overlapping red sandstone, and adjoins

* Geology of Pennsylvania, 1858, page 231. Notes collected about 1852.

a dyke of syenite, to which it owes, most probably, its highly crystalline structure.

"3. Another locality is near the northern road leading from Kimberton to the Yellow Springs; it adjoins the large ore-pit on Mrs. Lewis's farm. This limestone has been quarried, and converted into good lime.

"Ascending French creek, the next is at Scuyer's quarry, near Bachardt's oil-mill. This outcrop extends westward into the next farm.

"4. There is another on the south side of French creek at Vanlear's, half-way between Pughtown and Coventry, but south of French creek. This also has been quarried and converted into an good lime.

"5. A little to the west of Vanlear's is a small exposure of the limestone at Christman's, which has been converted into an excellent lime.

"6. There is another small exposure south of Coventry Village.

"7. Following the south branch of French creek occurs another isolated bed in Nantmeal township, south of Miller's grist-mill.

"8. A little west of Warwick furnace we meet with another small bed in contact with micaceous gneiss.

"9. A dyke or vein of sparry limestone forms the northern wall of the iron ore-pits at Crossley, one mile north of Knauertown. It is in contact with a wide dyke of granite, and includes several crystalline minerals, and exhibits every indication of having been at one time in a state of fusion.

"10. There is a long and narrow strip of limestone in Uwchlan township, west of the Little Eagle Tavern; its total length, as indicated by a succession of sink-holes, and one or two small quarries, and by two or three wells sunk into it, is probably one and a half miles. The rock is a very coarse, crystallized, white sparry limestone, abounding in numerous little flakes of plumbago. It has been found to produce, when properly burned, an excellent white lime. It lies chiefly in low meadow ground, and under a deep covering of soil, and being very narrow, is obscurely seen. It is therefore very difficult to pronounce whether it is an igneous vein or a bed in the metamorphic gneissoid strata, or again a closely-folded narrow trough, doubled between, but yet overlying these."

The serpentine outcrops of southern Chester county with Prof. H. D. Rogers' notes of 1853.

The southern edge of the South Valley hill belt of talc-mica slates is defined upon the map by a chain of dots and stripes of two colors representing outcrops of serpentine and outcrops of crystalline limestone.

Were these outcrops ranged in more than one line the task of explaining their appearance at the surface would be much easier. But a *single line* of them necessarily places them either at the top or at the bottom of the talc-mica schist formation; Mr. Hall choosing the former, Mr. Rogers the latter alternative.

The case is complicated by the fact that the outcrops along this one line are sometimes serpentine, sometimes limestone. It looks as if the serpentine might be a subsequent modification of the limestone; or else, that one and the same original magnesian sediment was heavily charged with carbonate of lime in some places, and was a non-calcareous silicious mud in others.

It would of course be possible for the two species of rocks to have no connection (although making their appearance at the present surface under precisely the same circumstances, and along one continuous straight line between a talc-mica region and a gneiss region) if they were sporadic deposits at very nearly but not quite the same geological horizon; like (for example) the Lower Helderberg coral reef deposit and the Oriskany sandstone deposit; except that the Oriskany is often seen actually superimposed upon the L. Helderberg, whereas no case is recorded of the serpentine and crystalline limestone of our line being seen in contact.*

* A trivial exposure of steatite rock on Taylor's run is mentioned by Mr. Rogers "close to an outcrop of granular limestone."—*Geol., Pa., p. 169.*

If Mr. Hall's structure be accepted, if the talc-mica belt be Hudson river slate, then this serpentine limestone range would represent the Upper Silurian calcareous deposits.

If Mr. Rogers' structure be accepted, if the talc-mica belt be primal slates passing northward underneath the Potsdam sandstone and Valley limestone, then the serpentine limestone range can have nothing to do with the Valley limestone formation.

But in that case the limestone and sandstone outcrops to the south of the serpentine-limestone range, and the numerous exposures of serpentine also to the south of the range, can also have nothing to do with the Valley limestone and Potsdam sandstone. And yet Mr. Rogers and Mr. Frazer assign said limestone and sandstone exposures, or some of them, to that relationship.

The subject is crowded with embarrassment; and all the more, seeing that the serpentine-limestone range along the south edge of the talc-mica belt ought to hold some discoverable relations with other ranges of serpentine crossing Delaware, Chester, and Lancaster counties; as well as with the famous serpentine outcrop between limestone and gneiss on the Delaware river, north of Easton, in Northampton county.* (See Report D[3], 1882.)

Continuing for the present to regard merely the serpentine limestone range at the junction of the talc-mica belt with the gneiss, the following description of it by Prof. Rogers (G. P. p. 169) will show that it is far from being as simple an affair as the map would make it. After describing the serpentines of Montgomery and Delaware counties, he comes to his "third belt of serpentine near Paoli," and proceeds thus:—

Serpentine near Paoli.—"We come next in order to the

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* The fact that the Northampton county serpentine underlies the Great Valley limestone formation in connection with Potsdam sandstone supports Mr. Rogers' views in Chester county, and strongly opposes Mr. Hall's conjecture that the Chester serpentine may be Upper Silurian. On the other hand the fine serpentine outcrops on lake Memphremagog at the Canada-Vermont line are clearly Upper Silurian, but they are far removed from any gneissic region. Mr. Hall, after examining the Easton serpentines, considered them altered calcareous slates lying at the base of the limestone formation, over the Potsdam sandstone.

most extensive serpentine range of Chester county. This has its eastern extremity on the farm of General Wayne, of Revolutionary memory, about one mile south-east of the Paoli Hotel, and just at the line of Easttown and Willistown. Its western termination is near the western line of East Goshen, and about two and a half miles N.N.E of West Chester. These limits give a total length of about six miles. Its course is W. about 25° S., coincident nearly with that of the strike of the gneiss and talcose slate which border it for the greater part of its length. Commencing in a narrow point of the General Wayne farm, it widens rapidly as we trace it westward, until, at a distance of a mile at and beyond Maris' grist-mill, its total breadth is nearly 2,000 feet. In this central part of its course it runs for nearly three miles almost parallel with the old State road to West Chester, at an average distance of one third of a mile, gradually approaching the road until it crosses it about four miles from the Paoli, or three fourths of a mile north-east of East Goshen Friends' meeting-house. It is here reduced to a breadth of no more than 400 or 500 feet. Under this average width it ranges on, passing the Barren Hill school-house and across Ridley creek, and thence for one mile further to its termination beyond the old blacksmith's shop at John Gheen's farm. Throughout its entire range this serpentine appears chiefly as a stratified rock, and in its widest central portion we may distinctly perceive that it has a synclinal or undulated structure. It is, indeed, rather an impure talcose slate, largely impregnated with serpentinous matter, than a zone of genuine intrusive serpentine. Dykes of this mineral it does, however, embrace, and these on a small scale are very numerous, but they bear in the aggregate a small proportion to the whole belt. Its stratified structure is well exposed at the crossing of the state road, where it dips 70° N.; also in the ravines which cut it near the Barren Hill school-house, and still more convincingly near the old smithy at John Gheen's in which latter locality it has a nearly perpendicular dip, but discloses under close inspection innumerable minute contortions and plications of the thin laminæ of the rock.

"The eastern end of this zone of serpentine is bordered both south and north by the talcose-slate formation, in which it seems to lie as a folded synclinal trough; but from the vicinity of Maris' grist-mill to its western termination, its southern margin is in contact with a massive hornblendic gneiss, its northern touching in some places upon ordinary talcose slate; but in others, especially towards the western end, upon quartzose and garnetiferous micaceous gneissoid rock, of the group I have called Azoic. This garnetiferous micaceous gneiss may be seen dipping steeply northward, conformably with it, close to John Gheen's dwelling. The prevailing dip of the hornblende gneiss bounding it on the south is northward 70°–80°.

"Along the northern edge, or a little outside of the northern margin of this line of serpentine, trap-rock occurs in greater or less abundance, and apparently as a succession of narrow elongated dykes. These seem not to be strictly parallel with the serpentine and other strata, but to observe a more north-east and south-west direction. Narrow dykes of this rock intersect, indeed, this range of serpentine barrens in many neighborhoods, and this is a feature which may be noticed in nearly all the outcrops of serpentine within the State."

It is evident that even a synclinal belt of serpentine 2,000 feet wide, or even 400 feet wide, can mean nothing else than a great thickness of the talc-mica schist formation metamorphosed more or less completely into serpentine. And a good cause for such alteration is present in an extensive outburst of *trap* close by; and everybody familiar with the surface of Delaware and Chester counties knows how almost invariably its trap and serpentine appear together. This of itself effectually divorces the serpentine outcrops of Chester county from the limestones.

Mr. Rogers continues his description thus:

Gheen's serpentine.—"There is a small and apparently insulated development of serpentine about three fourths of a mile S., 45° W., from the old smithy near Gheen's dwelling. It is evidently not in the prolongation of the long belt just described, but is almost exactly in the range of the Serpentine barrens one mile north of West Chester, with which it is possibly united, though no external indications of such connection present themselves, there being an interval of half a mile between the small patch and the eastern extremity of the main West Chester line of barrens. Though small, this area of serpentine is readily discerned, forming a little elliptical mound."

West Chester serpentine.—"In the same general line with the long range of serpentine traversing Willistown and East Goshen, though strictly about one third of a mile further S. E. than its line of strike, is the serpentine belt of the West Chester barrens. The N. E. point of this appears to be just S. W. of the east branch of Chester creek, or one fourth of a mile N. E. of the West Chester railroad. It crosses the railroad nearly two miles from the center of West Chester, exposing imperfectly its stratified structure in the railroad cuts; whence it ranges about one mile further between the forks of Taylor's run. The mean width of this belt is at least 1,000 feet. Though chiefly an impure and stratified serpentinous talcose slate, the tract includes many injections of genuine igneous serpentine.

"Like all the middle and western portions of the Paoli belt, this tract is bordered on the south by massive hornblendic gneiss, while it is fringed on the north by the earlier talcose slate and micaceous slate of the South Valley hill, into which it appears somewhat abruptly to graduate.

"The more compact varieties of this serpentine have been used for building stone in West Chester and its vicinity, and the material proved to be well adapted for many architectural uses. It has a very pleasing effect when newly built into walls, as it has a quiet tone of grayish green; but exposure to the elements for a few seasons causes it to fade, or to become more dull and grayish. Several neat structures have been built of it."

Here Mr. Rogers introduces clearly a distinction between two kinds of serpentine. It is of no consequence that he uses the old epithet "igneous," where more recent writers would have used the safer non-committal phrase "intrusive:" the distinction between the altered magnesian slates and the solid rock serpentine is the important point. Geologists may differ in regarding the solid rock serpentine outcrops as dykes or as sediments; they can hardly differ in regarding them as essential parts or products of the highly magnesian slate formation in which they lie; as merely those parts of it which have been, by some means or other, *excessively* metamorphosed. Those who do not believe in their being dykes point to their apparent stratification, as shown in the pictures of J. H. Brinton's great quarry in W. Thornbury township, (plates 13, 14,) where the cause of the hardening and cleaving of the mass is not a trap dyke, but a huge extrusion of granite.

Hoope's serpentine.—"To the south-west of the main West Chester belt of serpentine there occurs near Hoope's saw-mill a small outcrop of serpentine and steatite, which is evidently in the same line of strike with the large serpentine tract north of West Chester, and the small detached one to the east of that.

Cob's serpentine.—"Another trivial exposure of magnesian rock, chiefly steatite, occurs on Taylor's run, on the land of Caleb Cob, *close to an outcrop of granular limestone.* These are about half a mile south-west of the previously mentioned locality of serpentine.

Blackhorse serpentine.—"A still more trivial locality of steatite is at the Blackhorse tavern, on the road to Taylor's ford. It is in the same general line with the previously mentioned localities of magnesian rocks.

Wurth's serpentine.—"Again, on the same line, both serpentine and steatite present themselves about three fourths of a mile south-west of the Brandywine, on the farm of Mr. Wurth.

"All the above six exposures of serpentine and steatite occur so nearly in one line, and this is so probably a line of *dislocation* connected with the *synclinal fold* of the older strata, that we can hardly doubt that these outcrops derive their existence from one chain of injections of true serpentine mineral along the southern margin of the talcose primal slates."

Mr. Rogers considered the serpentine and steatite outcrop near Marshall's mill, W. Br. Brandywine, and the serpentinous strata with serpentine injections near W. Marlborough inn, a separate line.

Another group he made out of the following exposures: 1. Serpentine and steatite ½ m. S. E. of Willistown inn. 2. Serpentine with carbonate of magnesia, crystalline chlorite and Klinoclore near Darlington corner. 3. A large mass of serpentine, with lithomarge and fine talc, near Strode's mill. 4. Serpentine N. W. of Strode's mill. 5. Isolated patches in L. Oxford.

Unionville serpentine and corundum.—"We have arrived now in our progress towards the S. W. at a conspicuous belt of serpentine, about equal in magnitude to that north of West Chester, and one of the most interesting of the whole series for the crystalline minerals which it contains. It lies in the south-eastern corner of Newlin township, about one mile N. N. E. of the village of Unionville. It has a mean breadth of some 800 feet or more, and its total length is about one mile. It lies altogether within the micaceous talcose slate, many portions of which rock wear here a very quartzose and sandy aspect. This belt consists of stratified serpentinous talcose slates, with much injected or infused true igneous serpentine. It is intersected by several narrow dykes of fine-grained basaltic trap, which trend N. E. and S. W. Besides these, there occur some interesting mineral veins. One of these, which has attracted the notice of mineralogists, is a narrow vein of very hard white albite, including many crystals of *corundum*, some portions of the vein being indeed almost an emery or corundum rock. An attempt was made some years ago by a skillful and most zealous mineralogist of Chester county, D. Lewis Williams, to mine regularly this very hard and intractable but valuable material; but the undertaking was not long persevered in. Loose chunks or blocks of the corundum rock strewing in one place the north slope of the ridge of serpentine, derived either from the above-mentioned vein or from other injections, were collected at one time to the amount, it is said, of between six and seven tons, and exported to Europe.

"Besides the albite with corundum, there occur several veins or dykes of granite, consisting almost exclusively of felspar. This mineral is here in such purity, indeed, as to be in much request for the purposes of dentistry. Owing to the demand for felspar entirely free from extraneous associations, a successful quarry has been opened, and has already furnished a considerable quantity for the market. Associated with the *pure orthoclase*, which is in very large crystals, there is also occasionally much oligoclase or soda spodumene, another felspar mineral.

"There are several other insulated small localities of serpentine west of the Brandywine, but they are not of sufficient importance to be entitled to a special description."

State Line serpentine and chrome.—"A very extensive belt of stratified and injected serpentine rocks ranges near the State line from the Little Elk creek in Chester county across the Octoraro creek to Maryland, and thence across the Susquehanna. Its length from the Little Elk to the Susquehanna exceeds 17 miles, and the tract is prolonged beyond the river through the northern edge of Maryland for several miles further. Its mean width may be given at about one mile. This is a range of wild and stoney barrens scarcely tilled, except in a few spots on its two margins, and overgrown with stunted black oaks, and other trees characteristic of the magnesian soil of all these serpentine belts. Along its southern border this magnesian formation is in contact with black hornblendic gneiss, but apparently without conformity of dip. On the Susquehanna a different rock, a micaceous talcose slate bounds it on the S.; along its northern edge it is everywhere bordered by the micaceous talcose slate of the Primal series; and this latter formation seems to lap round its eastern extremity, near the valley of Little Elk river. Much trap-rock presents itself just west of the Little Elk along the southern edge of this range of serpentine, and dykes of that material occur within and adjacent to the belt, especially throughout its southern half, and apparently along its whole course. One of these may be seen on the main road leading to Carter's ferry at the crossing of Buck run."

Chromic iron ore.—"The zone of serpentine rocks now before us is especially remarkable for containing large quantities of chromiferous iron ore. It is indeed one of the chief sources of chromate of iron in the United States, having already furnished large supplies of this mineral for both the home and the European demand. The chrome ore penetrating the serpentine rocks in true lodes or veins, with more or less regularity, has likewise been met with in great abundance in a fragmentary state upon the surface of the barrens, and to a small depth amid the disintegrated materials of the serpentine. It has, therefore, been mined both by regular mine shafts, and by superficial pits or holes, and trenches. The scattered surface ore, locally called "sand chrome," has been extensively gathered from the beds of the ravines and alleys which intersect the barrens, and after being washed on the spot has been shipped away to market. When, for a succession of years after the first development of this mineral, the high price of $45 per ton stimulated the discovery and preparation of it, many thousand tons of the stream or "sand chrome" were transported to the sea-board, especially to Baltimore. More lately, since the richer deposits of the more accessible surface ore have been in chief part exhausted, resort has been had to mining in some of the more regular solid veins. Only two such subterranean excavations are now, however, systematically prosecuted, owing partly to the circumstance, that the present market for the mineral is easily glutted, and partly to the fact, that nearly all the most promising localities of the region are at present monopolized by one individual. Both of these mines are situated a little westward of the east branch of the Octoraro creek. It will suffice to present here the chief features of

"*Wood's chrome mine.*—This is situated not far from the Horse-shoe ford of the Octoraro, the vein of chromiferous iron ore observing a nearly N. E. and S. W. direction, and dipping 45° to N. W., or with the local slope of the ground. It has been mined throughout a length of about 300 feet. As a lode it is quite irregular, varying from a width of 20 feet to nothing, or expanding into large pockets of ore, and then contracting until the walls meet. It also throws off several branches, some of which return into the main vein. The shaft at present (1854) has a depth of about 150 feet, and an open drain meets the shaft about 20 feet below its mouth."

"This mine produces at present between seven and eight tons of excellent chrome ore daily, the fruits of the labor of three hammers and the attendant aid. The present price of the chrome ore is about $25 per ton. The gross yield of this mine is therefore nearly $200 per day. The finer pieces of the ore are packed in barrels on the spot as they come out of the mine, and are thus sent to Europe without re-handling. The rest of the ore, after dressing and washing, is transported to Baltimore and other home markets."

"*The line mine.*—The other chief mine situated immediately on the boundary line of Pennsylvania and Maryland, and called therefrom "The State Line Mine," is not now actively wrought. Its shaft is about as deep as that of Wood's mine. The aggregate former yield of the Line mine amounted to several thousand tons.

"There are several interesting minerals associated with the chromiferous iron ores and serpentine of this range of magnesian barrens, and nearly all the species occur equally at the two mines here spoken of. These minerals are enumerated in the general chapter on the mineral localities of the Primal district of the Atlantic slope of Pennsylvania."

Lancaster County serpentine and titanic iron.—"There is another shorter tract of serpentine barrens, containing both the stratified and the unstratified intrusive varieties of the rock, situated about two miles north of the State line in Lancaster county, on the waters of the Conewango. The southern edge of this is near the little village of New Texas. The whole belt is about three miles long, and more than half a mile wide, and it has somewhat the form of a crescent, its convex curve being to the N. W. Its north-east end is about one and a half miles E. of the Conewango creek, which it crosses about two miles N. of the State line, extending westward of the stream about a mile, until its south-west extremity is within two miles of the Susquehanna, and a mile and a half N. of the State boundary. From this locality much silicate of magnesia has been taken, and transported to the chemical works of Baltimore and elsewhere, for the manufacture of Epsom salts and other preparations of magnesia. The excavation of this mineral is no longer pursued; it was dug only in superficial pits."

At several places in this serpentine belt titaniferous (birds-eye) iron ore has been mined in Lancaster county.

The distinction between *stratified* and *unstratified serpentine* is insisted on, Mr. Rogers going on to say:

"A careful examination of these two belts of serpentine, near the State line of Lancaster county, cannot fail to convince any observant geologist that the material, ordinarily termed serpentine, as presented in these barrens, comprehends both a *stratified* and an *unstratified* rock. Pure serpentine is here found only in the form of dykes intruded through a stratified serpentinous talcose rock, evidently a metamorphic clay-slate, the mica and talc-slate formation of the Susquehanna. The stratified serpentinous rock seems to have been impregnated with the magnesian minerals during the intrusion of these veins of igneous serpentine. The evidences in support of this view are abundant in the ravines which intersect the barrens north of the village of New Texas. The genuine serpentine rock is itself a material of quite diversified aspect, some of it being of a dark green color, and very tough; other varieties less dense and heavy, and much more easily fractured, and of a pale or yellowish green. This latter kind usually abounds in contact with the chromiferous iron ore at Wood's mine and the other chrome localities. Certain small patches of the rock wear a slightly pinkish color, but the predominant hue is some variety of green."

The distinction between "*gneiss serpentine*" and "*serpentinous steatitic talc-slate*" Mr. Rogers makes in describing an outcrop in Delaware county, at the head of Gulf creek, ½ m. from Morgan's corner; 300′ wide, and a few hundred feet long, with a narrow "uplift of hornblendic gneiss" 300′ north of it; north of the gneiss, talcose gneissoid schists; north of these, limestone. In two quarries, the serpentine is stratified; in the others, not. In the quarry east of the road, dip steep north; in the other, 70° south. His section is reproduced in Fig. 19.

To complete Mr. Rogers' record of what he saw and thought of the serpentines of southern Pennsylvania in 1852. the following is here added:

"*The Serpentine and Steatite Range of the Schuylkill in the Southern Edge of Montgomery County.*—This, the most eastern zone of the magnesian rocks in southern Pennsylvania, lies entirely within the middle or micaceous belt of gneiss, or highly metamorphic Azoic rocks, but near its northern border. It is a long and straight line of outcrop of steatite or serpentine, extending from the northern brow of Chestnut hill between the two turnpikes, across the Wissahickon creek and the Schuylkill to near the Baptist meeting-house road, about a mile west of Merion Square. Along the eastern and central parts of its course the southern side of this belt consists chiefly of a talcose steatite. The northern side, containing much serpentine in lumps, dispersed through the steatite; but towards the western side this separation seems to disappear. The serpentine division, or band, is conspicuous on the line leading from Chestnut hill down to Thorpe's mill, where enormous blocks, without any distinct traces of stratification, cover the surface along the line of the bed or dyke. The same rock is similiarly exposed on the west side of the Wissahickon, opposite Thorpe's mill, and thence westward along the north side of a lane leading up to the Ridge road. The whole belt is vaguely exhibited at the summit-level of the land between the Wissahickon and Schuylkill valleys; but, descending towards the Schuylkill we again discern, on the north side of the line of outcrop, the huge blocks of mingled serpentine and steatite, until, near the Schuylkill river, they choke the bed of the ravine next north of the Soapstone quarry. On the west side of the Schuylkill this serpentine and steatite rock is still visible in large blocks, a little above the soapstone of that bank of the river; but between this point and the vicinity of Merion square, the rock, though discernible at a few points, is nowhere conspicuous. About one third of a mile west of Merion square it is quite prominent again, the surface being strewn with huge masses. It may be distinguished at once from any other mineral aggregate of the region, not merely by the enormous dimensions of its loose blocks, but by its rugged, frowning, dark aspect, and also by the general coating of dark lichens and other cryptogamous plants. The serpentine seems not to follow the steatite the whole distance to the western termination of the belt.

"Only in a few neighborhoods does the steatite, constituting generally, as already said, the southern half of the tract, present itself in sufficient purity and mass to be profitably quarried. On the east bank of the Schuylkill, however, about two miles below Spring mill, at the spot called the Soapstone quarry, it has long been successfully wrought; and on the west side of the river, in one place on the bank, and at another about one third of a mile west, the rock has been quarried, though upon a less extensive scale. In former years it was excavated to a small extent on the west bank of the Wissahickon, just opposite Thorpe's mill; but the band of steatite at this place appears to be too thin to warrant its being pursued at present.

"Both at the Wissahickon and the Schuylkill the steatite, which is regularly stratified, dips steeply to the N. 35° W., agreeing in its inclination with the *subjacent beds of mica-slate*; but on the west side of the Schuylkill, at the points where it has been exposed in quarries, it dips at a more moderate angle to the south-east, thus indicating a probably synclinal structure in this central portion of the belt. The material is used chiefly for the lining of stoves, fire-places, and furnaces. The principal market for it is the city of Philadelphia.

"Towards the end of the last century and the beginning of this, before the introduction of the marble of Montgomery county for street-door steps in Philadelphia, this easily-dressed stone was in some demand for that use; but it proved badly adapted to the purpose, because of the very unequal hardness of its different constituent parts, there being a difficulty in getting blocks free from knotty lumps of imperfectly crystallized serpentine, which make it to wear unevenly under the attrition of the feet. We may sometimes see in an old and much-worn door-sill of this rock these knots of the serpentine mineral projecting above the steatite like hob-nails in a plank." (Geol. Pa., 1858, p. 167.)

II. The talc-mica schist region.

South valley hill.

The northern border of the gneiss region already given (page 37 above) is the southern border of the belt of talc-mica, or hydro-mica schists (2 to 4 miles wide) which outcrop along the southern slope and summit of the South valley hill, and spread out over the south-western townships. The northern edge runs along the foot of the hill in contact with the valley limestone or marble.

The southern edge of the belt through Easttown is marked by a thread of chlorite slate; in northern Willistown, E. and W. Goshen, by an outcrop of serpentine; in E. Bradford, Newlin and W. Marlborough, by outcrops of limestone. West of the Doe run limestone exposures, the limit is obscure, as described in a previous chapter.

Mr. Rogers expands the belt westward so as to lap around, and fill in between the fingers of the two belts of gneiss, and the interval between the two belts; but he confesses to an uncertainty in his own mind as to the identity of the talc-mica schists north of the gneiss region, with the whole body of soft micaceous gneissoid schists of his "middle belt" as already described.

Prof. Frazer also says:—"The boundary of these rocks from the western edge of the Doe run limestone is very difficult to follow, but it has been taken as parting in the neighborhood of Chatham, south from Doe run to West Grove, hugging the limestone belt north of there, thence north of the Baltimore Central RR. to Big Elk creek, and down this to a point a short distance north of Hickory hill, when it turns south-west and reaches the serpentine mass east of Chrome.

"The great denudation of the southern part of the county makes the determination of the boundary an exceedingly unreliable one; nor are the rocks where they occur distinctive enough in character to separate always readily from the other members of the eozoic measures."

The *geological* relationship of the talc-mica belt to the gneiss region south and east of it is not understood by any one. There is an evident non-conformability between them. All that can be affirmed is that the mica slate is of later age, and overlies the gneiss; but how the contact is effected along the border-line common to the two areas is as yet undiscovered.

The geological relationship of the talc-mica slate to the Valley limestone is also in dispute. Both Mr. Rogers and Mr. Frazer place the mica-slate formation beneath the Valley limestone formation. Mr. Rogers makes it the base of the Palæozoic system, unconformably resting on the Azoic or Hypozoic gneissic system. He calls it *Lower Primal slate*, and makes it the lowest of three members of Formation No. I; the *Primal* (Potsdam) *sandstone* being the middle member, and the *Upper Primal slates* the uppermost member.

Mr. Rogers considers the Downington valley as a synclinal trough, the Primal Sandstone rising from beneath it on the one side in the North hill, and the Lower Primal slates rising from beneath it on the other side in the South hill. The absence of the sandstone in the South hill he ascribes to its thinning away southward, but he thinks that traces of its existence may be detected west of the Schuylkill.*

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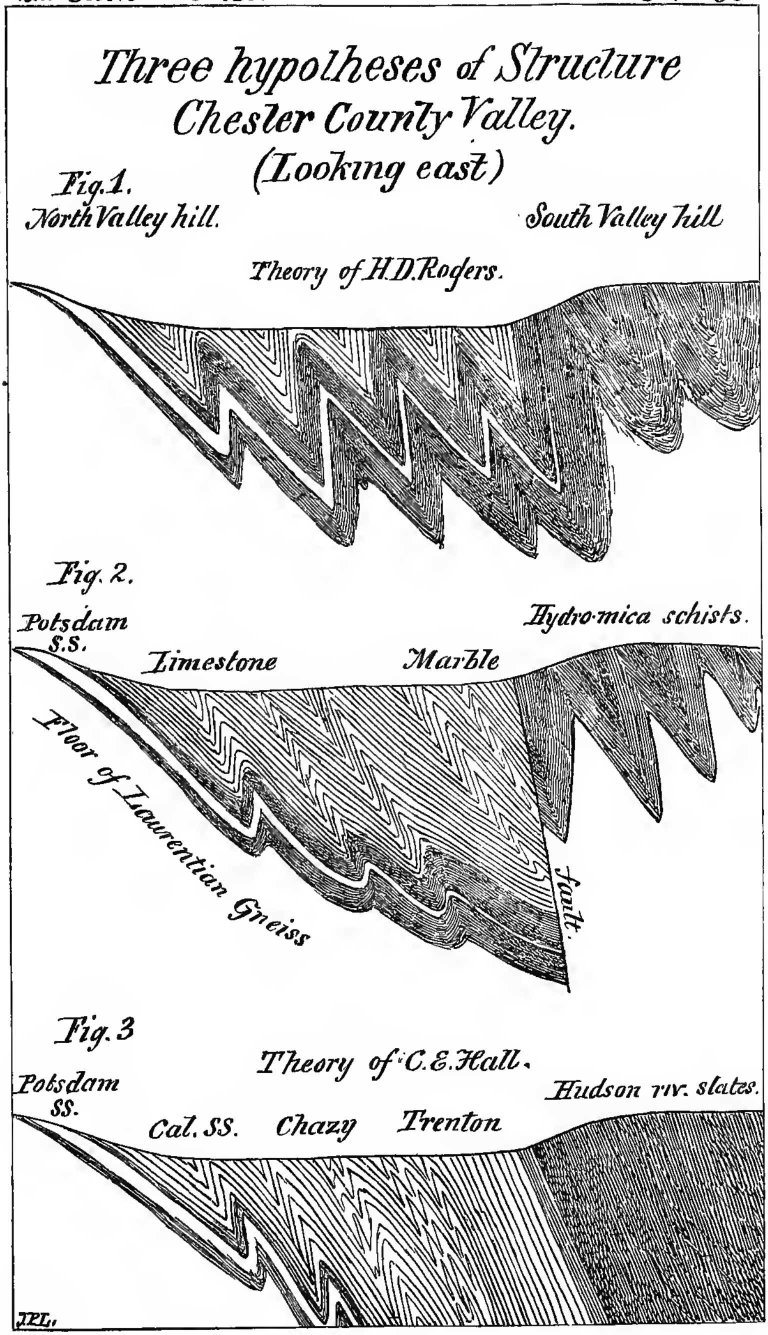
*Mr. Rogers says on page 166 (Geo. Pa., 1858,) that the Primal white sandstone "ceases almost entirely . . and no effort to discover it in a regular outcrop of any length or appreciable thickness has yet disclosed it on the west side of the Schuylkill, or even for several miles westward, until we reach points opposite the Spread Eagle and the Paoli."

North of Paoli, he says, its outcrop may be recognized at two or three spots just at the base of the South Valley hill; by the character of the soil; or by


Three hypotheses of Structure
Chester County Valley.
(Looking east)
Fig. 1.
North Valley hill.
South Valley hill
Theory of H.D. Rogers.
Fig. 2.
Potsdam S.S.
Limestone
Marble
Hydro-mica schists.
Floor of Laurentian Gneiss
fault.
Fig. 3
Theory of C.E. Hall.
Potsdam SS.
Cal. SS.
Chazy
Trenton
Hudson riv. slates.
JPL.

Mr. Theo. D. Rand looks upon certain thin outcropping sandstones in Tredyffrin township as genuine Potsdam sandstone. This view will be argued more fully in describing the Valley limestone formation.

Mr. Hall, on the contrary, is positive that the mica slates *overlie* the Valley limestone; and his arguments are, 1, because they are conformable in their nearly vertical south dip; 2, because transition beds of impure limestone and calcareous slates form a true upward passage of the limestone into the slate;* 3, because he sees at the east end of the range, at the Schuylkill, the slates folding in two small anticlinal

fragments in the soil; and in one case in T. Biddle's well. It cannot exceed a very few feet, and cannot be continuous, for numerous opportunities for detecting its presence are afforded by road cuts.

On the south road, 1½ m. E. of Downingtown. *i. e.* ⅓ m. W. of the viaduct, it crops out "unmistakably" in the road gutter, and in a neighboring house well, as a soft, decomposed, sandy rock, somewhat talcose, nearly vertical.

West of this no trace of it appears until near Coatesville (westward) it projects conspicuously, as a rugged outcrop, at the mouths of numerous ravines; 30′ to 40′ thick, sometimes thinner; always hard, semi-vitreous, siliceous, vertical, it continues to skirt the valley to its western end in Lancaster county, where "a union of the two lines of Primal sandstone," that of the South Valley hill and that of the North Valley hill, is effected "near the Conewago creek in Drumore township," and running on (first as a *synclinal* and then as a *south dipping monoclinal*) for a mile toward McCall's ferry on the Susquehanna.

This extract would come better into the description of the North Valley hill Potsdam rocks were it not so important a statement of Mr. Rogers' geological sentiments respecting the talc-mica belt of the South Valley hill.

* *Passage beds* from the talc-mica slate into limestone are also recognized and discribed by Mr. Rogers (on page 165) as visible at Callwell's furnace, at the mouth of Matzan's run, opposite Conshohocken on the Schuylkill, thus:

1. *Talc slate*, vertical; on the north slope of the South Valley hill. Then, going north,
2. Limestone, crystalline, and marble, mottled; narrow band.
3. Talcoid, nacreous slate; 100′?
4. Limestone, impure, altered; under south end of engine-house; 50′.
5. Talcoid, garnetiferous slate; under the furnace and to 100′ of the brook.

Limestone, magnesian; continuous both sides of Matzan's run. Good exposure of sub-crystalline mottled white and blue limestone, weathering yellow, dip without contortion 77° to N. 25° W. on north side of the run, say 200′ S. of Conshohocken bridge.

These passage beds range west up the south bank of the run nearly to its head, some of the limestone bands being quarried.

Mr. Hall *reverses* the order of the passage beds given by Mr. Rogers; so that in his opinion the talc-slate No. 1 of the above section is at the top and the talcoid-garnetiferous slate No. 5 is at the bottom overlying conformably the top strata of the Valley limestone formation.

Fig. 9. Section on Aramink creek; from H. D. Rogers.

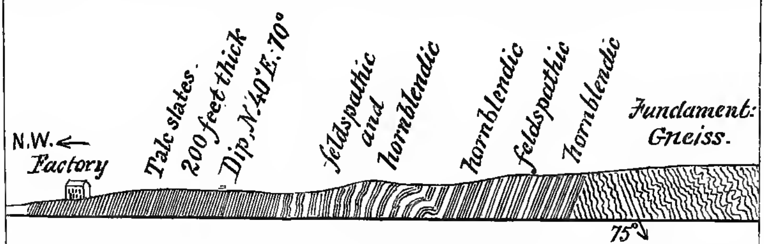


Fig. 18. Section at Caldwell's furnace H.D.R.

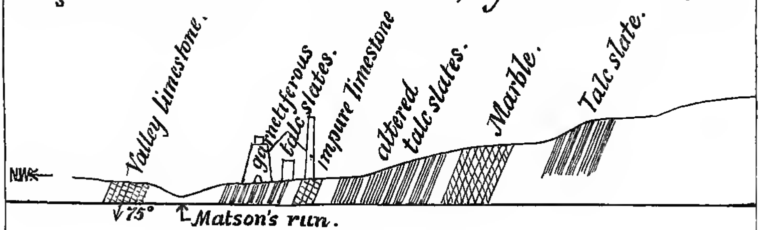
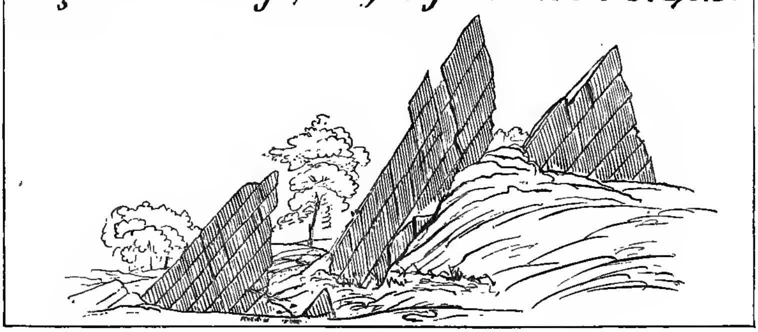


Fig. 19. Section of South Valley hill, E. of Morgan's C.

Fig. 20. Cleavage, at N. foot of Bethel hill. → S.E.



spurs *over* the limestone; 4, because the slate belt spreads across the Octoraro through Lancaster to and across the Susquehanna at the Maryland line where roofing slates and characteristic Hudson river fossils occur; and 5, because a similar belt of slates neighboring a similar belt of limestone on the south, runs for miles east of the Hudson river, where the weight of evidence is in favor of the later age of the slates.'

Objections can be brought against all these arguments, some of which seem to be serious objections.

There are important opposing facts, such as: 1, the appearance of such slates *beneath* the limestone in the North valley hill from Pomeroy westward: 2, the apparent superposition of the limestone on the slate at Columbia and York; 3, the certain existence of a great slate formation *under* the limestone at Reading and Lebanon, along Yellow Breeches creek in Cumberland county and elsewhere; 4, a great development of slate *beneath* the Potsdam sandstone in Virginia; 5, and especially, the acknowledged synclinal structure of the limestone valley in Montgomery and Bucks county at its east end, and the apparent synclinal structure of its west end in Lancaster county, where the point of limestone lies in a groove of slate.

To Mr. Hall's view however Prof. Frazer himself furnishes one important argument by his description of a slate hill in London Grove township, which he himself considers to be of synclinal structure between two areas of limestone; and he says, 1, that in this instance the limestone *ought* to *underlie* the slate; and 2, that the slate can not be distinguished in character from the slate of the South Valley hill. But he suggests that possibly the London Grove slate may be another slate formation; or the limestones which border and apparently underlie the slate may be an older formation than the Valley limestone. Certainly, however, the simplest mode of viewing this case is to consider the London Grove slate ridge as an eastward projection of the acknowledged South Valley hill slates of the Octoraro country in a narrow outlying basin of Valley limestone.

The most serious of all objections to Mr. Hall's view is the fact that it makes the Valley limestones and the South hill slates plunge together, as one mass, southward against the gneiss region; necessitating a fault hard to construct upon any hypothesis. For even if a fault could be conceived along the straight line of the south edge of the slate belt past West Chester as far as Doe run, how can any conceivable fault be carried round the west end of the gneiss region to the Maryland line?

Another argument in favor of the view taken by Mr. Rogers and Mr. Frazer, and opposed to that taken by Mr. Hall, is derived from the *magnesian* quality of the South Valley hill slate belt. For the top of the limestone formation (Trenton) is not magnesian; but the middle and lower parts (Chazy and Calciferous) are characteristically magnesian. Magnesian slates should therefore be looked for *under*, not *over*, the limestone. The Utica and Hudson river slates which overlie the Trenton limestone are not magnesian, but characteristically argillaceous. It is perfectly natural to find *talc-slates* rising from beneath the bottom limestones in the South Valley hill. But it would be unnatural to see *talc-slates* plunging down over the top limestones into the South Valley hill. We should rather expect to see *roofing slates* doing this, and showing Hudson river fossils, as they do at the Peach bottom quarries on the southern York county line.*

This objection is reinforced by the very magnesian quality of the *passage beds* above described.

The highly magnesian quality of the deposits of the South Valley hill is shown by the fact that the slate belt immediately in contact with the (magnesian) marble belt of the valley has always been known as the *Talc-slate belt;* and it has never been separated distinctly from the *Mica-slate belt*, which runs along its south side; the two together constituting the *Hydro-mica schist belt* of Frazer, Hunt, and Hall.

Dr. Hartman in 1857 expressed it thus: "The *talc-slate*, which lies next the limestone, is elevated into a high ridge, and is usually known as the South Valley hill; this forma-

*Here the Easton serpentines between the limestones and the Potsdam teach us much.

tion passes so gradually into the *mica slate*, which is situated on its southern border, as to render it impossible, except in particular instances, to delineate them separately. The *mica and talc-slates* enter . . . . from Montgomery county by a narrow zone, about one mile in width . . . . gradually widening . so as to occupy the southern margins of E. and W. Whiteland, E. Caln, the northern parts of Easttown, Willistown, E. and W. Goshen, E. and W. Bradford, Highland, and E. and W. Fallowfield, where it rapidly expands and passes into southern Lancaster. In W. Fallowfield the belts of talc and mica slate are suddenly deflected to the south, embracing nearly the western half of U. and L. Oxford, and E. and W. Nottingham, and passes into Maryland."

On Dr. Hartman's map the colored *talc-mica belt* has a definite south-east limit, which follows Doe run; passes a little east of Cochranville, to Edenton; and then follows the "Limestone road" through Russellville and Haysville, and the N. W. corner of Oxford borough, to the bend of North-East creek, (south of New Prospect,) where that creek issues from the Serpentine belt.

That this limitation is empirical seems evident from what follows in his memoir: "The townships of London, Brittain, Franklin, New London, and the greater part of E. and W Nottingham, U. and L. Oxford, and Londonderry, are occupied by *gneiss* and *mica slates*, *interspersed* with occasional belts of *hornblendic* and *stratified sienitic* rock."*

* In Dr. Hartman's revised geology of Chester county, published in the History of Chester County, 1881, pp. 435 to 440, he expresses very peculiar views. He describes the Valley limestone as "primitive or auroral," and afterwards the Pequea limestone of West Caln township as "sesondary limestone, No. II." Between these he places the slates and sandstone of the North Valley hill. With regard to the southern edge of the Valley limestone he writes: "In many places where it is in contact with the talc-slate it is slaty, and is strongly marked by the igneous action which upturned the latter." Of the talc-mica slate belt he writes: "The talc-slate lies next the limestone, and is elevated into a high ridge, usually known as the South Valley hill." "The mica and talc formations of Chester county are about two thousand feet thick, and in their mineralogical features they correspond with the gold-bearing talc-slates of Virginia and North Carolina, with which they are continuous. These strata are evidently sedimentary, and were probably deposited at the bottom of a great estuary, &c."

The separate character of the *mica-talc belt* as distinct and individual is recognized by all geologists who have studied it. The only question is, whether there be *outliers* or *extensions* of it south and east of any such border as Dr. Hartman and others have attempted to draw upon the map of the county; or, whether such apparent outliers or extensions may not belong to a *different mica slate* formation, quite unconnected with the talcose slates of the South Valley hill.

Prof. Rogers attempted no such limitation of the talc-mica belt on the colored geological map of Pennsylvania, published in 1858.

Prof. Rogers, although he recognized the peculiarity of the *talc-mica belt* did not permit himself to draw any limiting line from Highland township southward to Nottingham. In this he has been followed by Prof. Frazer in his final manuscript map. But in publishing this map I have defined such a border, for two reasons:

1. Because Prof. Frazer in his original manuscript map was disposed to do so, and was only prevented by the occurrence of similar rocks in London Grove township, &c. This difficulty is acknowledged by Prof. Rogers, who, however, thought best to merge the talc-mica rocks with the gneissoid schists and slates of his "middle belt," as already described above.

2. Because of the remarkable topographical feature, already alluded to on page 16, viz: That all the water-courses of the western border of South Chester, flow westward into the Octoraro; their heads being arranged almost precisely along the talc-mica belt limiting line given on Dr. Hartman's map.

This westward drainage certainly demands geological explanation, and as certainly receives one if such a limit to the Octoraro talc-mica slate country be accepted as correct. In fact, why should *all* the water-flow of the western township be westward into the Octoraro unless it were originally determined by a general westward dip of a higher formation resting upon the declining underground western slope of the gneiss region, which has suffered so much erosion as to be now only a few hundred feet above ocean level, but originally must have been a mountainous mass of very considerable elevation, apparently many thousands of feet.

It is that erosion which has doubtless removed the *talc-mica* covering from the whole Brandywine country, leaving to the present surface only so much of it as lay at the base of its western slopes.

Prof. Rogers says (page 154, Vol. I, Geol. Pa., 1858,) "If the actual limit between the lowest Primal rocks (*talc-mica* belt) and the gneiss could be minutely followed, it would be found to wind in and out in a zig-zag manner between the uplifted spurs of gneiss, each successive trough to the south lying somewhat further towards the west than the preceding one," . . . . the whole in the form "of a hatchet or cleaver, the long slender belt between the Schuylkill and the W. B. Brandywine representing the handle, and the wide slate district of the south-western townships of Chester, and the Southen townships of Lancaster representing the blade." "It is even broader in York county, and broader still in Maryland."

Of course, had Prof. Rogers known of the existence of Hudson river fossils in southern York county he would have revised his theory; but, in the end, he might have left it standing good as a whole, and accounted for the fossiliferous roofing-slates at Peach Bottom on the theory that the Palæozoic sea, in Hudson river times, had extended to the Atlantic seaboard, and that these roofing slates are the only remains of its deposits of that age spared in the otherwise complete erosion of Hudson river age deposits south of the Cumberland valley.

This is the course which Prof. Frazer is forced to pursue. Whereas Mr. Hall sees in the Peach Bottom fossils a key to the real age of the whole of the talc-mica rocks in York, Lancaster and western Chester counties, rocks which he regards as overlying the Valley limestone, and therefore naturally of Hudson river age. Prof. John Frazer assistant to Prof. Rogers in 1835, and personally very familiar with Chester county, came early to this conclusion and maintained his belief in it as long as he lived.

Mr. Rogers' rejection of this theory deserves the greatest consideration, 1, because of his real genius for taking broad views in geology, and for divining the true state of things in cases where there was much obscurity; and 2, and especially, because the part he took in the great Taconic controversy with Dr. Emmons would have led us to expect the very reverse of such a rejection. In fact, his theory of the slate belt of the South Valley hill opposes the theory which he advocated respecting the Taconic slate belt east of the Hudson river. The latter he contended was of Hudson river age; this would have naturally led him to assign that age to the South Valley hill belt. Dr. Emmons' theory that the Taconic slates lay *beneath* the Potsdam and Valley limestone was based upon their not being *roofing slates*, but talc-mica slates, &c.; in other words, non-fossiliferous and metamorphic. Mr. Rogers, on the other hand, with Prof. James Hall, contended that the fossiliferous Hudson river slates of the Mohawk country were metamorphosed into talc-mica slates, &c. (with obliteration of fossils) in the Taconic country. Why, then, should not the almost non-fossiliferous Hudson river age slates of Berks, Lebanon, Dauphin, and Cumberland counties not be recognized in the non-fossiliferous metamorphic slates of Chester, Lancaster, and York?

Mr. Rogers must have had strong reasons in his own mind for *not* carrying his Taconic theory of eastern New York and Vermont into southern Pennsylvania, Maryland, and Virginia. Whether objections which were predominant in his mind are to stand good for all time with future geologists is to be seen; but certainly the progress of geology in other countries, while it tends to confirm Prof. James Hall's and Prof. Rogers' views in regard to the Taconic slates, tends to weaken Prof. Rogers' views with respect to the talc-mica rocks of Pennsylvania. For example:

The *quartziferous talc-mica schists*, diorites, clay-slates, conglomerates, and strongly developed gneisses and granites of the Bergen peninsula in Norway, after being studied by Naumann, Von Buch, Esmark, Keilhau, Kjerulf, and Hjörtdal, who came to various different opinions respecting them, have recently been studied by Hans H. Reusch with new and satisfactory results.*

He has found in the clay-slates (†) fossils characteristic of the lower part of the (Upper) Silurian series (Clinton and Niagara,) *Halysites catenularia* and *Cyathophyllum* changed into white calcspar; a few tubular bodies, presumably *Syringophyllum organum;* some gasteropods, *Murchisonia* or *Subulites?;* some trilobites, *Calymene, Phacops* or *Dalmanites;* and some brachiopods.

The granite veins are crumpled and folded; the stratified gneiss beds have received by pressure a *transverse stratification;* the whole mass shows great plasticity. The gneiss of Ivenningdal, although really and truly stratified, (apart from cleavage,) sends out veins, and contains included metamorphosed fragments.

The limestone beds containing the Silurian fossils have been changed into marble, not by contact with any eruptive rock, but simply by molecular movements set up by pressure; as has also been observed by Swiss geologists in the case of the limestone beds of the Bernese Oberland.

The clay with trilobites, &c., at Vagtdalen has become a muscovite (mica) schist, with porphyritically inclosed clusters of mica.

The gneiss which appears among the undoubted Silurian beds seems to be of sedimentary origin (sandstone.)

The granite is clearly stratified and sedimentary.

The fossils are nearly all elongated and compressed; conical coralla into flat elongated biscuits, &c.

The stones in the green conglomerates at Osören are all flattened and elongated; cross-sections of many of them look like lanceolate leaves. The microscope shows the same effect produced on the grains of the hone-stones of Eidsmarken.

Prof. Rogers' account of the *talc-mica belt* in his final report of 1858 is too valuable to be omitted, (see Geog. Pa., Vol. I, pages 154, 155:)

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* Silurfossiler og Pressede Konglomerater i Bergens kifrene, Univ. Prog. 1883. Kristiania 1882. (See Nature, p. 567, Oct. 5, 1882.)

† Some have considered the whole series of these schists as of igneous origin.

A. East of the Schuylkill, the principal mass is an alternation of thin beds of bluish gray sandstone, and still thinner layers of brownish sandy slate, much like those above Columbia in Lancaster county. But west of the Schuylkill the mass is much altered, and the lower beds [?] next the gneiss might be called semi-porphyroidal; the observer is liable to confound their weathered fragments with the uppermost [?] hornblendic felspathic gneiss adjoining Headd's. "Until my own researches enabled me carefully to study and trace the several strata of this zone, the propriety of referring these porphyroidal beds to any system of rocks newer than the gneissic formation was never, I believe, entertained."*

East of the Schuylkill the mass is threefold:

1. An uppermost white sandstone, (conspicuous in Barren hill,) thin bedded, yellowish white, very compact, with much imperfectly developed felspar, and tending to rhomboidal fracture. "The more solid layers seldom exceed two inches. Other more schistose bands, consisting of the same quartzose felspathic matter in intimate fusion, contain likewise many minute partings of crystalline *mica* and *talc*, and the surfaces of the more solid felspathic beds exhibit very frequently at these partings innumerable minute crystalline specks of pure *black schorl.*" Thickness, 35′ to 40′; further east, near Willow grove, probably 100′; in the southern trough of Bucks county, 300′.

2. A middle division of imperfect *talc-mica* slate.—*Where much altered*, it consists of wavy, nearly parallel laminæ of quartz, mica, and probably some talc, with innumerable crystals of dodecahedral garnet, (as near the mouth of the Aramink, opposite Conshohocken,) the waviness being due to the interference of the garnets and quartz segregations. *Where less altered*, it is an impure sandstone, pervaded with particles of imperfect mica and talc; decomposed to an unctuous earth, mottled deep red

* Why the metamorphism should be confined to the stretch of the belt west of the Schuylkill is not explained. Mr. Hall agrees with Mr. Rogers that east of the Schuylkill the rocks are primal (Potsdam) but contends that the rocks west of the Schuylkill are a different belt of rocks, and of Hudson river age.

and blue, highly ferruginous, the origin of the iron ore deposits. Abundant fragments of white quartz (like pale chert) strew the surface, and are segregations dropped from the rock in the slow erosion. Including sometimes imperfect felspar, these liberated plates of cherty quartz may readily be mistaken for fragments of the quartzose-felspathic layers of Barren hill primal sandstone. Apparent thickness, 200′.

3. A lowermost division of semi-porphyroidal altered sandy slate or argillaceous sandstone, remarkably regular in lamination and bedding; laminæ alternately light and dark, exceedingly thin (many in an inch), consisting (where most metamorphosed) of white, earthy, imperfectly developed felspar, and perfectly developed earthy hornblende. Cross-sections show a multitude of ovoid concretionary crystallizations; generally only specks in size; sometimes as large as bullets, and then frequently genuine crystals of felspar. In some layers the laminæ are studded with isolated hornblends. Thickness, at the Schuylkill, 300′; at Spring mill only 100′ visible.

These lowest rocks can be well studied on Arominк run, eastward to the ferry-house opposite Spring mill; in the point of the hill at Spring mill just north of Wm. Penn furnace; and on the Wissahickon. They make good macadam for pikes, easily quarried, tough and durable. The middle rocks are mostly concealed; but show their débris in these soil. The upper sandstone is well exposed at the old iron ore hole at Spring mill; in the ravines of Barren hill; best of all at Edge Hill village, in the R.R. cut.

All the above is given merely for record and reference, and properly belongs to the description of the Potsdam sandstone, or North Valley hill further on; but Mr. Rogers identifies these rocks with the mica-talc strata of the South Valley hill west of the Schuylkill, and therefore his description of them had to precede that of the latter.

B. West of the Schuylkill, "the Primal slates," says Mr. Rogers, (page 156,) "put on some new and interesting features, losing others which are distinctive of the group to the eastward of the river."

"The speckled semi-porphyroidal basal beds are less easily recognized next the gneiss. They are noticeable south of Paoli, but not on the Brandywine. This may indicate the lack of original deposits westward; or a difference of original deposit; or a difference of metamorphic action.

"A variety of silicious talco-micaceons slate" takes their place. In places west of the Brandywine the rocks are so crystalline as to simulate the more micaceous beds of the gneiss region. "An extensive comparison however of the materials of the two formations enables one almost invariably to determine definitely between the real micaceous slate and that which only simulates it."

It is impossible to sub-divide the mass. Transverse cleavage has effaced the original bed-planes; and innumerable closely compressed plications give a uniform dip in one direction.

The whole mass may be described as "an alternation of *talcoid silicious slate*, *talco-micaceous slate* and *quartzose micaceous* (thin laminated) *schists*."

Next the limestone runs a belt of generally *talcoid slate* full of lenticular lumps of granular quartz, which seem to represent a segregrated excess of silica in the original deposit; especially where the universal S. E. cleavage is not coincident with the bedding. Where they do coincide the lamination is more parallel and the silica granules more dispersed in the talc. But alternating with the talc beds are more micaceous slates.

The middle portion of the belt, and that which adjoins the gneiss region, consist of beds of more micaceous silicious schists.

But a *roofing slate* variety also exists,—a nearly pure clay-slate, which seems, says Mr. Rogers "to occupy a horizon comparatively low in the series, for it is never interstratified with the talcose or upper division, but with the highly-crystalline micaceous rocks which seem to prevail most in the central and lower."

Mr. Rogers cites no locality where he saw roofing slates, and he may refer to those on the Susquehanna river; but if they occur along the edge of the gneiss region in Chester county they go to sustain Mr. Hall's view, according to which what Mr. Rogers calls the bottom beds are really the top beds of the belt, and then the roofing slates would be exactly where we find them at the foot of the Kittatinny mountains in Lehigh and Northampton counties.

The Brandywine section of the South Valley hill slate belt is thus described by Mr. Rogers on page 158:—

Talc-slates, dipping 80°, northward, with cleavage 80°, southward, adjoins the limestone a few hundred feet south of the Downingtown RR. station. From this contact onward (southwards) down the Brandywine past Taylor's ford bridge and for a thousand yards further, are exposed a succession of talc and talc-mica slates (more or less quartzose,) dipping steeply, mostly southward, but occasionally northwards; all the cleavage steeply southwards, except in one instance. Mr. Rogers sees in this section a closely complicated mass of slates of moderate thickness. Mr. Hall interprets it as a less complicated and therefore very thick formation.

III. The Valley Limestone Region.

Together With its Bordering Potsdam Sandstone.

The most striking feature of the Chester county geological map is the straight stripe of blue which crosses it from east to west representing the *Valley limestone* formation.

The geological map of the State shows this blue stripe terminating eastward at Willow Grove in Montgomery county, and westward at Quarryville in Lancaster county. Its extreme length is 55 miles in an almost perfectly straight line N. 18° E. Its maximum breadth east of Downingtown and again west of Willow Grove is only two miles. At Coatesville it is a little more than one mile wide, and tapers rapidly into Lancaster county.

The topographical features of this Chester valley or Downingtown valley have been already described, see pages 16 to 19 above. Its geological features are in part simple and easily understood, and in part so obscure as to give rise to much discussion and diversity of opinion, but the preponderance of evidence is in favor of regarding it as a long, straight, deep trough or basin of limestone, with its northern side sloping southward at angles varying from 30° to 60°; and its southern side turned up vertical, or even overturned a little so as to make the beds on that south side of the trough dip 80° to 90° southward.

Such is Prof. Rogers' description of it in his Geology of Pennsylvania, 1858. And such is Prof. Frazer's view of it embodied in his township notes, given in this volume. Mr. Hall, on the contrary, considers it a monoclinal valley, the whole mass of limestone dipping southward beneath the talc-mica-schists of the South Valley hill.

But even on the supposition that it is a trough, with vertical (or overturned south) dips along its southern side, there are reasons for considering the trough cracked and faulted along its whole length in Chester county. No such fault can be clearly proved; but the existence of such a fault would make easier to comprehend the very extraordinary *straightness* of the south edge; and might also help to explainthe absence of the underlying sandstone of the North hill in the South hill; that is, supposing it to be really absent, and not merely concealed among the talc-mica-schists, as described by Mr. Rogers, see page 99, above.

The age of the *Chester valley limestone formation* cannot be called in question.* It is *Formation No. II* of the First Geological Survey; the *Auroral limestone* of. Prof. Rogers, 1858; the *Calciferous*, *Chazy*, and *Trenton limestone* formations of the New York survey; the same as the great limestone of Lancaster and York counties; the limestone of the Kittatinny valley, which stretches from Easton to Chambersburg; the limestone of Kishacoquillas and Nittany valleys, McConnellsburg, Milliken's, and other coves in middle Pennsylvania. It is the Upper Cambrian limestone

*Dr. Hartman's opinion that it is "primitive" and not "secondary," and that it is different from the Pequea limestone of West Caln township and of Lancaster county is quite untenable. In fact he gives to both the name "Auroral." See History of Chester County, 1881, page 436.

of Sedgwick, the lower Silurian of Murchison, and the Siluro-Cambrian of Sterry Hunt. It is the Knoxville limestone of the South and the Magnesian limestones of the West.

It overlies the *Potsdam Sandstone* (Rogers' *Primal white sandstone*) Formation No. I. This rock rises from beneath it to form the North valley hill; and also appears in anticlinal ridges through it, east of the Schuylkill river, as described by Mr. Hall in Report C[6], and as shown by the colors on the State map of 1858, and more in detail on the sheets of Mr. Hall's large geological map accompaning Report C[6].

On the geological map of Chester county the Potsdam sandstone is colored yellow, and may be seen bounding the north edge of the blue limestone belt all the way from the Schuylkill river west to Pomeroy. Why Prof. Frazer does not continue this yellow-colored border of the limestone into Lancaster county, as Prof. Rogers does on his State map of 1858, will be explained directly. It is here only necessary to mention that Prof. Frazer confines the yellow color to the *sandstone* of the North Valley hill; while Prof. Rogers includes in his yellow color the *Primal slates* which overlie and underlie the sandstone, and form with it his triple *Primal group*.

This *Primal group* Prof. Rogers sees represented in the South valley hill by the talc-mica-slates, which he therefore calls *Primal slates*, and colors yellow. The absence of the sandstone in the South valley hill he looks upon as a mere accident of deposition; the sandstone, which is so thick in the North hill, feathering away to nothing underneath the trough of the valley, and therefore not appearing in the slates when they rise to the surface again in the South hill, except towards the western end.

Prof. Frazer shows that the Valley limestone lies on Potsdam sandstone from the Schuylkill to near Coatesville; that here for a short distance thin mica-schist layers come in between the limestone and the sandstone, (these would be Prof. Rogers' *upper* primal slates;) and that west of Pomeroy and all the way to Quarryville in Lancaster county no sandstone underlies the limestone, but instead of that the limestone rests upon felspathic gneiss beds, gneissoid mica-schists, &c., (these would be Prof. Rogers' *lower* primal slates.) These are the rocks which separate the west end of the limestone trough (at Quarryville) from the southern point of the great Lancaster limestone plain; and these are the rocks which spread out westward to the Susquehanna river and into York county.

The great question is: are these gneissoid mica-schists, bordering the limestone on the north, the same as the talc-mica-schists bordering it on the south?—which they certainly ought to be on the theory that the *valley limestone* lies in a synclinal trough, without a fault.

There is no difficulty in seeing in these northern gneissoid-mica-schists the same formation as that described by Prof. Rogers (page 51 above) as his *middle or micaceous belt;* but it is almost inconceivable that they should be the same formation with the talc-mica-schists of the South hill; from which they are separated by only a mile of limestone, beneath which the change of character must take place so rapidly and along so extensive a line that it sets explanation at naught.

Let us take a section of the valley at Downingtown. *On the north* we have a gneiss country upon which lies a plate of Potsdam sandstone about 100′ thick, without slates, descending conformably southward beneath the limestones of the valley. *On the south* we have the limestones vertical, changed to marble; and against them (beneath them?) no sandstone, but many hundred (perhaps 2000) feet of talc-mica-schists, serpentinous schists and serpentine, occupying a belt nearly 3 miles wide, and then the gneiss country. Is it possible that so vast a change in the character of the Potsdam (Primal) formation should realize itself in a cross distance (beneath the valley) of only two miles? At Pomeroy where the limestone is only a quarter of a mile wide such a change seems still more incredible. Granting its possibility here, or at Downingtown, or at any other given point along the range of 30 miles across Chester county, would it not be a miraculous coincidence if the change took place along the whole 30 miles in such a way as to prevent the talc-micas from showing themselves in the North hill and the sandstone from showing itself in the South hill?

Yet all this must happen if the *synclinal structure* of the valley be true.

What then are the grounds on which the *synclinal structure* of the valley has been accepted? They are in short

1. Its acknowledged synclinal structure in Montgomery county, where the Potsdam sandstone borders it on the south, and where its round basin-shaped east end is perfectly manifest.

2. The apparent necessity for considering it synclinal at Quarryville in Lancaster county, and the analogy of the little isolated synclinals north of Quarryville.

The only way to conceive of it as synclinal at both ends and yet monoclinal midway would be by imagining a long straight longitudinal fault sharing away its southern side, and a steepening of its south dips until they become vertical (downwards) against the face of the fault. This would certainly be an uncommon phenomenon, requiring an unusual amount of proof. It would be uncommon because the great amount of vertical limestone strata along the fault does not at all resemble the ordinary "brush" produced by the friction of the two sides of a fault.

3. If the valley limestone be synclinal then we can comprehend the existence of outlying troughs of limestone still further south, such as have been described on pages 65 and following, above.

4. An argument which is of great weight with Mr. Rogers is derived from the supposed overturned (nearly vertical) dip of the limestones all along the South hill. This brings the synclinal of the Valley into strict analogy with that of most of our great Pennsylvania synclinals; for example, that of the Pottsville coal basin, and especially of the great Cove synclinal north of Harrisburg, the south side of which is overturned to about 60°.

These are the only arguments in favor of the synclinal structure of the Chester county valley; but they are arguments of very great weight, and can only be overcome by arguments of still greater weight in favor of its monoclinal character.

But if the Valley be *monoclinal* a new set of difficulties are encountered, for it can be conceived of as monoclinal under two entirely different conditions:

a. We may conceive of the south-dipping (nearly vertical) limestones at the foot of the South hill descending *conformably* beneath the talc-mica-schists. This is Mr. Hall's view, and he therefore looks upon the schists as Formation No. III (Hudson river) and describes the passage beds as showing the gradually upward gradation of the limestones into the schists.

b. We may conceive of the south-dipping (nearly vertical) limestones as cut off from the schists by a profound fault 40 miles long, leaving the schists to be of any age, Primal or otherwise.

The objections to Mr. Hall's view (*a*) have already been alluded to, but may be briefly stated here as—

(1.) merely transferring the difficulty a few miles south, viz: to the southern edge of the talc-mica-schist belt. For, if the schists be Hudson river slate, then they must lie in a synclinal of limestone; and if so, the Valley limestone should rise again on the south side of the schist synclinal, in a broad and long belt of limestone, lying upon gneiss (with or without Potsdam.) But no such limestone belt appears; merely thin outcrops of limestone of doubtful age and relationship, and very limited areas, certainly bearing no comparison with that of the Valley.

(2.) Mr. Hall insists upon the monoclinal character of the valley on the ground that if it were synclinal the limestone beds at the foot of the South hill ought to be as magnesian as those at the foot of the North hill, whereas the latter alone are magnesian, and the former nonmagnesian. This agrees very well with the chemical character of the whole formation elsewhere in the State, the top of it (Trenton) being nonmagnesian. But on the other hand it is fatal to the *passage beds*. For how are we to imagine the nonmagnesian upper (Trenton) limestones passing upwards by clay-slate alternations into intensely magnesian (talc-mica) schists of Hudson river age; seeing that the Hudson river formation wherever it is known is nonmagnesian, and when altered assumes the character of *roofing slate*, not *talc slate*.

(3.) A curious argument for Mr. Hall's view is derived from the *graphitic* and *phosphatic* indications along the foot of the South hill, very suggestive of the possible existence of the *Utica slate* formation, next overlying the *Trenton lime* stone.

(4.) Another indication of the same sort is afforded by the *limonite* deposits along the foot of the South hill; for some of the largest deposits of limonite in Lehigh and Berks county (Balliets & Moselem) occur where the upper limestones (Trenton) descend beneath the Utica and Hudson river slates.* But on the other hand, the principal mines of Cumberland and Franklin counties are at the *bottom* of the limestone in *damourite slates.*

One objection to the simple *unfaulted* monoclinal structure above described seems insuperable, viz: that the outcrop should run on indefinitely far, both eastward into New Jersey, and also westward into Maryland and Virginia. We see that the Valley limestone beds are plicated at and beyond the Schuylkill river, and come to an end eastward by spooning up in synclinal form. Nothing but a similar synclinal structure could possibly bring them to an end in Lancaster county. How is it possible then for them to descend beneath the talc-mica-schists in Chester county.

The alternative is a fault: theory (*b.*)

But if the limestone beds plunge vertically against a fault where do they go to? How deep? Again, such a fault would make it necessary that the dip of the limestones should not be so steep as that of the schists; in other words the limestone beds and schists should *converge* going down.

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* The Valley limestone is usually compact and slightly crystalline; in a few instances granular; occasionally talcose or slaty. Color, blue to white; each color not confined to a particular stratum, but often *alternated in the same bed.* Dip, very uniform, to the south, 60° to 65°. Iron ore beds, *usually* near the junction of the talc slate and the limestone; rich ore, but more or less silicious; those in E. Whiteland (Trimble's) yielding an abundance of phosphate of alumina (Wavellite.) Plumbago in large beds, in W. Whiteland, at the contact of talc slate and limestone; beds *earthy*, and used to adulterate or counterfeit the super-phosphate fertilizer sold to the farmers. (Hartman.) The alternations of white and blue (magnesian and nonmagnesian) layers is important in establishing the identity of the Valley limestone with No. 11 of the Great Valley at Harrisburg. See Report M.M

And again, such a fault should be shown by some convergence of the two sets of beds horizontally east or westward.

To decide these two points by any ordinary observation of the ground would be impossible. But Prof. Frazer has observed dips and strikes all along theline across the county, and selected pairs of exposures near each other.

An analysis of these dips and strikes ought to bring out some law of structure; or at least indicate the probable existence of one. To make the demonstration perfect would require an elaborate and costly survey.

In studying this table the reader must imagine himself at the Schuylkill, looking west along the range of the South valley hill, having the schists on the left (south) and the limestones on the right (north.) The dips and strikes at the top of the table are the furthest off near the Lancaster county line.

Schists.		*Limestones.*		*Townships.*
Dip *N. 45° W.*†	*40°*	60°	S. 10° E.	Sadbury.
S. 20 E.	85	60	S. 15† E.	
S. 30 E.	70	85	S. 5 E.	
S. 35 E.	70	65	S. 30 E.	
S. 10 E.	70	70	S. 10 E.	Valley.
S. 35 E.	80	57	S. 20 E.	
S. 15 E.	80	60	S. 20 E.	
North	*85*	*45*	*North.*	
		67	S. 15 E.	
S. 10 E.	74			Caln.
		70	S. 10 E.	
S. 20 E.	85	55	S. 0 E.	
S. 10 E.	80	85	S. 10 E.	
		60	S. 10 E.	
	90			
		85	S. 10 E.	E. Caln.
S. 10 E.	80			
S. 10 E.	70	90		
S. 10 E.	70			
		70	S. 10 E.	W. Whiteland.
		70	S. 5 E.	
N. 10 W.	*88*	90	(S. 10 E.)*	
		80	S. 15 E.	
S. 20 E.	70	80	S. 15 E.	
S. 20 E.	80	75	S. 20 E.	
S. 45 E.†	65	85	S. 10 E.	E. Whiteland.
S. 10 E.	80	*73*	*N. 45 W.*	
S. 20 E.**	90	78	S. 20 E.	
S. 15 E.	60-90	74	S. 15 E.	
N. 10 W.	*70*	90	(S. 10 E.)***	
S. 15 E.	50	80	S. 45 E.†	Tredyffrin.
S. 0 E.	50	80	S. 0 E.	
S. 10 E.	50	80	S. 10 E.	
N. 10 W.	*50*	90		

* Strike N. 80° E. ** Strike N. 70° E. *** Strike N. 80° E.

† These three are noted S. E., and may not be as much as 45°.

Of the 29 limestone exposures only 2 show a *northward dip;* one due north at an angle of 45°, the other north-west at an angle of 73°. All the rest show *southward dips*—two due south; two, S. 5° E.; ten, S. 10° E.; five, S. 15° E.; four, S. 20° E.; one, S. 30° E.; one, S. E.; and two not noted.

Of the 27 schist exposures 5 show a *northward* dip—N. W. 40°; N. 85°; N. 10 W. 88°; N. 10 W. 70°; and N. 10 W. 50°. (These may be south dips *overturned* into north dips.) All the rest show *southward* dips—one due south; eight, S. 10° E.; three, S. 15° E.; five, S. 20° E.; one, S. 30° E.; two, S. 35° E.; one S. E., and one the direction not noted.

	South	S. 5° E.	S. 10° E.	S. 15° E.	S. 20° E.	S. 30° E.	S. 35° E.	S. E.
L..	2	2	10	5	4	1		1
S..	1		8	3	5	1	2	1

It is evident from the central figures 10—5—4, in the limestone, and 8—3—5 in the schists, that somewhat less than 15° S. E. may be safely assumed as the mean direction of *dip* in both; and it appears from the map that E. 15° N. is the exact *strike* of the line of contact along the South valley hill.

All other directions of dip (and strike) observed along the line may safely be considered as local variations, easily accounted for by the violent change which the once horizontal rocks have suffered in being pressed up vertical.

If these local variations be sufficiently numerous, they may account for the divergencies noticeable between the *strike* of the limestones and the strike of the schists in each pair of observations; for the rocks are not seen in contact; the observations were made at some little distance from each other; and a very small distance—a rod or two—would be quite sufficient to allow of a divergence along a line of vertical upturn in plastic limestone strata and still more plastic schists.

Nevertheless, these divergencies must be taken account of in constructing any theory of the structural contact of the two formations. To show what the divergencies are, they may be represented as a *convergence of the lines of* *strike* either in an east or in a west direction, selecting only *perfect pairs of south-east dips*, thus:

Schist dip.	*Limestone dip.*	*Convergence of strike lines. Westward.*	*Eastward.*
S. 20° E	S. 15° E.,		5°
30	5		25°
35	30		5°
10	10		None.
35	20		15°
15	20	5°	
20	0		20°
10	10		None.
20	15		5°
20	20		None.
45 ?	10		35° ?
20	20		None.
15	15		None.
15	45 ?	30° ?	
0	0		None.
10	10		None.

If the contact of the two formations be a plane of conformability of deposition it is hard to see why most of the convergence should be to the eastward. But if the line of contact be along a great fault then the beds of schist are successively swallowed up by the fault going east. In other words, the strike lines of the schist country run diagonally (eastward,) towards and terminate against the south edge of the limestone.

But it must be observed, that in seven cases out of the sixteen there is no divergence recorded; the strike of the limestone being parallel to that of the schists. The data are therefore too meager to hazard a theory.

Analysing the list of *dips* in the same way, we get the following:

Dip.		*In the schists.*	*In the limestone.*
orthward	40°	1	
"	45°		1
"	50°	1	
"	70°	1	
"	73°		1
"	85°	1	
"	88°	1	
Vertical	90°	2	4
Southward	85°	2	4
"	80°	6	5
"	78°		1
"	75°		1
"	74°	1	1

Southward	70°	6	4
"	67°		1
"	65°	1	1
"	60°		4
"	57°		1
"	55°		1
"	50°	4	

It is evident that the normal dip in both formations is towards the south, and at a very high angle; but whether this be an *overturned north dip* or an original south dip is not shown by the table.

Another inquiry must now be made, viz: What amount of concordance or discordance exists between the *angles of dip* of the limestones and those of the schists? Great and general discordance would go far to prove either 1, the existence of a *fault along the line;* or 2, a plane of *sedimentary nonformability.*

The following table will show the discordance of the pairs of adjoining outcrops given above:

Dip of Schists.		*Dip of Limestones.*		*Convergence of Strata. Downwards.*	*Upwards.*
N. W.	40°	S. E.	60°	80°	
S. E.	85	"	60	25	
"	70	"	85		15°
"	70	"	65	5	
"	70	"	70	Parallel.	
"	80	"	57	23	
"	80	"	60	20	
N.	85	N.	45		40
S. E.	85	S. E.	55	30	
"	80	"	85		5
"	70	"	90		20
N. W.	88	"	90	2	
S. E.	70	"	80		10
"	80	"	75	5	
"	65	"	85		20
"	80	N. W.	73	27	
"	90	S. E.	78	12	
N. W.	70	"	90	20	
S. E.	50	"	80		30
"	50	"	80		30
"	50	"	80		30
"	50	"	90		40

In 5 cases the two adjoining dips are nearly the same, varying at most only 5°; in 16 other cases they differ from 10° to 40°; and in one case 80°.

The planes of stratification would meet in 11 cases if extended *downwards*, and in 10 cases if extended *upwards* into the air.

At first sight these facts seem to speak loudly in favor of a great east and west fault crossing Chester county, and throwing the mass of hydro-mica-schists up from below (or down from above) against the up-turned (or down-turned) limestone strata of the valley.

But any one who has practiced the making of connected cross sections in a complicated country knows that the utmost diversity of dips within very short distances may consist with perfect conformability of stratification and a total absence of faulting.

On the other hand the line of the South Valley hill can hardly be called a complicated belt, in view of the usually steep and often vertical attitude of its rocks,—both of the limestones at the foot of the hill, and of the hydro-mica-schists of the hill slopes. But the map in Report C[6] shows a set of diagonal plications traversing the eastern end of the valley; and, if the whole valley be of synclinal structure, and the south side folded vertically back towards the northern side, there ought to be numerous subordinate complications or creases in it which would necessarily and variously affect the angle of dip at all exposures.

One other consideration, perhaps of no great value, must not be entirely overlooked.

The drainage system of southern Lancaster, southern Chester, and Delaware counties as exhibited on the maps—all the minor streams heading at the line of the South Valley hill and flowing southward—suggests an uplift northward. An upthrow fault along the south edge of the Valley limestone, with the *upthrow on its south side*, would explain this peculiar drainage system. But in that case the basset edges of the limestone strata against the fault would have been brushed vertically *upwards*, making the valley a synclinal; and under this supposition the schists would be an older formation than the limestone, as almost all geologists have hitherto regarded them.

With regard to the *Potsdam sandstone*, Prof. Frazer draws attention to the fact that the Lancaster County limestone plain does not seem to rest upon a floor of *Potsdam sandstone* everywhere, but only in its middle and northern parts. The uplift which crosses that county east and west just north of the city of Lancaster, exposes the *Potsdam sandstone* several hundred feet thick in Chickies rock on the Susquehanna above Columbia, and also at the west end of the Welsh mountain (Laurel hill in Earl township;) and the *Potsdam sandstone* is exposed more or less evidently along the edge of the limestone along the Chester county line as far south as the Gap in the North Valley hill and somewhat further west; but no *Potsdam sandstone* has been detected anywhere along the southern edge of the limestone area; it seems to be replaced by (Rogers' primal) slates. It is not unreasonable therefore to suppose that the original southern limit of deposition of the sandstone was a line drawn from Pomeroy west to Columbia; and that south of that line mica-schists were deposited instead of sandstone.

But this only renders it the more extraordinary to find exposures of what seems to be *Potsdam sandstone* at various places in southern Chester county.

With regard to the isolated limestone exposures in southern Chester enough has already been said, (pp. 55, 58, 66, &c., above.) The probability is that some of these are synclinal remnants of the *Valley limestone* formation, resting on *Potsdam sandstone;* but the strange relationships of the limestone patches to neighboring schists are still unexplained. The London Grove schists, (as described already above) seem to lie *above* (in a synclinal of) the limestone. But Prof. Frazer remarks that at Fruitville, at Neffsville, and at Manor P. O. in Lancaster county, in passing from the sides to the axis of an anticlinal of limestone, the last rock to appear just as the limestone disappears is some member of the mica-schist family; which would put the schists *beneath* the limestone.

Some of the isolated limestones of southern Chester seem to be much older than the *Valley* limestone and to be locked up between beds of the Laurentian gneiss; and some of the exposures are evidently anticlinal in structure; as, for example, that at Chadd's Ford.*

[* In 1861, I communicated to the American Philosoph. Soc. a small drawing which I had made of the limestone exposure in a large quarry on the Brandywine, above Chadd's Ford, (Fig. 1); and compared the structure with that of

In fact we have no means of proving that all the limestone exposures of southern Chester and Delaware counties are of the same age and formation; but it is hardly probable that that they are; they are all much alike; and they contain no fossils by which they could be distinguished.

Whether synclinal or anticlinal these steep dipping limestone strata would naturally be exposed in belts, or along east and west lines across the map.

As Prof. Frazer remarks, "the whole country is so plicated and the limestone strata are apparently so thin, that their exposures at the present surface are of the most fantastic and bewildering shapes; and the rocks which adjoin them are puzzling enough.

"In many places the limestone is in contact with a sort of feldspathic porphyry or a sort of conglomerate. Where this rock is abundant (as on the Delaware State line) its feldspar is generally completely decomposed into kaolin; and this would seem to be a good indication that the original rock is much older than any palæozoic strata.

"In the middle of the county the detached limestone outcrops, although ranging themselves belt-wise, suggest a number or series of beds. For example, on the right bank of the Brandywine, about a mile west by south of Dilworthtown, [the quarry above Chadd's Ford, above mentioned,] the limestone is plainly included between strata of crystalline rock, to be described in my township report hereafter.

"The limestone of these detached outcrops moreover, is, as far as our data suffice to assert anything generally, *less magnesian* than the white crystalline limestones of Chester Valley and of Lancaster county."

It must be kept in view that lenticular beds of crystalline limestone appear in the gneiss region of northern, as well as in the gneiss region of southern Chester, (see p. 82, above;) and in all of them *graphite* exists; but this is not necessarily a Laurentian characteristic, for *graphite* exists in quantity in the *Valley limestone* beds along the base of

a coal bed quarried in Tazewell county, Virginia, (Fig. 2.) At that time the quarry plainly showed the limestone strata rising and sinking again in a sharp compound overturned anticlinal axis; evidently interbedded among the micaceous gneisses of the locality. Proc. A. P. S., No. 66, Vol. VIII, page 282.)

the South valley hill, on the Susquehanna below Harrisburg, and elsewhere.

I will now give Prof. Rogers' description of the *Valley limestone* formation in Chester county; and then his description of the *Potsdam sandstone* and *Primal slates* connected with it, along the North valley hill; as published in his Final Report, Geology of Pennsylvania, 1858, Vol. I, page 209–219:

The Valley limestone. Rogers, 1858.

"This interesting belt of the Auroral limestone, the borders of which have been already indicated in a previous chapter devoted to the southern outcrops of the Primal sandstone, is worthy of a more full and connected description than it has yet received. Externally the tract, with its highly cultivated farms, numerous thriving villages, factories, furnaces, and mills full of prosperous industry, presents a scene unsurpassed in the United States. The soft, picturesque beauty of the plain or bed of the valley is much enhanced by the two ranges of slate hills, still clothed with the remnants of the natural forests. It lies between these like the deck of a slender, shallow boat between its sloping sides. Its surface is in almost every part irrigated with running brooks of pure, transparent water, and it is crossed by several swift-flowing, sparkling streams, as large as the rivers of some countries. The grandest of these is the Schuylkill. It is here a broad current, and bears deservedly the title of river. The enclosing hills, or two edges of the general upland, between which this valley lies, at an average depression of nearly 300 feet, are superbly carved into innumerably wooded ravines and narrow dells. This is especially true of the slope overlooking the valley on the south. From any point on the southern table-land near the head of one of its ravines, the view is truly enchanting; broad slopes of foliage and a shady dell fill the foreground of the picture; wheat-fields and pastures, orchards and snug, tidy farm-houses, many of them of the dignity of country mansions, occupy for miles the middle distance; and the extended background is a rich succession of fading hills and far-stretching mountains. Breaking what might otherwise approach to monotony in the curves of the landscape are here and there deeper gorges in the north and south barriers of the valley, furnishing waterway for the larger streams, the Schuylkill, the Wissahickon, the Brandywine in both its branches, and the Octorara. The narrower parts of some of these are precipitous, and so shut in and wild as to present a most graceful contrast in their tangled foliage, rough rocks, and mossy cliffs, with the neighboring scenes of open pastures and sunny corn-fields."

The *southern border* of the limestone belt crosses the Schuylkill at Spring mill and follows Gulf creek into Chester county, a little less than a mile south of the Baptist meeting-house. "It there follows the foot of the South valley hill about the same distance north of Glassley and north of the Paoli, to within a couple of furlongs of the Warren tavern, and from thence half a mile south of the Steamboat tavern, and somewhat more to the north of the Indian King.

"Near Downingtown the belt has decreased much in width, being little more than three-fourths of a mile broad. The belt passes about two furlongs south of the town. From Downingtown, the foot of the hill indicates the margin of the limestone, which passes rather less than a quarter of a mile below Coatesville to Freeman's mill on Buck run; thence to Cloud's mill, near Philip's tavern, on the Gap and Wilmington turnpike; and to the Octorara creek, near the junction of Cloud's run.

"In Lancaster county it follows Cooper's run as far as the dam near the Valley mills, but continues along the valley a furlong south of the stream. We thence trace the same southern margin across the West Branch of the Octorara, about a fourth of a mile below Buckman's tavern, and thence to Kunkle's and Eckman's run, at which place the limestone terminates.

"*North border.*—On Eckman's farm the line doubles back towards the east, and pursues nearly a straight course, by the Reform meeting-house, to Buckman's tavern; thence running straight to the Octorara, a fourth of a mile above

Noble's factory. The greatest width of the limestone in Lancaster county is not much more than half a mile.

"Returning into Chester county, the northern boundary continues direct to Parkesburg. At Coatesville it passes one furlong and a half north of the village. Two miles east of Coatesville the belt widens, and the northern edge passes a fourth of a mile south of East Caln church. Still expanding, the northern margin passes one third of a mile north of Downingtown to West Whiteland township line, where it is within a furlong and a half of the Valley turnpike; and thence continues north-east for about three and a half miles.

"The width of the limestone, taken along the eastern township line of West Whiteland, is a little more than two miles; and the northern margin is a nearly straight line from thence to the Valley creek, which it crosses half a mile from its junction with the Schuylkill.

"As the belt passes into Upper Merion it is overlaid on the north by the red sandstone; a portion of which, jutting forward as far as the King of Prussia tavern, conceals that part of the formation which lies to the north of Reesville. From thence the northern line continues direct to within half a mile of Norristown, and, turning down towards Swede's church, crosses the Schuylkill one mile below the bridge.

"*In its chemical composition* this limestone is, with the exception of an occasional stratum, highly *magnesian*, and many layers contain the carbonate of magnesia in the full proportion (namely, about 45 per cent) requisite to constitute the rock the peculiar definite chemical combination called *dolomite*. More usually, however, the amount of carbonate of magnesia is somewhere between 10 and 30 per cent. As a general rule, the lower part of the formation is the most magnesian. This portion contains likewise a larger share of silicious and talcose matter than the beds higher in the series. The lime which this limestone yields, though invariably more or less magnesian, produces, on the whole, a very superior cement, the magnesia present in it giving the mortar the property of concreting with more rapidity than belongs to a cement of lime alone. Many of the more highly magnesian limestones can be made to furnish very excellent hydraulic cements.

"*The geological structure* of this populous and rich limestone belt, though curious, is extremely simple. Measured from one extremity to the other, the limestone, coincident very nearly with the bed of the valley, has a total length of about 58 miles. Its eastern end is just north of Abington in Montgomery, and its western at the source of Big Beaver creek in Lancaster. In form, it resembles very much a long slender fish; and this likeness is increased when we include as part of it the two spurs into which the bounding narrow sandstone ranges of Edge Hill and Mount Washington terminate, near the Pennypack, E. of Willow Grove. As pictured in the map, it resembles a slender garfish, fins and all, with its tapering jaws asunder. The widest portion of the valley is between the Wissahickon and Valley creek, where, from the southern barrier of the Primal slate to the northern margin of overlapping red sandstone, the maximum distance is nearly three miles, and the average distance about two and a half miles. From the East Branch of the Brandywine it tapers very gradually and slenderly to its western termination. From the Wissahickon eastward it closes up much more rapidly, ending bluntly from the intrusion of the low anticlinal wave S. of Willow Grove, which spreads it into the broad snout already noticed.

"The general structure is that of a long and slender basin or synclinal trough, the southern side of which is much more steep than the northern. From the neighborhood of the Gulf Mills, a little west of the Schuylkill, to its western end, this oblique symmetry prevails with scarcely any interruption. The strata of the southern side of the valley dip perpendicularly, often a little overturned into a steep south dip, but sometimes inclined steeply in the normal direction, or northward; and it is only towards the western extremity, where the whole trough grows shallow, and rises as it flattens up and thins away, that the north dip ceases to be steep. The strata of the north side of the valley (or from the synclinal axis northward) dip at an average inclination of about 45° southward, or more strictly S. 20° E. But even this inclination is not absolutely constant, for in the wider central division of the valley this northern part of the trough contains in some places one or two short, low, and narrow anticlinal waves.

"Between the Schuylkill and the eastern termination of the basin, the general simplicity of the synclinal structure is much more frequently interrupted by the presence of included anticlinal flexures, the more prominent of which—as, for example, those of the Conshohocken Ridge, or Bethel Hill, Barren Hill, and that of the Church Ridge, with others already described—lift to the day conspicuous local outcrops of the Primal upper slate and white sandstone.

"This eastern end of the basin is obviously much more undulated than its central and western portions, and the greater frequency of compressed waves in the strata is evidently connected with that longitudinal prolongation of the still sharper folds which corrugate the narrow zone of gneiss embraced between the Attleborough sandstone range and the southern edge of the red shale. It is indeed but a local exemplification of a very general fact, that of the westward declension and cessation of the stronger crust-plications entering Pennsylvania from New Jersey.

"The position of this great synclinal trough between two sets of flexures, one set entering and enclosing it from the north-east, the other from the south-west, proves its relation to the same general cause which has preserved the troughs of coal, converting them to anthracite in a part of the Appalachian chain just opposite.

"Indeed the whole tract of the Atlantic slope and the Appalachians, embraced between the Delaware and Lehigh on the north-east, and the Susquehanna on the west, is a tract of general depression of the crust lying between the two more uplifted districts,—that of the mountains of New Jersey and New York on the one hand, and that of the Blue Ridge and the Juniata on the other.

"If, while inspecting the geological map of the State to assist our conceptions, we lift away in imagination the superficial deposit of Mesozoic red shale and sandstone concealing a part of the older rocks of the Atlantic slope, we shall perceive this sinking and dying-out of the north-eastern and south-western groups of anticlinals much more obviously.

"It is to this fortunate abatement in amount of vertical uplift of the crust in the district between the Delaware and the Susquehanna, that Pennsylvania is indebted for the inestimable advantage above her sister States to the N. E. and S. W., of so remarkable an extension southward, or towards the tide, of her fertile and iron-yielding Auroral limestone; and it is to the same cause that she owes her inexhaustible basins of anthracite nearer to the seaboard markets by very many miles than any of the other Appalachian coal-fields."

Anticlinal folds in the Valley limestone:—Prof. Rogers not only asserts the existence of numerous plications in the floor of the Valley, but indicates their size and position in Fig. 21, p. 175, Geol. Pa., 1858, representing a cross-section from Diamond rock, on the North hill, to Paoli, on the South hill.

His sections north of Coatesville, (Fig. 22,) and north of Parkesburg, (Fig. 23,) exhibit similar plications in the underlying primal sandstone and slates.

Mr. Hall, in Report C[6], and in his map, has described anticlinals which bring up the Potsdam sandstone through the limestone, along lines crossing the valley diagonally, east of the Schuylkill. These undulations are also described by Prof. Rogers, (Geol. Pa., Vol. I, pp. 159, 160,) where he gives cross-sections, Figs. 10, 11, 12, 13, near Willow Grove; and similar undulations are shown in the very beautiful and elaborate pictorial cross-section along the banks of the Schuylkill, described in Geol. Pa., p. 210.

It is very evident that such plications of the *Valley limestone* formation must exist; otherwise its thickness here would be extravagantly great, in comparison with its thickness in other parts of the State. In Blair county, indeed, the total thickness of the limestones of No. II amounts to between 6000 and 7000 feet; but in the Cumberland valley it seems to range between 2000 and 3000 feet. Between Downingtown and Norristown the Valley is two miles wide, with dips of 60° to 80°. If the Valley were here monoclinal, the limestones would be 9000 feet thick; if simply synclinal, the thickness would still be more than 4000 feet; whereas it is probably not more than 1000, if that much. Consequently plications must necessarily be supposed, and these must be sharp and closely compressed, as they always are at the bottom of a deep trough; but the smooth erosion of the valley, and the scattered nature of the exposures, except along the Schuylkill river, makes it impossible to define the places and sizes of these plications, and thereby to obtain even an approximate thickness for the formation. Nor is it possible to tell how many of these folds are snapped and faulted, or to what distance such faults run. Some of the little anticlinals however are plainly visible, with their crests turned so smoothly as to inspire an observer with the conviction that the limestone mass was in an eminently plastic condition when the folding took place.

We know positively that the folding did not take place since the Mesozoic age, for the Mesozoic red sandstone lies undisturbed upon the folded limestones east of Norristown. We must refer the folding then to the end of the Coal era, when all the rest of Pennsylvania was similarly folded. But if so, then the Valley limestones have been covered with Hudson river slate formation No. III,* and perhaps with the still higher Silurian and Devonian formations, which have all been subsequently eroded. The plication of the *Valley limestone* then took place under a great weight of perhaps 10,000 or 20,000 feet of superincumbent rocks, and this would suffice to explain its evident plasticity. And this must be true whether Mr. Hall's view of the Hudson river age of the South valley hill talc-mica-schists be correct or not; and whether or not the *Valley limestone* once spread continuously all over Chester and Lancaster counties.

Metamorphism.—"Throughout this limestone basin, the

* A portion of which still remains much further south than this, on the Susquehanna river at the Maryland State line.

Fig. 21. Section from Diamond rock to Paoli, southeast.

Fig. 22. Section north of Coatesville, looking northeast.

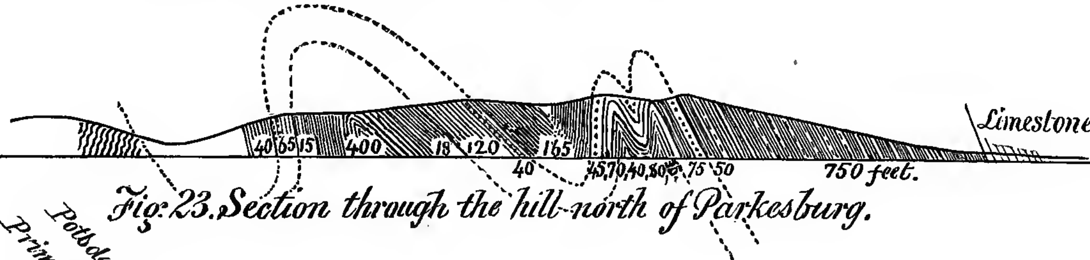
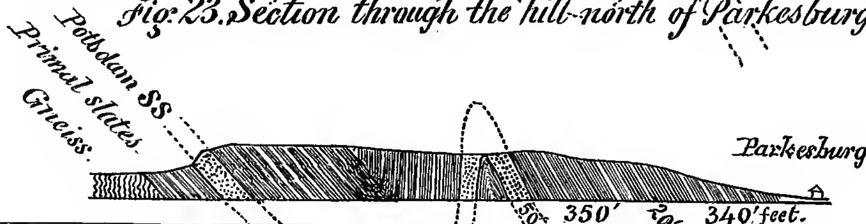


Fig. 23. Section through the hill-north of Parkesburg.



J.P.L.

From H.D. Rogers.

southern steeply upturned outcrop exhibits a far higher degree of *metamorphism* by heat than the northern, and this alteration appears greater where the strata approach most nearly the vertical position, and is greater still where they are inverted, that is to say, between the Wissahickon and the Brandywine. It is chiefly within these limits that the elsewhere bluish and yellowish limestone is in a condition of crystalline and granular marble, white, shaded, or mottled, from the dispersing and segregating action of a high temperature upon its changeable ingredients.* An examination of the map and sections will show that all the marble quarries hitherto opened are included within this steeply upturned or overturned outcrop, the best of them lying within half a mile of the southern edge of the formation, or of some sharp inverted anticlinal like that of the Conshohocken Ridge. It is likewise along this most convulsed and cleavage-intersected side of the trough that, from the same cause, as will hereafter be explained, nearly all the largest, deepest, and richest deposits of brown iron-ore or hæmatite have hitherto been met with.

"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 rather thick. Its color is a pale greyish 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 inter-

[* It is now felt by geologists that no very high heat is required for metamorphism, but that *pressure* (with moisture and time) are sufficient, provided the constitution of the sediments favor chemical and molecular changes.]

secting 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 quarry-man and lime-burner; 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 the 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. (See sketches of the quarries.)"

[* If it could only be proved beyond a doubt that they *are* the very same beds.]

Marble quarries west of the Schuylkill.

The following are the only notes which Mr. Rogers' gives from the Schuylkill westward.

"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 Schuylkill navigation; but a large amount is converted into lime on the spot, designed for the same markets.

"A large quarry of the 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 lime-kilns.

"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 east and west 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 feldspathic 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. Nearer the Steamboat tavern the more usual granular structure prevails; throughout all this range, however, the rock yields an excellent lime.

"At Downington the limestone is chiefly of a light color and compact. Several quarries of compact and granular limestone have been opened in this vicinity.

[Matthew Berry (lessee) and M. Baldwin (owner); blue limestone quarry near Downingtown; opened in 1831; largest block, two yards; rock stratified, jointing regular; texture fine; used for building, lime burning, and ballast; on line of Penn. R. R.; used in building Villanova college, Villanova station, railroad bridge, abutments, and piers; cars loaded at the quarry; two grades of material; bridge stone $2 per yard, or $7\frac{11}{27}$ cents per foot; foundation stone $1 per yard, or $3\frac{19}{27}$ cents per foot; no stone dressed at the quarry; no discoloration at the joints; stripping 2 feet; no rock sawn; no water in the quarry; all hand work, with derricks, powder, and dynamite; full time. (Census report, 1880.)]

"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 feldspathic 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 mills 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.

"The practice of the landholders is to let out the right of working the quarry for a certain period, and the tenant during that time may excavate as much stone as he may require. Many quarries also are opened and worked by the proprietor for his individual supply. No record is therefore kept to enable us to ascertain the number of perches annually quarried.

Of the *trap dyke* in Easttown township, Mr. Morely says that it is visible in the bed of the Schuylkill river at Conshohocken, and "follows the summit of Bethel hill into Delaware county, terminating near the road leading from the Lancaster turnpike to the King of Prussia village. This is by far the longest and widest trap dyke of the valley or its borders, its length being a little more than six miles."

Marble quarries east of the Schuylkill.

"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 five 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 evenness 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, (1853.)

"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 is 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, &c. The thickness of the good blue marble in this quarry is 22 feet, and that of the black variety 8 feet.

"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 Pott's 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, (1853.)

Marble quarries in Upper Merion, (1853.)

"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 private and public 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 northorn 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, &c.

"*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.*

Iron ore mines east of the Schuylkill.

"The first ore ever dug in this valley east of the Schuylkill was near Spring mill, on the farm of J. Kirkner, at the excavation near the road leading to Barren hill. This was about thirty years ago, (say 1820.)

"*Hitner's banks, near Marble Hall.*—Iron ore seems to abound in great quantity in the deeper trenches or basins upon the limestone or mable north of the Conshohocken axis. From one locality near Marble Hall Mr. Hitner

[* This is another bond of connection between the *Valley limestone* formation of this belt, and the *No. II limestone* of the valleys of middle Pennsylvania.]

drew, in 1852, about 10,000 tons of good ore, and in 1853 rather more than 12,000 tons.

"It is estimated by those best informed that from the belt of country embracing the ore pits at present wrought on this east side of the Schuylkill, the amount now taken is about 60,000 tons. This belt has a mean breadth of about one mile, extending from the Barren and Edge Hill range of Primal sandstone, northward to the middle of the valley beyond the narrower limit of the crystalline limestone or marble. Its length, as far as it has been hitherto explored by digging, is not less than seven miles. The ore is not equally plentiful all across this zone, but seems to range in long narrow strips, following, as it were, so many deeper troughs of ferruginous soil, covering the undulating outcrop of the limestone. The most productive belts seem to be one north of the Barren Hill range, and one north of the zone of white and clouded marble.

"Good iron ore occurs in scattered localities north of the general margin of the broad belt here mentioned. Thus Mr. Wood, about one mile north of Marble Hall, finds a shallow deposit of iron ore in soil overlying limestone. This limestone would seem to be very thin here, for sandstone is reached at a small depth below it.†

Iron ores west of the Schuylkill, (1853.)

"There are several excavations for iron ore in the Narrow Limestone valley south of Bethel hill. Two of these localities are east of the gorge by which Gulf creek passes through that hill.

"One group of pits, or that which is nearest the Schuylkill, is somewhat more than one mile S. W. of it, and almost 150 yards S. of the road along the north side of the valley. One of the pits is mined by Mr. Whitehall, and the other by Mr. Fisher. The ore, which appears to be excellent, is smelted at Merion furnace.

"The old pit near the fork of the road, at the Baptist meeting-house, has a shaft some 76 feet deep, and was soon to be reopened by the aid of a steam engine. The ore is

[† See Mr. Hall's Report, C⁶.]

declared to be of superior quality. Formerly it partially supplied Merion furnace. It is owned by Caldwell & Roberts. This ore rests on white marble. Another old opening of ore, now neglected, lies almost 200 feet further east on the S. W. side of the road.

"About 100 yards N. E. of Henderson's marble quarry, in Upper Merion, is an ore bank wrought by George Fisher. It is of considerable size, and until recently (1854) yielded good ore; but at present the brown hydrous oxide of iron has more earthy matter mingled with it than formerly.

"George Fisher has a second ore bank about 1,250 feet N E. of the one just named. Here the ore is tolerably good. A new opening connected with this supplies ore to the iron work of Phœnixville. In these banks the average proportion of dirt to ore is about three to one.

"Thomas Widdart's ore bank, situated like those of Fisher's on Henderson's property, is about 800 feet S. of Fisher's second opening. The quality of the ore here does not materially differ from that of the other banks. The old bank having nearly failed, a new one has been opened within the last two or three years..

"Milliton's bank, on Jones' land, is situated W. S. W. of Fisher's, near the school-house; the ore is pronounced good. It is smelted at Jones' furnace, above Conshohocken. In this excavation the proportion of dirt to ore is about three to one.

"Otto's bank, on Potts' farm, contains good ore; but this has not yet been obtained in large quantities. Here the proportion of dirt to ore is about two to one. In 1854 this bank was but newly opened. "Supple and Hampton each have ore banks in this vicinity, both of them of medium extent.

"Hughes and Jones have several ore-banks in one group leased for mining by sundry persons. No one of these excavations is large, though they form a considerable group.

"The next neighborhood in the valley at which iron ore is dug to any extent is in the vicinity of Howellville, Tredyffrin township. South of the village there is a small newly-opened ore bank, from which good ore has been obtained.

"Another ore bank, owned by Mr. Wilson, lies N. W. of Howellville, on the Swede's Ford road, and this was but a small digging in 1854.

"Woodman's ore bank, on the land of William Roberts, situated about 500 yards W. of the Valley Forge road, and 500 yards N. of its forking with the Swede's Ford road, yields an excellent ore. It contains the unusual proportion of two parts ore to one part dirt. The chief drawback is a rather copious influx of water. This ore is smelted at Phœnixville.

"Nathaniel Jones and Charles Beaver have ore mines near the Baptist church, half a mile from Centreville. Buck and King have also opened a bank. All these three are in considerable excavations.

"Samuel Beaver has an ore bank near the foot of the North Valley hill, about half a mile S. E. of the head of Valley Forge dam. This bank is of considerable size, and yields good ore. It is unusual to find so large a deposit so near the northern margin of the valley, though unquestionably the lower, more magnesian beds of the Auroral limestone are much the most ferruginous, and where they support a deep deposit of earth, largely derived from their own disintegration, they constitute one of the main sources of the surface brown iron ores.

"Holland's bank, about one and a half miles N. W. of Howellville, yields an excellent ore, which has been smelted at Phœnixville. The depth of the excavation in 1854 was 43 feet.

"Still further west in the valley, or past the meridian of the Paoli, there occurs another district of successful ore diggings. The first of these is William Buchanan's ore bank, about 400 yards N. of Oakland hotel, on the railroad, and 100 yards W. of a cross-road. This is an excellent deposit, portions of the bank yielding two parts ore to one part dirt. The ore is taken to Jones' furnace on the Schuylkill.

"G. W. Jacobs' bank, situated between the North Valley and the Columbia railroad, about two miles E. of Oakland, is a comparatively new excavation, but a promising one. The same proprietor has two other banks, about one fourth of a mile S. of the Ship tavern, both yielding well.

"Maguire's bank, on a cross road one mile N. of the Ship, is rather a large excavation of good ore.

"Mr. Evans has an ore bank three fourths of a mile E. of the Ship, which yields ore of a superior quality, and gave indications in 1854 of a large deposit.

"Frederick Neal's ore banks, extending one fourth of a mile upon a cross road, include three pits yielding good ore. He has a second opening on Lea's estate, near the North Valley railroad. When seen it was a small, newly-opened digging yielding a good ore. A mile or more N. W. of Downingtown there is an ore digging very near the foot of the North valley hill, but this has never been extensively opened, nor does it promise a large supply.

"West of Coatesville there have been two or three excavations for ore towards the southern side of the valley between the West Branch of the Brandywine and Buck run; but these have never furnished large supplies."

The notes which follow on pages 217, 218, 219, give some very interesting details of the iron mines of Lancaster county, all bearing upon the fact of their genesis from and in the ferruginous mica schists at the contact of the latter with the limestone beds which, as Mr. Rogers thinks, overlie the schists.

Potsdam sandstone and primal slates in the North valley hill.

The following is Prof. Rogers' description of the *Primal series* along the North valley hill, where the middle member of it, the *Potsdam sandstone* proper, is best developed. (Geol. Penn., Vol. I, p. 173.)

"Commencing west of the Schuylkill about one mile east of valley Forge, the Primal white sandstone of the North Valley hill, so called, emerges into view from beneath the overlapping margin of the Middle Secondary red sandstone at the eastern point of the hill known as Mount Sorrow, or that upon which Washington and his forces were encamped, amid great sufferings and privations, in the memorable winter of 1777–78.

"Here the Primal rocks, consisting chiefly of the older semi-crystalline slates, cross the East Valley creek in a broad contorted belt, not less than half a mile in width. As we trace the formation westward, it would seem to expand rapidly, and to embrace a much larger portion of the *white sandstone*, and a less relative amount of the underlying slate.

"This change seems to take place in that section of the ridge which is called Mount Joy, for when we reach the western point of Tredyffrin township, or the vicinity of Ayer's store, the chief rock visible is the white sandstone; indeed, this is the case in the vicinity of Diamond rock, though the north flank of the ridge at this latter point includes also a considerable thickness of older Primal talcose slate.

"Throughout this part of its length, the belt of the Primal rocks is disturbed in dip by two or three closely-folded undulations, and it is in consequence of these that the sandstone at the Diamond rock is spread over the southern slope and summit of the ridge in so broad an outcrop. The lesser contortions and fractures connected with these undulations are the evident causes of the numerous veins and cavities, filled with crystals of quartz, which occur in the compressed and fractured masses of the sandstone at Diamond rock, and which have conferred upon this cliff its name.

"A partial interruption in the continuity of the North valley ridge occurs at the depression above Ayer's store, and it would seem that the outcrop of the Primal rocks takes here a sudden offset northward, the result, apparently, of the cessation of the undulations prolonged thus far from the eastern end of the ridge, and the introduction of one or more new anticlinal waves in the strata extending from this point westward.

"It is pretty obvious, that near Ayer's store, almost the whole of the broad outcrop of the Primal rocks has been swept from off the gneiss, and only a single monoclinal line of the sandstone left at the base of the hill in contact with the limestone of the valley.

"From this jog or local change in its course, the Primal belt ranges with remarkable straightness towards the west, and with no actual interruption, until in Lancaster county it coalesces with the range bounding the Limestone Valley on the south.

"It presents, however, several decided fluctuations in its breadth, due to changes in the dip, and especially to the introduction of a less or greater number of *anticlinal undulations* in it. The structure of this zone is pretty well exposed in all the principal gorges through which the tributaries of the Bandywine and the Octorara drain through it in their progress southward. In these natural sections, though the edges of the strata are generally much obscured by fragmentary rubbish and soil, it is easy to detect the presence of usually two, and sometimes even three, *closely-folded anticlinal plications*, the dip being generally at a high angle to the south-east.

"From the changes which arise in these flexures, the breadth of the whole belt varies from a quarter of a mile, in some places, to at least three quarters in others.

"In sundry cases we may detect *sharp saddles*, or anticlinal uplifts *of the subjacent gneiss rocks*, sub-dividing the whole belt, at least at the level of the beds of these transverse valleys, into a succession of parallel, closely-folded, synclinal troughs.

"In some instances the lower strata of the Primal series, thus brought up on the back of the gneiss, is so crystalline and gneissoid from metamorphic action, especially where it is contiguous to dykes of intrusive granite, that to determine always the boundary which separates the two sets of rocks is by no means easy.

"For several miles east of the east branch of the Brandywine, there seems to be but an insignificant thickness of *Primal talcose slate* associated with the white Primal sandstone; but approaching the west branch of that stream, or the vicinity of Coatesville, both the upper and lower Primal slates appear in the series in rapidly and steadily augmenting force. There is no feature connected with the Primal rocks of this district of Pennsylvania so remarkable as their appearance and disappearance within the narrow limits of a few miles. This fluctuation is perhaps most conspicuously exhibited in the striking contrast presented in the composition of the North and South valley hills between Valley Forge and Downingtown, in which district it has been already shown that there is on the south side of the limestone even a total absence of the white Primal sandstone, or a bed of it so thin as generally to escape detection; while on the north side of the valley the formation is developed under a thickness of at least 50 feet at Diamond rock and elsewhere. Again, to the south of the basin there appears to be a vast expansion of the lower Primal slates in their metamorphosed condition of talco-micaceous slates; but to the north of this great trough, at a distance no greater than two or three miles, there is a great deficiency of this schistose group. (See Fig. 25, section through Coatesville to mouth of Buck run.)

"It would seem that both the sandstone and the argillaceous or slaty members of the series had in this part of their original area been thrown down in irregular patches, and in beds of quite inconstant thickness.

"When we reach the west branch of the Brandywine, and examine the constitution of the Primal series there, or study it in sections still further west, we are struck with a marked difference of type compared with that which it possesses at or east of Downingtown. Near the latter place, at the pass of the Brandywine, through the North Valley hill, the Primal slate is almost wanting; and the white sandstone, folded in several successive waves, seems at first, until these are recognized, and their influence estimated in multiplying the thickness of the belt, to be a formation of enormous depth, whereas it nowhere in reality surpasses 100 feet.

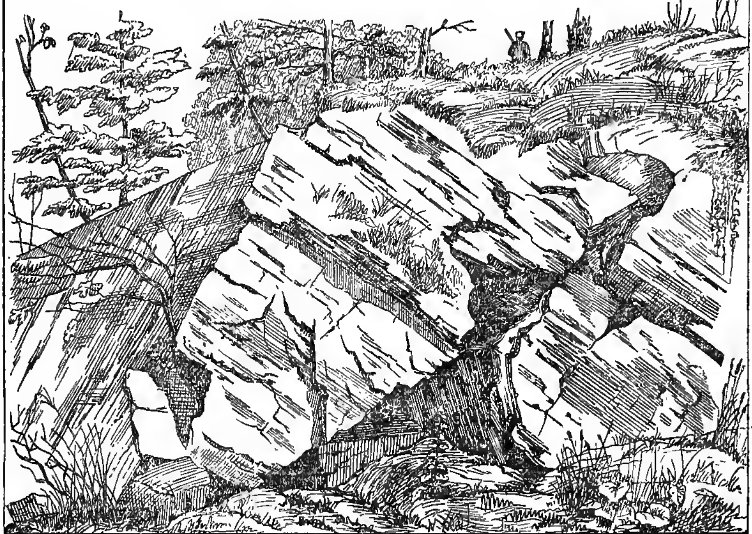
"The first outcrop of the rock, or that which bounds the valley, presents the sandstone in its usual indurated or slightly vitreous condition; and in this characteristic state it contains in the thin partings separating its remarkably parallel layers, delicate coatings of pure white talc; while imbedded in the surfaces of the sandstone are numerous very small needle-shaped crystals of black schorl, always more or less broken, as if from a difference in the law of shrinkage, or cooling of the rock and the mineral.

"The other outcrops or folds of the stratum which lie further north, and nearer to the border of the gneiss, and which are more injected with igneous granite, show a still more advanced stage of metamorphism. There the rock consists of an excess of granular quartz, involving specks of crystalline feldspar, the presence of which, and of the included talc, renders it sometimes difficult to distinguish the altered stratum from some fine-grained white granites. The schorl is, however, a sure guide to the recognition of the sandstone, however altered.

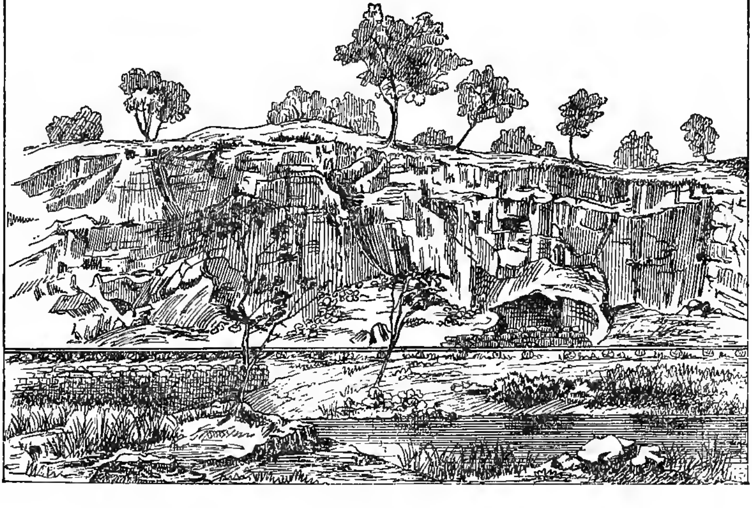
"An inspection of the section across the Chester County Valley and its north and south bounding hills, one extending from Phœnixville to the Paoli, another along the east branch of Brandywine through Downingtown, and the third through Coatesville by the west branch, will serve to show the relative development of the different members of the Primal series in these different districts, and by comparison, exhibit those remarkable fluctuations in their dimensions to which we have alluded. This comparison will show that, while in the two eastern sections very little Primal talc-slate occurs on the north side of the valley, the series embraces at Coatesville an enormous preponderance of the slates over the white sandstone, the *upper* Primal slate having a thickness of at least 700 feet, while the chief bed of the white sandstone measures no more than 30 or 35 feet. (See sections.)

"Following the formation westward along the same outcrop north of the valley, we find it well exposed near Parkesburg, at the passage of Buck run through the ridge. Here the belt appears to contain three outcrops, in a denuded, anticlinal, and synclinal flexure, its whole width

Valley limestone without cleavage
South of Norristown.



Valley limestone with vertical dip and cleavage,
Conshohocken.



from the limestone to the gneiss being a little less than one third of a mile. In the vicinity of Parkesburg the strata, in descending order, are as follows:

"1. The upper or newer Primal slates, possessing a total thickness of about 700 feet, are sub-divided by an intercalated thin bed of yellow sandstone, situated here very near the middle of the group, which may be regarded as the upper Primal sandstone of Coatesville and Chickies ridge. Above this upper sandstone there are 300 feet of thinly-laminated micaceous slaty strata—internally, olive brown—externally, very brown and ferruginous. These contain in their lower part thin layers of white sandstone.

"The yellow sandstone is itself about 200 feet thick, and between it and the micaceous slate occurs an alternation of thin and slaty layers of sandstone with the ordinary Primal slate. Underneath the yellow sandstone there succeeds another group of laminated slaty strata, some 350 feet in thickness, resting upon the upper beds of the main deposit of white Primal sandstone.

"2. The middle or white Primal sandstone member of the series is in the neighborhood about 50 feet thick. In its southern or first outcrop, north of Parkesburg, it is quarried in one or two places, and being very evenly and thinly bedded, it affords large slabs, well adapted for building and for flagging. On the surface of some of these we discern the characteristic broken crystals of black schorl in more than usual size and abundance.

"3. The lower member of the Primal series, a thick groups of brown silicious slates, more or less talcose and micaceous, is generally too much obscured at its outcrop by a covering of fragmentary matter, derived from the sandstone crest of the ridge, and from the adjoining gneiss, to enable us accurately to estimate its thickness; and this cannot be less than 300 or 400 feet.

"These strata, especially the upper and middle groups, are well exposed on the Strasburg turnpike, immediately north-west of Parkesburg; and the middle member, or the white sandstone, conspicuously so in the gorge of Buck run, one mile east of the village.*

"*Fossils.*—The only fossil known to exist in the Primal rocks in Pennsylvania, the *Scolithus linearis*, is to be met with abundantly in the Primal white sandstone in the line of outcrop we have been tracing, especially in that portion of it which is embraced between Downingtown and Valley Forge. At the foot of the ridge, for a mile east of Ayer's store, specimens of this simple cylindrical form, arranged perpendicularly to the bedding of the sandstone, are numerous by the roadside."†

Mr. Rogers (on page 180) says that the three members of his Primal series, Formation No. 1, are all represented in the North Valley hill, the upper slates forming its south slope, the Potsdam sandstone its crest, and the lower slates its north slope, overlying the gneiss. But besides its typical beds of white and yellowish white quartzose sandstone, it contains coarse loosely aggregated sandstones and fine-grained silicious conglomerate beds, merely indurated by heat or pressure, and filled with the fossil *Scolithus linearis*.

"These slates (upper and lower Primal) have each a thickness of several hundred feet, but the sandstone embraced between is nowhere of great bulk, indeed seldom exhibiting a diameter of a few yards, and nowhere 100 feet. The slates are chiefly silico-argillaceous rocks, as may be easily seen, where they are in their normal condition in the belts further to the N. W. There they are ordinary sandy slates, with included beds of argillaceous sandstone; but along these more metamorphic southern ranges bordering the Chester county valley, their structure and aspect display almost

"*Under about the same type the Primal rocks range forward to the westward into Lancaster county, and we meet them in approximately the same relative development in their next outcrops to the north, namely, in the Mine Ridge at its eastern spurs. This narrow regular belt of the Primal strata in the North Valley ridge keeps its course insulated between the Auroral limestone on its south, and the gneiss on its north, the whole way to the westernmost branch of the Octorara creek, in Bart township, where, by the cessation of the gneiss, it coalesces with another and broader belt of Primal rocks, that of the Mine ridge." (H. D. R.)

† Discovered by Mr. Rogers, in 1853. (See Geol. Penn., Vol. I, p. 181.)

the extremest degrees of metamorphism of which argillaceous strata are susceptible.

"The visible boundary of the Auroral limestone, as marked by the overlapping edge of the Mesozoic red sandstone, is traceable from Port Kennedy to near the eastern point of the North Valley ridge; but at the foot of Mount Sorrow the slates of the Primal series emerge to view in contact with the margin of the red sandstone, and from this point forward to the W., as far as the point of first appearance of the gneiss, the border of the Primal slate is defined by the undulating boundary of the red rocks—namely, over the northern flank of Mount Sorrow, and across Valley Forge creek at the dam. But from the eastern apex of the belt of gneiss near the Baptist church, the margin of altered Primal rocks defined from this point onward by that formation, trends off somewhat more south-westward, assuming a higher position on the northern slope of the main ridge. The precise place of the line of contact of the Primal and gneissic rocks is not susceptible, in many parts of the ridge, of exact determination; yet the boundary can be sufficiently well inferred from the external features, the change in the soil, and the surface fragments. Guided by these signs, and by occasional outcrops of both formations, we can follow the limit along the northern slope the whole way to the point in the spur of the ridge where this first breaks down at the passage of the road which leads down its flanks into the valley, and also at Ayer's store. From the Valley Forge creek to this gap or depression, the ridge is very straight, even, and continuous, and is everywhere crowned by the outcrop of the hard, altered Primal sandstone, which appears to have been trenched away by a rush of waters through this depression. Here, and at the crossing of the road from Pickering creek towards the Paoli, it is easy to recognize, on the southern slope of the ridge, the upper Primal slate in the condition of a talco-chloritic crystalline slate; but it is more difficult to detect the lower Primal slate of the northern slope of the hill. This is beautifully exposed at Valley Forge creek, is cut in the Pennsylvania Mining Company's shaft, and is visible frequently in fragments on the Paoli and the other roads over the ridge; but it is not generally discernible in place, being extensively covered by the fragments and the sand of the Primal sandstone of the crest of the ridge, swept over it by retreating waters.

"The actual constitution of these Primal schists is that of talco-chloritic slates, in which the talco-chloritic and quartz constituents are distinctly segregated, and in many portions thoroughly crystallized. Indeed, so completely are these masses converted to the structure and composition of the talco-chloritic schists of the genuine gneissic family of rocks, that they have hitherto been invariably referred to that group; and it is with much difficulty that a geological observer, not intimately acquainted with the phenomena of metamorphism in the rocks of our Atlantic Slope, can persuade himself that these are genuine Palæozoic masses, or beds of a fossiliferous age, converted by mere igneous agency to the antique aspect they present. But a study of the gradations or alterations assumed by these strata, as they may be traced from the zone of maximum change to the districts of least transformation further north-west, puts the correctness of this conclusion beyond all doubt.

Primal white sandstone and slates in Mine hill.

Commencing in Lancaster county, Prof. Rogers thus describes the belt of Primal rocks which enters Chester county in Sadsbury township and spreads (colored yellow on Prof. Frazer's map) over a large part of West Caln township. An inspection of the State geological map of 1858 will show how Prof. Rogers constructs the region in anticlinal and synclinal belts.

"Between the synclinal trough of Auroral limestone terminating westward in Drumore, or the same basin prolonged through the Primal rocks to the Susquehanna, near McCall's Ferry as a southern limit, and the south edge of the limestone of the Pequea and Conestoga valley, there spreads a broad undulated tract of the Primal rocks, embracing a number of short, narrow, insulated basins of Auroral limestone, divided from each other by anticlinal waves, which elevate the lower Primal slates to the surface, but nowhere bring to view the subjacent gneiss rocks.

"In this district the more prominent stony ridges consist of the Primal white sandstone, but by far the largest extent of the surface eastward of Big Beaver creek, a tributary of the Pequea, belongs to the Primal slates. There we may recognize a series of little limestone basins. This general anticlinal zone rapidly contracts as it extends eastward between the range of gneiss, which now bounds it on the south and the limestone of the Pequea basin on its north.

"It there begins to take the name of the Mine Ridge, and under this title extends until it is opposite the eastern end of the Pequea basin. The narrowest and lowest part of this ridge is at the notch called the 'Gap,' through which the Columbia railroad passes, and where its summit is not quite 500 feet above the level of the ocean. The width of the ridge, or rather of the belt of Primal rocks, in this vicinity, does not much exceed half a mile. There, and to the westward for some distance, the structure of Mine Ridge is very simple; it is composed of the three members of the Primal series already described, the white sandstone being in considerable relative force, and the whole undulated into one synclinal with one anticlinal wave; or, in other words, into three moderately gentle dips. That margin which reposes against the gneiss, dips rather steeply from it, or northward; but this dip is succeeded near the gap, or central crest of the ridge, by an anticlinal flexure making a south dip and a second north one, the beds affected by the latter descending beneath the limestone at the foot of the hill. Advancing westward, the only difference in the structure of this elevated zone of the Primal rocks is, that additional anticlinal flexures introduce themselves from the westward into the belt, until in the longitude of Big Beaver creek we may count at least six of these waves.

"In the opposite direction, or eastward from the 'Gap,' the structure of the Mine Ridge becomes complicated in a different manner by the appearance of a succession of anticlinal spurs north of the main crest.

"If we trace this main crest out to its eastern termination we shall find it ending west of the West Branch of Brandywine in a long trough or synclinal point, and north of this we may notice a long narrow anticlinal belt of the gneiss rocks coming in from the east to divide this spur of the Mine Ridge from another basin of Primal strata lying yet further north in the center of West Caln township.

"Nearly west of this uplift of the gneiss rises an anticlinal spur of the Primal sandstone north of the true Mine Ridge, and projecting forward into the south-eastern corner of the limestone basin of the Pequea, enclosing a little synclinal cove of that limestone between it and the main ridge.

"Still advancing northward to the north boundary of Caln and West Brandywine townships, we reach another and much longer synclinal belt, prolonged from the Mine Ridge, but quite out of line with it. This is divided in part, or towards the east, by a narrow strip of uplifted and denuded gneiss, penetrating across the West Branch of Brandywine, some three miles, to within a couple of miles of the limestone in the neighborhood of Compassville. It is probable that the anticlinal wave which uplifts this second belt of gneiss is the same with that which arches into a ridge or spur of the Primal rocks a little north of the above-named village. In any case it is obvious, from the structure and topography of the district, that the two or three successive spurs which protrude themselves westward into the Limestone valley, to enclose as many lesser valleys or synclinal coves of the Auroral strata, are the results of the gradual declension in that direction of so many undulations, which further eastward are in sufficient force or elevation to lift out the gneiss.

"The most northern of the three synclinal ranges, into which that of the Mine hill may be said to expand itself in its progress eastward, terminates in a low point west of the North Branch of the Brandywine, near Springtown Methodist church. Traced then westward by the Manor Presbyterian church, it extends in a widening belt, and, crossing the West Branch of the Brandywine, becomes the broad and but little cultivated belt known as the Barren Ridge, the crest line of which follows nearly the boundary between West Caln and Honeybrook townships. The northern edge of this belt is defined by the southern margin of the gneiss from Indian Run valley to the Pequea.

"Between the western end of this belt, which may be viewed as terminating near the line which separates Chester and Lancaster counties, and the south-western end of Welsh mountain, there extends, nearly in its line of prolongation, a narrower outcrop of the Primal rocks intervening between the gneiss on the west and north, and the limestone of the Pequea basin. It is probable, however, that this strip of the sandstone along the margin of the valley is not everywhere discernible, for the district presents indications of a succession of faults, extending westward from the gneiss into the limestone, and bringing these two formations into contact by engulfing and hiding from view the interposed Primal series."

Primal white sandstone and slates of the Welsh mountain.

"The third and last principal belt of the Primal strata north of the Limestone basin of Chester county, is that of the Welsh mountain and its spurs. It commences about four miles east of Morgantown, where the Mesozoic red sandstone overlaps the end of the ridge, and extends in a direction a little south of west to a point about two miles south of the village of New Holland.

"In this belt the white sandstone is not as firmly cemented a rock as it is in the North Valley hill. Advancing westward, the ridge assumes a more systematic anticlinal form (see general section V,) the sandstone dipping in both directions beneath the Matinal limestone; and as the axis sinks, the upper slates, which are of a dark-brown color, occupy the surface, and hide the sandstone. Where the axis is high, as near as the Sorrel Horse inn, two and a half miles from Churchtown, the sandstone formation exhibits marks of much more igneous action than in other parts of the range. It is partially vitrified, very compact, and traversed by innumerable planes of cleavage, with imperfect crystallization. This is not the result of contact with any igneous rocks, for the nearest trap-dyke is distant more than half a mile, and has produced but little alteration in the limestone in its immediate neighborhood.

"In this belt we meet with all the three divisions of the Primal series which characterize it in the North Valley hill, and in Chickies ridge at the Susquehanna; but the Primal white sandstone member appears to be in yet greater force than in any of the outcrops situated to the south-east. The general structure of the main Welsh mountain seems to be very analogous to that of the Mine ridge near the 'Gap.' In other words, it consists of an anticlinal and a synclinal wave, and, towards its western end, appears to be still further complicated by the rising of another shorter anticlinal, entering it from the gneissic district to the east, to form its westward spur. The upper or newer Primal slates, reposing upon the white sandstone, are in some places excessively ferruginous at their uppermost limit, where they alternate with the lower beds of the Auroral magnesian limestone, so that large accumulations of iron-ore may be looked for at the north base of this ridge, where the limestone of the Morgantown or Conestoga valley is in contact with its strata. It is precisely under these relations, both as respects the geology and the topography, that the large mine called Jones' occurs near the head of that limestone valley, two and a half miles north-east of Morgantown.

"I have intimated in another chapter, that there exists a prolongation of this band of Primal rocks, not quite in line with the axis of the Welsh mountain, but nearly a mile to the north of it. This belt extends from near Jones' mine eastward for about three and a half miles to Pine creek, terminating about one and a half miles north of the Warwick iron mines. Like the Welsh mountain, it has a stony surface, a sandy and sterile soil, and is covered almost entirely with forest. These two Primal ranges are probably connected by a neck of the same strata between Springfield and Jones' mines; but the surface there being low and much obscured by the untilled swampy tracts which form the water-shed between the Conestoga and the South Branch of French creek, the continuity of the Primal strata cannot be easily made out.

"The extreme western point of the Primal strata of the Welsh mountain is at Mill creek, near the Old Peters road. The Welsh mountain is the north-west boundary of the gneissic district of Chester county. From its western spur, the view over the fertile and highly-cultivated plains of the Conestoga is, in the month of June, when the crops are ripening, extremely attractive, for this is one of the most fertile and best-tilled of all the grain-fields of the United States. The charm of the landscape, in which the middle distances abound in all the features of agricultural beauty, is not a little enhanced by the contrast between the fertility of the plain and the wilderness-like aspect of the background of forest-covered hills, or mountain-spurs, by which the scene both south and north is bounded."

Primal white sandstone of Black Horse hill.

"That there should occur in the interior of the gneissic district of northern Chester county one or more insulated synclinal belts or troughs of the Palæozoic strata, ought not to surprise us after what has been already disclosed of the existence of a succession of anticlinal and synclinal undulations in the western part of the district, and of the series of synclinal dislocated basins in the very heart of the region, containing long lines of iron ore. The most conspicuous detached basin of newer rocks, resting within the gneiss, is one in the west corner of West Vincent township.

"It is a long belt of Primal white sandstone, which here forms a regular ridge elevated above the general rolling plain of the gneiss rocks, and known in the neighborhood as the Black Horse hill. Its length is about two miles, and its breadth is not less than 2000 feet. From the crumbled condition of the sandstone at its outcrops, and in the absence of any quarries or good natural exposures, it is impossible to recognize the dip of the strata; but that these constitute a synclinal belt or outlying trough is very obvious. It is worthy of note that this tract of Primal sandstone lies nearly in the range of the long synclinal trough of that rock, forming the hilly belt known as the Barren Ridge west of the North and West Branches of the Brandywine.

Prof. Frazer describes three principal and a few very subordinate and doubtful areas of the Primal rocks, north of the Chester valley, summarily, thus:—

One area, bounded by the gneiss on the north and the limestone on the south, stretches through Caln, East Caln, West Whiteland, East Whiteland, and Tredyffrin townships.

Another, bounded by the gneiss, stretches from the southern part of Honeybrook to Coatesville. Here it borders the Valley limestone through Valley township to Pomeroy, makes a high northern loop around Pomeroy and Sadsburyville and down to Parkesburg, whence it runs westward into Lancaster county, between the north and south boundery lines of Sadsbury township.

A third crosses from Lancaster county into West Nantmeal near the town of Springfield in contact with the southern limit of the dolerite mass occurring there. Thence it enters and turns back from Warwick, and, passing through the northwestern part of West Nantmeal and Honey Brook, reënters Lancaster county.

Some minor areas as those at Guthriesville and Cornog's are small, obscure, and of doubtful character.

"In mentioning thus the "Primal" the quartzite and quartzose sandstone alone are considered here. It will be seen further on that abundant evidence sustains the view that the greater part if not all of the weathered feldspar porphyries, conglomerates, &c., in the townships both north and south of the Chester valley are really *Lower Potsdam.* The effect of this would be to add a border of these rocks to the area of the (silicious) Potsdam as at present indicated on the map, and thus contract by this much the remaining area of real Azoic or Hypozoic."

The so-called Potsdam sandstone exposures seen along the eastern feeder of the Brandywine, north of Downingtown, embarrass the student by changing from quartzite to hornblende-gneiss by insensible gradations. Every intermediate variety of rock can be collected, and it is often impossible to say whether one is looking at a breccia or conglomerate or at a crystalline rock, whether at the original sediment simply metamorphosed, or at a subsequent sediment made out of its materials and again metamorphosed.

I V. The Northern gneiss region.

The *azoic* country of Northern Chester is colored pink upon the geological map of the county, while the overlying *Potsdam sandstone* is colored yellow. But the reader will notice what Prof. Frazer says at the close of the last section respecting this coloration, viz: That the yellow color is confined to the quartzite and sandstone beds alone, and does not include the underlying, much-weathered feldspar-porphyries, conglomerates, &c., which (following Prof. Rogers) he regards as part of the Potsdam or primal formation No. I; consequently the area of actually denuded and exposed gneiss is not so extensive as the map would make it. His description of the gneiss area is as follows:

"The western border of the Mesozoic sandstone is the eastern border of the azoic rocks from Valley Forge as far as to the end of the narrow tongue of red sandstone west of St. Mary. The azoic border line keeps on west a mile and a half further, closing up on the margin of the chlorite. It then suddenly breaks off south-eastwardly along the foot of the southern branch of French creek.

"At the junction of this with the westwardly branch it takes a direction due west along this branch, the Potsdam or Primal rocks occupying in both cases the opposite bank of each stream. Here it is cut out again by the Primal and a broad belt of trap of limited range, which it almost surrounds, and then runs in a west by south direction between Talbotville and the county line, and passes a few miles into Lancaster county.

"Its returning line follows the county line for a short distance, and turns eastward along a road nearly parallel with and a little north of the southern border of Honey Brook township. Barely enclosing the isolated limestone outcrop before referred to, it turns north-east to and follows the west branch of the Brandywine for about four miles.

"Here it turns abruptly to north of west in a bay the outline of which is not easily described, and includes Martin's Corner and Wagontown, and thence to Coatesville, where it commences the eastwardly sinuous course marked out by the northern limit of the Potsdam sandstone and quartzite. This course presents it in north-western Caln, south-eastern East Brandywine, and Lower Uwchlan, where it makes a long loop. Coming close to the border of West Pikeland without crossing it, it makes two and a half waves through Charlestown and four short ones in Schuylkill, ending again at Valley Forge.

"There are two detached areas of these rocks in Sadsbury, which together cover more than half of the township, but do not pass outside of it. There is some reason to believe that the rocks of these latter areas are more nearly allied to those south of the Chester valley than to those just described. Several sub-divisions of this area of Azoic will be found described in my township report."

Prof. Rogers' description of the gneiss of northern Chester, published in Geol. Penn. 1858, vol. I, pp. 83 to 90, is as follows:

Area and Boundaries:—"The *northeastern* boundary, formed by the southern overlapping edge of the red sandstone, is a gently curving line, commencing at the eastern point near Valley Forge, which passes Wheatley's lead mine near Pickering creek, crosses it at Kenzie's mill, and then, with a gentle sweep convex south-westward, passes immediately by the little village of Kimberton. From this point its course is nearly straight to Coventry village, opposite the junction of the two branches of French creek; crosses French creek about two miles northwest of Kimberton, and follows the north side of this valley to Coventry, except at one bend of the stream opposite Pughtown, where the line for half a mile takes the southern side.

"From Coventry village the boundary between the gneiss and red sandstone, trending first a little north and then slightly southward, runs nearly due westward for more than seven miles, to the north-eastern point of the main ridge of Welsh mountain near the village of Springfield. But there is an insulated belt of the gneiss situated a short distance to the north of this boundary on the north branch of French creek, and this may be more strictly viewed as the northern extension of the formation.

"*The north-western limit* of the gneiss is traceable from the sources of Pine creek, a tributary of the north branch of French creek, south-westward along the southern base, first of the eastern spur of Welsh mountain to Springfield, and from thence along the base of the main Welsh mountain over the Lancaster county line north of the little village of Cambridge, to within two miles of the western end of the ridge.

"This whole area of gneissic rocks divides itself westward into two main spurs or broad fingers, the shorter and more northern one terminating at the point just indicated, some two miles east of the western end of the Welsh mountain; while the southern and much longer extends forward between the North Valley hill and the southern base of Mine ridge, to the north-west branch of the Octoraro.

"This division of the gneissic area into two western branches is the result of two wide *anticlinal* undulations, and the reception between them of a broad *synclinal* belt of the Primal strata, penetrating the gneissic region eastward from the head waters of the Pequea in a gradually contracting basin, extending as far as the north branch of the Brandywine in West Nantmeal township.

"This synclinal belt of Primal rocks, a prolongation from the limestone basin of the beautiful and fertile valley of the Pequea, is itself a complex trough, penetrated from the eastward by *two narrow anticlinal spurs* or fingers of the gneissic rocks, causing it to branch into three subordinate troughs.

"The gneiss may therefore be described as throwing towards the west two large long anticlinal belts, and between these two others, much shorter and narrower. These latter start off from the main southern division in the neighborhood of the west branch of Brandywine, and extend for a few miles a little S. of W., the southern one to a point about one mile east of the little village of New Italy, and the northern one to about two miles E. of Compassville.

"The gneissic rocks for the most part constitute the valleys; the Primal strata the ridges between them; the gneiss being easily eroded, and the hard, firmly cemented, and even semi-vitreous [Potsdam] sandstone, opposing a superior resistance to the excavating action of the waters which shaped the surface.

"*The southern limit of the northern belt* commences at the east branch of Brandywine, near Ackland's grist mill, and running almost due westward, follows the south side of the south branch of Indian run, leaving the Manor Presbyterian church to the S. of it about half a mile. Thence, after crossing the west branch of Brandywine near McDuff's grist mill, the boundary between the formations coincident nearly with the north base of the barren ridge of Primal white sandstone, extends along the south edge of the valley of Two-log run, beyond which it crosses the county line about one mile and a half S. of the village of Cambridge; and now deflecting northward, and in one mile more turning again westward across the Pequea, it runs for three miles further towards the W. end of the Welsh mountain, to unite with the north-western boundary of the same area of gneiss, already indicated as ending at this point. This wide finger of the gneissic district is bounded in its western portion on its southern side by a narrow belt of Primal sandstone or slate, separating it from the limestone of the basin of the Pequea.

"*The northern limit of the southern belt* we may approximately define as crossing the west branch of the Brandywine near Wagontown, and as extending thence towards the W. S. W. along the northern side of the valley of Rock run till it crosses Buck run north of Morris' grist mill, or more than half a mile N. of the E. Sadsbury Friends' meeting-house. Thence it ranges more nearly westward to the vicinity of the Mine Hill gap, passing near the Black Horse.

"From the Mine Hill gap the line, coincident throughout nearly its entire length with the southern base of Mine ridge, pursues a direction somewhat more southwardly, till it passes Copper Mine run in the vicinity of the old copper mine from which the Mine Ridge derives its name.

"Beyond this point to the western extremity of the visible zone of gneiss the northern boundary observes a course very nearly south-westward, and unites with the southern limit a little west of the north-west branch of Octorara creek, where the belt of gneiss thus bounded ends in an acute point, inclosed between the North Valley hill and the southern spurs of the Copper Mine ridge.

"*A subordinate tract* of gneissic rocks on the northern branch of French creek is insulated superficially from the main area by a long narrow tongue of the Mesozoic red sandstone; and its dykes and ridges of trap-rock extending from Rock run, where it forks away from the main area of red sandstone, and runs westward to the county line just north of Springfield. The narrow strip of gneissic ground thus cut off, commences in a point near Rock run, spreads to a width of nearly a mile north of the Warwick Iron Mines, and then contracts again, passing the Hopewell Iron Mines, till it ends in a western point north of Springfield. It is an exceedingly interesting mineral zone. It includes the Knauer Town Copper Mine, Steel's Iron Pits, and the iron ore mines of the Hopewell furnace.

"*Character of the gneiss.*—A marked difference is presented between the gneissic region north of the Chester County Valley, and that already described lying south of it. In the latter district there occurs, as we have seen, a great diversity in the composition of the rocks of the older metamorphic class; there being an abundance, if not a prevalence, of the softer micaceous varieties, and a general deficiency of the more massive granitoid kinds. Here, on the other hand, we encounter chiefly the granite-like varieties of white feldspathic gneiss, with hard hornblendic gneiss, such as constitute the typical gneiss rock of the central ridges of the South Mountain, or highlands between the Delaware and the Schuylkill. By far the most prevalent variety is a feldspar-quartz rock, of a grayish white color, holding only a subordinate amount of mica, and disposed in comparatively massive beds. Certain of the more minutely granulated sorts, of a whitish aspect, resemble so nearly some portions of the Primal white sandstone when excessively crystalline from metamorphic action, that to discriminate between the two formations is by no means easy, but demands the closest care. Nor is this to be wondered at, for the composition of the white Primal sandstone is often just such as would be derived from a white feldspar and quartzose gneiss of this description. Micaceous gneiss does occur in the area before us, but nowhere in outcrops of any considerable breadth; and true mica-slate—except merely in thin subordinate layers—has been nowhere met with. Towards the northern side of the region there would seem to be a larger relative amount of massive hard hornblendic gneiss, while centrally, and along the southern border, the white feldspathic sort is by much the most abundant.

"*Undulated structure of the gneiss district.*—That the wide area of gneiss now under description is undulated in a succession of anticlinal and synclinal waves, is obvious to any practised geological observer who studies its structure with due care. Indeed, the evidence furnished by our map and sections is even more conclusive, as regards this feature, than it is for the gneiss region south of the Limestone Valley, for in that district the closely folded and convulsed condition of the strata renders the detection and tracing of the anticlinals of the gneiss extremely difficult, while here the undulations are, in the main, more open, symmetrical, and susceptible of continuous tracing. Along the northern or north-eastern border of the district, especially south of the valley of French creek, the topographical features, of themselves, plainly suggest the presence of a succession of anticlinals. The present margin of the red sandstone marks pretty evidently the approximate ancient shore-line of that wide estuary, which floated the sediments to form the red sandstone; and this shore-line was determined by the northern sides, and eastern ends, of a succession of hills or anticlinal ridges, which kept off the waters from the country further south. It is only necessary to travel down the valley of French creek, from Knauer Town to Kimberton, to recognize the probable truth of this picture. The notion of an undulated or folded structure in the gneiss, finds corroboration in the parallel arrangement of the hills and valleys, and in the sudden changes in the dip of the strata, wherever we make a transverse section through the region; but it receives the most positive demonstration when we study the topography and distribution of the gneiss on the western side of the county. There, as we have already seen, several long tapering tongues of the gneiss formation project forward towards the west, including between them actual troughs of the Palæozoic rocks, a feature not attributable to any other mode of elevation of the gneiss than that of an undulation of its general floor, in the manner of long anticlinal waves. Some of these waves, no doubt, are so closely compressed, or folded, and others are so irregularly dislocated, as to render the analysis of them obscure or even impossible, yet the geology of the country clearly establishes their presence.

"*Faults.*—Even in the more central tracts of the district, we are presented with some interesting evidences of these crust-undulations. I allude now to a succession of parallel dislocated synclinal axes, running through West Pikeland and West Vincent townships. Though externally the presence of these *faults* with a synclinal dipping of the strata is not recognizable in any exposures of the strata, the artificial development of the ground, in a series of excavations for valuable deposits of iron ore, has recently enabled me to discover their existence and true structure, and to show that all the principal accumulations of ore are seated upon them. These faults are all connected with the trough-like or synclinal position of the strata supporting the ores.

"But the most conclusive proof of undulations in the gneiss, and one which accounts for the presence of these deposits of iron ore, is the occurrence at almost every dislocation of an insulated patch of the Mesozoic red sandstone.

"The iron ore usually rests in a cleft or deep narrow trough, confined between steeply-dipping beds of gneiss, or a wall of granite on the one side, and moderately steep south-east dipping strata of the red sandstone, within or behind which no ore is ever found, on the other.

"These strata of red sandstone are invariably highly altered and crystalline, for they contain frequently minute crystals of mica, specular iron ore, graphite, and even feldspar. Yet, in other layers of mottled and half-baked red shale, in close alternation with these more altered ones, we see proof of their unquestionable identity in composition and origin with the red sandstone formation, from the general southern margin of which some of them are separated by an interval of four miles.

"It seems highly probable that, at the completion of the deposit, there were several very narrow troughs of it, reposing within some of the deeper valleys lying between the hills of the basin of Pickering creek; and that at the time of the elevation of the formation, or possibly, contemporaneously with the movements which accompanied the injection of the mineral veins of the Phœnixville and Perkiomen district, these troughs were dislocated longitudinally, and all the superficial red sandstone washed away, except those narrow strips which were caught or nipped within the broken synclinals between the sides of the faults.

"We may account for the existence of these outlying narrow belts of the red sandstone, and for the presence of the deep and rich deposits of hematite iron ore which they contain, and which have evidently been derived by percolation from thin strata, by the long-continued trickling of the surface-waters in the line of fracture.

"Above the Friends' Meeting-House, a bed of a singular, hard, hornblendic rock crosses the road, appearing also on the road leading from the Yellow Springs to the Red Lion, two miles above the latter place.

"*Pipe-clay* occurs in Uwchlan township, in considerable abundance.

"*Graphite* is said to occur in West Nantmeal, disseminated through blue quartz, but none was met with.

"*Iron ores of the gneiss.*—Allusion has already been made to the deposits of brown hematitic iron-ore in West Pikeland and West Vincent townships in the valley of Pickering creek; and it was stated that these, with very few exceptions, are in close relation with lines of sudden fracture, or parallel longitudinal faults, ranging along the lesser valleys of the district; it was intimated, also, that these dislocations are only so many *ruptured synclinal troughs*, enclosing narrow belts or outcrops of a material which, by all lithological analogy, can only be referred to the Middle Secondary red sandstone, altered more or less by some igneous metamorphic agency. I shall now offer to the reader some sketches of the three or four principal deposits in the neighborhood of the Yellow Springs, which have been developed by mining, and which serve best to disclose the law which seems to regulate the distribution of the ore.

"Commencing with the most north-eastern principal excavation, the first which we meet with is one about a mile and a half north-east of the Yellow Springs on the new road to Kimberton, and on land owned by Mr. Lewis.

"*Lewis's ore bank.*—This deposit, of which a considerable quantity of good brown hematite is sent (1853) to the iron-works at Phœnixville, rests in a triangular cleft or narrow trough between steeply-dipping gneiss rock on its S. E., and more gently-pitching altered red sandstone and shale, declining south-eastward at an angle of 45° on its N. W. White feldspathic granite occurs near the southern wall of the fissure. The ore itself is confined almost entirely to the loose earthy matter occupying this long open trench, very little of it penetrating the adjoining rocks. It is a somewhat sandy variety of ordinary brown iron-ore. The excavations here, all of them open to the day, extend to a depth of between 30 and 40 feet below the level of the soil, and their longitudinal distribution is N. E. and S. W., for this is the direction of the trough which includes the ore. Some of the more altered, or highly crystalline fragments of the red sandstone, contain numerous flat plates or spangles of plumbago, besides crystals of specular oxide of iron. The more argillaceous layers of this outlying fragment of the red sandstone formation, exhibit a less degree of alteration from the normal aspect of the red shale, though they are generally mottled and much discolored, and even sub-crystalline, and speckled with minute centers of segregation.

"The topographical relations of this gulf in the strata, containing ore, are just such, it should be observed, as we might look for upon the assumption of a synclinal flexure in the strata, with or without a disruption. In other words the line of the fault or fissure is centrally along the bed of a narrow but quite extended valley; and it should be mentioned, that such are the external conditions under which we find nearly all the larger deposits of iron ore in this district.

"It may not be amiss to state here, that it is in this same line of valley that we find another collection of hematitic ore a little more than one mile to the N. W. of the Yellow Springs; and it is an interesting fact that the bed of ore, a little S. of Kimberton, lies almost exactly in the same line. I would not, however, here wish to intimate, that either of these two last-mentioned deposits can be recognized as occupying the line of fault in the strata in which we recognize the loose ore. It seems probable, indeed, that the western deposit is not connected with any synclinal trough in the rocks, but is the result of an extensive decomposition of very ferruginous beds of the gneiss. Possibly, however, this part of the valley, like that at the Lewis mine, may once have been overspread by a narrow thin capping of ferruginous red shale and red sandstone [of Mesozoic age].

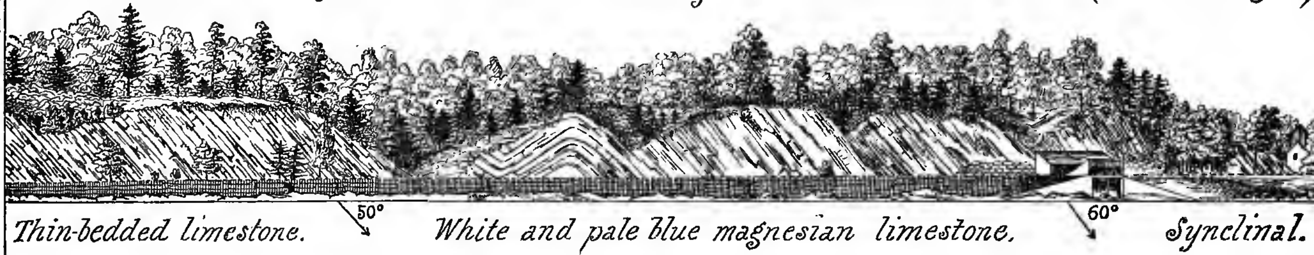
"*Fegeley's ore beds, near Yellow Springs.*—About half a mile N. E. of the Yellow Springs, two rather extensive excavations have developed a large deposit of the brown iron-ore; one of which is known as Fegeley's mine. They occur in the bed of a little narrow valley which runs just N. or back of the high hill, at the S. base of which the Yellow Springs are situated, and which is separated from the valley containing the Lewis ore bed by a narrow belt of gneissic hills. Both of the ore pits at Fegeley's lie within one long trough or trench in the strata. This is embraced by steeply-dipping and twisted beds of micaceous gneiss on one side, and by a narrow outcrop of altered red sandstone on the opposite or N. W. side. This sandstone dips south-eastward, at an average inclination of about 40°, to abut apparently against the wall of gneiss rock, making with it a long, deep, narrow trough or trench, 100 feet or less in width at the surface, and in many places perhaps as deep. Irregular injections of half-decomposed feldspathic granite penetrate the gneiss of the southern wall of the basin. Ore occurs, confusedly mingled in with the rotted materials of the gneiss and granite; but the main body of the ore is in loose earth resting against the N. sloping wall of red sandstone. The principal excavation at Fegeley's mine is about 200 feet long, 100 feet wide, and 50 feet deep; but ore is known to exist in many places in the bottom of the pit. The irregular bed of ore itself is about 40 feet wide.

"The outcrop of red sandstone which bounds this line of iron-ore on the N. W. forms a low ridge, not more than 200 yards broad, traceable, at intervals at least, by the soil and surface fragments for half a mile or more N. E. and S. W. All topographical indications suggest that exploration should be made for ore in the line of prolongation of this ore-deposit of Fegeley's.

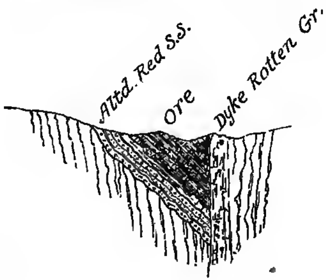
"A short distance to the N. E. of Fegeley's chief ore-pit, there is a yet larger one in the next field, accompanied by corresponding geological features, and where likewise the ore dips to the S. E., reposing against a slanting wall of altered [Mesozoic] red sandstone. In the bottom of this pit the bed of ore has a thickness or width of about 12 feet.

"A careful inspection of the ore and all the attendant phenomena disclosed in these excavations, cannot fail to suggest the notion, that the [Mesozoic] red sandstone is the source of the iron ore, and that it has yielded it up by a process of filtration and percolation of the surface waters, by which it has been carried down into the cleft between the rocks, and left there to concrete.

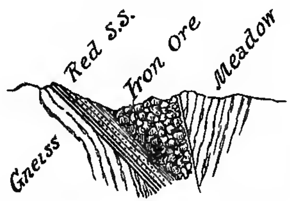
Pictorial section along the left bank of the Schuylkill above Conshohocken. (From H.D. Rogers.)



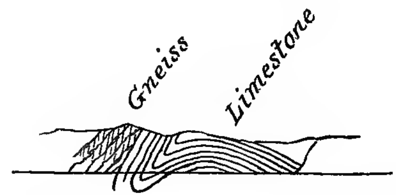
Steitler's Ore Bank



Jones' Mine



Nevin's Quarry



"The average annual yield of Fegeley's mine is about 2400 tons. It is conveyed to the furnaces at Phœnixville (1853).

"The mine adjoining Fegeley's yields about 2000 tons.

"*Latschaw mine.*—A third line or narrow belt of iron-ore occurs to the S. W. of the Yellow Springs, commencing probably in the meadows of the valley of Pickering creek. S. E. of this attractive place of public resort, two principal mines are seated along this line; one about three fourths of a mile further S. W. of the springs, known as the Latschaw mine; the other, about three fourths of a mile further S. W., called generally the Steitler ore bank, owned by Reeves, Buck & Co., of Phœnixville. These are seated apparently on one line of fault, which brings in contact in a narrow trough, a long narrow outcrop of Middle Secondary red sandstone and steeply-dipping beds of gneiss. Nearly the same geological conditions prevail at both of these mines, namely, crushed beds of red shale or sandstone dipping to the S. E., and abutting against nearly perpendicular strata of gneiss, with generally an intervening vertical wall of white feldspathic granite in a more or less decomposed state.

"In the Latschaw mine, the stratum of red sandstone seems to have been caught in a deep fracture in the gneiss, and greatly squeezed and crushed. The iron ore reposes on the slanting face of this compressed mass of sandstone and of shale, and is even dispersed or mingled through its fragmentary materials along the line of the fault. So crystalline is the red shale and sandstone, and so full of scales of segregated mica and plumbago, that the observer is sometimes at a loss to decide, from hand specimens, whether the rock is really an altered sandstone or a variety of gneiss.

"*The Steitler ore bank.*—This valuable deposit of iron-ore, evidently lying in the same great fissure in the gneiss which contains the Latschaw deposit, fills a deep triangular trough between beds of crushed red sandstone on the N. side, dipping S., and a perpendicular dyke of white feldspathic granite, which bounds the gneiss and forms the southern wall of the fissure. Except in the existence here of a more regular and massive dyke of granite, the geological conditions under which the ore occurs are almost identical with those which prevail at the Fegeley and Lewis mines in the basins N. E. of the Yellow Springs. The annexed sketch represents the relations of the ore, and of the different strata to each other.

"The Steitler ore bank has been wrought for the past eight years without interruption, yielding annually from 3000 to 5000 tons. It was first worked some fifty years ago by a Mr. Vanleer. The ore from this mine is rich, and generally of excellent quality. A little black oxide of manganese, and also a little sulphuret of iron, are occasionally found with the ore. Very beautiful masses of fibrous hæmatite, some of them delicately stalactitic, are frequently met with in this mine, which contains a more than usual abundance of those hollow geodes, which are sometimes called Bombshell ore. It is not uncommon in this and other kindred deposits to meet with beautifully white plumose mica, enclosed within these and other cavities of the ore. The source of such mica, so insulated, is a point of much interest in the theory of the origin of crystalline veins and minerals, and every occurrence of this sort may furnish food for chemico-geological speculation.

"*Jones' mine, near Yellow Springs.*—This small excavation for iron-ore is near the Latschaw mine, but not upon the same line with it, being seated upon another rupture in the strata, about one eighth of a mile S. of that. At this pit there seems to be a line of fault in the strata, filled with fragments of gneiss, of intrusive white granite, and of highly-altered crystalline red sandstone. The iron ore, in a crude and sandy state, is interspersed through this confused mass, which it serves more or less to cement. On the south side of the trench containing the ore, we meet, as usual, with steep strata of gneiss, and on the north side with south-east dipping beds of a rock which, from its highly crystalline condition, and its abounding in mica and in specular iron-ore, greatly puzzles the observer to determine whether it also is gneiss, or a highly-metamorphosed form of the argillaceous red sandstone. This mine is not at present deep enough to exhibit the geological phenomena in that distinctness under which we witness them at the Steitler and the Fegeley mines, and some doubt must remain whether we have here another outlying narrow belt of the red sandstone or not. Here is a little sketch, which is deemed to represent correctly what is actually visible at this opening in the strata.

"*Iron ore in Uwchlan township.*—Iron ore occurs on the West Chester and Pottsgrove State road, one fourth of a mile N. of the Little Eagle tavern in Uwchlan township. It occurs in gneiss, and evidently at a fault in the strata, and some of the fragmentary rock adjoining. The ore resembles much the altered red sandstone of other ore localities. This ore has not been much explored, and the two or three pits here dug are very superficial. On nearly the same line or strike, similar iron-ore may be recognized near the Morgantown road, on a farm of Morgan Hoffman, and a small ore-pit has exposed good ore in a field, owned by William Parker, nearly in the same line, which coincides almost precisely with the strike of a narrow belt of *sparry limestone*, which ranges through Morgan Hoffman's farm to George Downing's. Whether this limestone is a true igneous dyke or vein of carbonate of lime, or a closely-compressed synclinal trough of sedimentary limestone metamorphosed by heat, I will not undertake to say. It extends about a mile and a half in a straight line. It is an interesting fact, having some bearing perhaps upon the question of the origin of the iron-ores I have been describing, that several of these deposits adjoin, if they are not closely connected with, outcrops or outbursts of *limestone*.

"This is the case at the Lewis ore bank, where, it is said, a narrow strip of *limestone* has been uncovered in the excavations for ore.

"It is likewise true of the locality of Kimberton, where a small exposure of highly-crystalline sparry *limestone* with spangles of plumbago, occurs within 100 or 200 feet of the limestone, and we have seen that it obtains also in regard to the ore at William Parker's, which is evidently adjacent to the limestone belt of Morgan Hoffman's farm."

The description of the Yellow Springs brown hematite ore belt by Prof. Rogers, in 1853–4, given in the preceding pages, is all the more valuable because a number of the mines thus described have been abandoned, and new ones opened, some by the Phœnix Iron Company, and others by other parties.

The principal mines now wrought are the Stauffer, the Fussel, the Jones, (hematite, not the Jones magnetic, of Berks county,) the Monocacy (Old Prizer) and the Monocacy (Tustin) mines. These were visited by Mr. Andrew S. McCreath, the chemist of the survey, in 1882, who sampled their ores, and afterwards analyzed them in the laboratory of the survey at Harrisburg. See analyses *A*, *B*, *C*, *D*, and *E* below.

The situation of these mines, as well as of those described by Prof. Rogers, is shown in the page plate map. Their description will be found in the township report. See Index.

Stauffer mine, owned by the Phœnix Iron Company, situated 2 miles north of Chester Springs, in West Vincent township.

283 pieces of brown hematite iron ore were selected from all parts of the ore pile, mixed and analyzed. See analysis A.

Fussel mine, Phœnix Iron Company, 1 mile north of Chester Springs, West Pikeland township.

15 pounds of fine ore (brown hematite, screened but not washed) taken from various places in ore pile. See analysis B.

Jones mine, worked by James Harvey, half a mile northwest of Chester Springs, W. Pikeland township. Ore goes to Phœnix Iron Company's furnaces.

223 pieces of brown hematite taken from the ore pile. See analysis C.

Monocacy (Old Prizer) mine, one quarter mile north from Chester Springs railroad depot, W. Pikeland township.

270 pieces of brown hematite taken from the ore pile. See analysis D.

Monocacy (Tustin) mine, adjoining the Monocacy (Old Prizer) mine.

255 pieces of brown hematite taken from the ore pile. See analysis E.

Iron ore mines near Chester Springs.

	A.	*B.*	*C.*	*D.*	*E.*
Bisulphide of iron,	None.	None.	None.	None.	None.
Protoxide of iron,	.032	None.	None.	None.	None.
Sesquioxide of iron,	57.750	52.857	58.178	67.857	68.714
Sesquioxide of manganese,	.723	.123	2.141	.091	.091
Sesquioxide of cobalt,	.070	.030	.100	.300	.310
Oxide of zinc,	.050	None.	.050	.090	.090
Alumina,	1.185	4.675	2.655	1.816	1.835
Lime,	.980	.730	1.610	1.130	1.070
Magnesia,	.237	.313	.630	.353	.353
Sulphuric acid,	.200	.135	.030	.050	.060
Phosphoric acid,	.290	.398	1.777	1.537	1.511
Carbonic acid,	None.	None.	None.	None.	None.
Waterandcarbonaceousmatter,	11.491	11.590	15.318	14.294	14.444
Silicious matter,	26.590	29.500	17.190	12.650	11.420
Total,	99.598	100.351	99.679	100.168	99.898
Metallic iron,	40.450	37.000	40.725	47.500	48.100
Metallic Manganese,	.504	.086	1.491	.064	.064
Sulphur,	.080	.054	.012	.020	.024
Phosphorus,	.127	.174	.776	.671	660
" in 100 parts iron,	.313	.470	1.904	1.412	1.372

Remarks: All dried at 212° Fahrenheit.

In order to keep Mr. McCreath's analyses together, the following analysis of the ore of the *Hopewell mine*, of the *French creek mine*, (both in Warwick township,) and of magnetic ore found in the gneiss of Honeybrook township, are inserted here. See analyses F, G, and H.

Hopewell mine, about 1½ miles north of Warwick.

20 lbs. of ore sampled from different parts of the ore pile.* See analysis F.

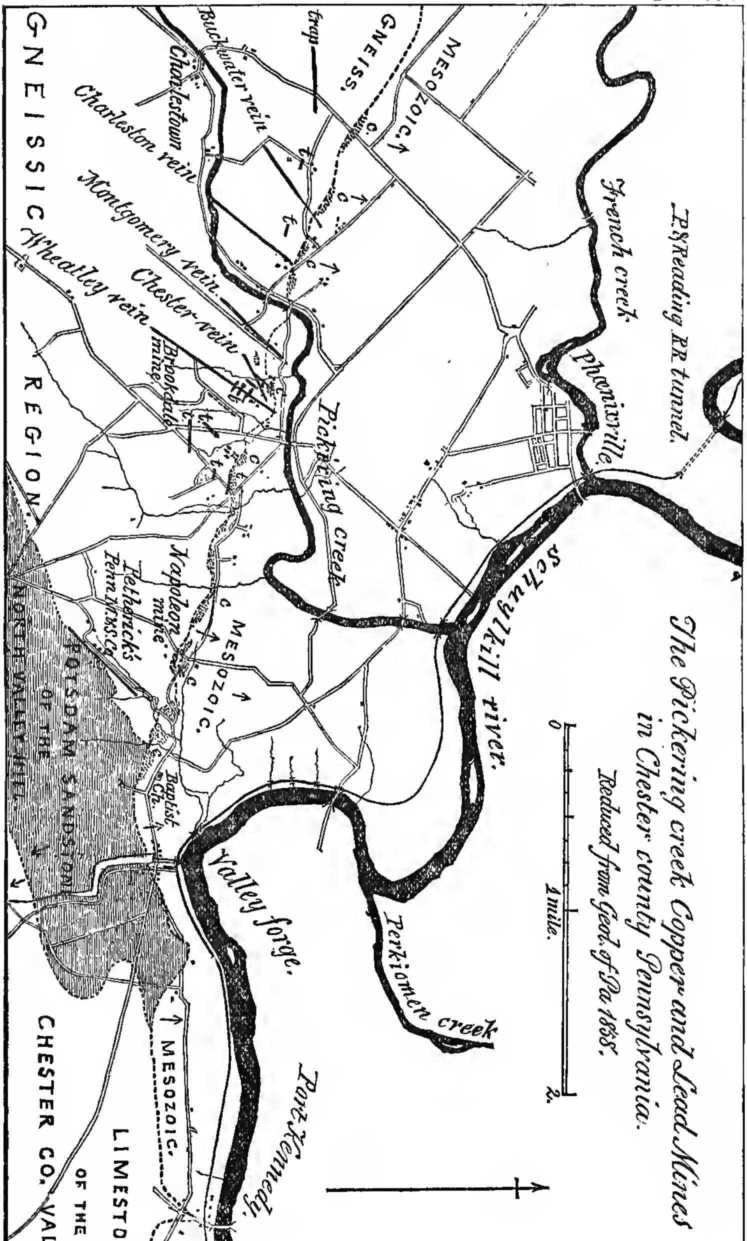
French creek mine, at the falls of French creek, about one mile north of Knauertown, in Warwick township.

20 lbs. of ore sampled from the ore pile at the furnace in Phœnixville.* See analysis G.

	F.	*G.*
Metallic iron,	37.850	50.000
Metallic copper,	.260	.608
Sulphur,	1.496	4.189
Phosphorus,	.055	.002
Lime, (chiefly as carbonate,)	——	9.430
Magnesia,	——	1.452
Silica,	23.190	6.690
Phosphorus in 100 parts iron,	.145	.004

Dried at 212° Fahrenheit.

*Samples made by Mr. A. S. McCreath himself.


The Pickering creek Copper and Lead Mines
in Chester county Pennsylvania.
Reduced from Geol. of Pa 1858.
0
1 mile.
2.
P. & Reading RR tunnel.
French creek
Phœnixville
Schuylkill river.
Perkiomen creek
Valley forge.
Port Kennedy.
Pickering creek
MESOZOIC.
GNEISS.
trap
Buckwater vein
Charlestown
Charleston vein
Montgomery vein
Chester vein
Wheatley vein
Brookdale mine
Napoleon mine
Fetherick's
Penn'k Ss. Co.
MESOZOIC.
Baptist Ch.
GNEISSIC REGION
POTSDAM SANDSTONE OF THE NORTH VALLEY HILL
MESOZOIC.
LIMESTONE OF THE CHESTER CO. VALLEY.

Magnetic iron ore in the gneiss of Honey Brook township, on Mr. A. S. Bare's farm, about one mile from the junction of the East Brandywine and Wilmington and Northern railroads.

Sample sent to the laboratory of the survey at Harrisburg, by Mr. J. Rife, of Lancaster, and analysed by Mr. A. S. McCreath, (1882.)

Partial analysis.

	H.
Metallic iron,	49.600
Sulphur,	.018
Phosphorus,	.092
Titanic acid,	21.440
Silica,	5.790

V. *The Mesozoic red sandstone region.*

The description of the Mesozoic formation as a whole will be reserved for another report, but as its lower beds invade Chester county, (see page 27 above,) and as some of its most interesting features are exhibited west of Valley Forge and at Phœnixville, within the limits of Chester county, a general statement of its geological character is here in place.

Prof. Rogers, in 1835, showed that this formation had nothing to do with the Old Red sandstone of Scotland; but consists of sediments deposited after all the Palæozoic formations (including the Coal Measures) had been elevated and folded into what are now the Appalachian and Allegheny mountains.

Then an arm of the ocean stretched across New Jersey, and through Bucks, Montgomery, Chester, Berks, Lancaster, York, and Adams counties into Maryland and Virginia, and in this estuary many thousand feet of stratified muds and sands were deposited which Mr. Rogers named *Mesozoic* (Middle age) *red sandstone.*

These strata in America were supposed at first to represent the great *Permian red sandstone* formation of Russia. Afterwards they were suspected to be the *Triassic red* *sandstone* of England. Then reasons were assigned why they should be considered the equivalents of the lower strata of the *Jura* mountains.

American geologists now write habitually of the *Triassic red sandstone* of the Connecticut valley and of North Carolina; but Prof. Cook has recently found what seemed to be Permian plants in the lower beds near Amboy.

For the purpose of this report it is only necessary to say that these Schuylkill Valley rocks are virtually the latest which were laid down in Pennsylvania, in a part of the State left sunken beneath sea level after all other parts of the State had been elevated high into the air; and that they were deposited in some places on gneiss, in other places on Primal slates and Potsdam sandstone, and in other places on the Valley limestone.

The absence of limestone and sandstone along the edge of the Mesozoic in Chester county, (referred to on pages 21, 22, above,) shows that an age of erosion had elapsed since the uplift of the continent, before the first Mesozoic sediments began to fill the estuary. But this compels us to believe that the estuary was not at that time under water. Consequently there must have been a subsidence of the continent (or elevation of the sea level) in order to fill what had up to that time been an aerial valley or plain. If, as is probable, the Primal slates, Potsdam sandstone and Valley limestone formations had been deposited over all south-eastern Pennsylvania, then we owe the great estuary valley or plain to the gradual removal of a part of these deposits by atmospheric erosion during long ages subsequent to the Coal age.

The first sediments deposited in the estuary, when it had become established by the invasion of the sea, were shore gravels or conglomerates, the materials being derived from the neighboring gneiss country. Over these conglomerates were then deposited many thousands of feet of fine sand and mud, in alternate layers, until the estuary was filled from shore to shore, that is, from the Philadelphia gneiss hills across to the Reading hills. Lastly, the whole formation was completed by a top-conglomerate deposited along the Reading hills, and along the south foot of the South mountains in York and Adams county: a conglomerate of a very peculiar character, called the Potomac marble which does not appear any where in Chester county, and therefore requires no description in this report.

The Mesozoic sand and mud deposits laid down upon a wide floor of Valley limestone and against a shore of gneiss, ought to have been approximately horizontal; for it can hardly be supposed that the previous erosion had gone far enough to make the estuary very deep; and although the rivers which brought in the sediments seemingly traversed a continental area to the south of the estuary, the tides must have been rapid and powerful, and must have distributed the sediments with some evenness, considering the fine texture of the floating materials.

But the fact is, they are not horizontal, and there is no more difficult question in American geology than that raised by the constant north-north-west dip of the Mesozoic red sandstones and shales all the way up the Schuylkill river from Norristown to within ten miles of Reading.

This dip is so considerable, varying from 5° to 15°, as to give by calculation an altogether incredible thickness to the Mesozoic formation as a whole in Montgomery and Berks counties. The distance across the formation from Willow Grove to Coopersburg in Lehigh county is about 25 miles; a constant dip of only 5° for this distance would give us 10,500′ of strata; but the dip being often much higher than 5°, a thickness of 20,000 feet might be assigned to the formation.*

That such a thickness is quite incredible appears from the fact that on the Delaware river above Lambertsville the

* The average north north-west *dip* of the Mesozoic formation is placed by Prof. Rogers (page 670) as high as 15° or 20°. "Perhaps it nowhere exceeds 25°, nor is it ever met with lower than 10° or 12°. * * * * Throughout a breadth of nearly *thirty miles*, where the Delaware river crosses the strata, it preserves a uniform inclination of about 20°, although it is penetrated and overflowed in several places by masses of eruptive trap-rock," which although often of "enormous magnitude, have scarcely caused any sensible difference in the inclination of the opposite walls of the fissures." This statement greatly increases the difficulty of accounting for the general northward dip of the Mesozoic formation; for 30 miles of breadth, at 20° dip, would give the clearly impossible thickness of 55,000′.

limestone floor appears at the surface with Potsdam sandstone, brought up indeed by a fault, but certainly not from any great depth. Again, in Lancaster county the Mesozoic is evidently thin, the limestone floor appearing through it. In Chester county the distance from French creek across to the Schuylkill at Pottstown is only 5 miles, and the thickness calculated from the dip only about 2,000 feet.

One might imagine a succession of faults, which repeat the stratification at intervals across the belt.

That there are such faults is rendered probable 1, by the discovery of such in the southern part of England, by which the thickness of the Mesozoic there has been much reduced; 2, by the frequent occurrence of trap dykes, and 3, by the actual occurrence of the great fault north of Lambertsville.

If the reader will turn back to the description of the ore mines on page 166, he will see what importance Prof. Rogers assigns to faults in the underlying gneiss floor in breaking the edge of the Mesozoic formation into separate flakes, and thus creating angular trenches in which deposits of brown hematite ore were afterwards accumulated. He will notice also that *trap dykes* play an important rôle in this faulting. How far the *whole floor* of the Mesozoic area is thus faulted, and to what height above the floor such faults break the Mesozoic deposits themselves, cannot be told; but the great outbursts of trap which form high ridges in the present eroded surface of the Mesozoic country probably issue from the largest of these faults; while the trap which issued from the smaller ones was unable to reach the present surface.*

Prof. Rogers thought that he could overcome the difficulty of accounting for the almost universal northerly dip by a theory of false bedding. He supposed the Mesozoic strata to be deposited like the cart loads at the end of a railroad embankment, or the slag heap of an iron furnace, the material all coming from the south.

One of the most important contributions to our knowledge of such *false-bedding* was published by the late Prof. Ed. Desor, in a letter to M. A. Falsan, entitled "*Sur les deltas*

* **For a description of trap dykes, see a few pages further on.**

torrentiels, anciens et modernes," (Nice, 1880.) In this study of the remarkable deposits along the Nicean shore of the Mediterranean M. Desor gives cross-sections of beds of sand and gravel shot from the mountains into very deep water, and resting on each other, not horizontally, but at angles of 25°. Similar instances are adduced from the observations of MM. Martins and Bravais, in Switzerland, on the beds of the delta of the Aar, which extend 1,200 meters into the lake of Brienz, the dip being at first 30°, gradually decreasing (at 300 meters out) to 20°. M. Dausse studied similar delta deposits in the lake of Geneva. The cross-sections of MM. Colladon and Falsan show alternate gravel and sand beds dipping 45° In all these cases there can be no question of subsequent uplifting. The simple explanation is that the materials have been shot by mountain torrents into deep water close to the shore.

The recent survey of the Durham hills and Reading mountains by Professor Prime and Mr. D'Invilliers (see Report D^3, now in press,) has furnished some new and important data for settling the question of the Mesozoic deposits.

While it is true that in the southern and middle region in Bucks, Montgomery, and Chester counties the dip is constantly north-west, it now appears that along the Schuylkill, within ten miles of Reading, there are numerous exposures dipping *towards the south.* East of the Schuylkill river, along the foot of the South mountains, there is a *general south dip*, not only of the Mesozoic conglomerate (Potomac marble) but of the Mesozoic red shales and sandstones; and this dip is a little *west* (not east) *of south.* Moreover, in the neighborhood of the Berks and Lehigh county line an extensive district of Mesozoic rocks, at the foot of the mountains, is full of exposures all dipping towards the south south-west and south-west. These dips range from 30° and 40° up to 60° and 70°, and even 75° !

How far this state of things may continue towards the Delaware river cannot be made out, on account of the character of the surface. But so far as the district in question is concerned it is evident that we must imagine: either, 1, an immense depth to the northern part of the estuary, with steep mountain shore slopes, on which the conglomerate was deposited at high angles; or, 2, a depression of the middle belt of the estuary floor after the Mesozoic deposits had been spread upon it; and this depression would have been very deep in the absence of anticlinals and faults.

We may hope that in the course of time the Mesozoic problem will be solved by artesian borings, giving the actual depth of the limestone (or sandstone or gneiss) floor at various places. A bore-hole at Phœnixville, another at Pottstown, and a third at Sellersville in Bucks county, would suffice to solve the mystery.

The south boundary of the Mesozoic rocks, says Prof. Rogers, (Geol. Pa., Vol. II, p. 668,) from Trenton to Willow Grove, overlaps the gneiss; from Willow Grove to Valley Forge it overlaps Potsdam sandstone, and especially the Valley limestone; from Valley Forge to and along French creek as far as Warwick furnace it overlaps the gneiss, and from Warwick furnace into Berks county the Primal slate and Potsdam sandstone of the Welsh mountain range.

The composition of the rock he describes (page 669) as mainly a reddish brown shale, alternating with brownish clay sandstones. Some beds are merely a homogeneous, consolidated, laminated clay. Other beds are gritty sandstones, but always with enough red ferruginous clay to make the color a pale reddish brown.* Occasionally there

*The coarse brown grit, or siliceous conglomerate, has long been employed as a material for the hearths of charcoal iron furnaces. It will not bear the anthracite heat. The hills west of the Schuylkill have furnished hearthstones for many furnaces. This rock, which is generally gathered from the surface, where it is often found in large detached blocks, is harder and coarser than the variety procured in Rockland county, N. Y., known as Haverstraw stone. (Goel. Pa. II, 674.)

It is a general fact well worthy of notice, as bearing upon the question of the nature of the currents and the condition of the surface at the origin of the Mesozoic formation, that not only these coarser grits, but indeed all the strata, viewed individually, are comparatively limited in their extent. We cannot trace any of the single layers over a wide area, but each bed appears to thin away at no great distance, and the whole mass therefore to be made up of is a nearly white sandstone layer, composed entirely of loosely compacted sand.

The middle mass of the formation has but little sand in it.

The sandstone layers are chiefly in the lower part next the Philadelphia rocks, or in the upper part next the Reading rocks. These furnish the beautiful brown-stone building material so much used in the cities.

"In the central and upper parts we not unfrequently meet with dark gray and blue shales, containing much carbonaceous matter in a partially pulverulent state, and here and there a chunk of true compact *lignite*, more or less bituminous, but retaining distinctly the fibrous structure of the wood. This lignite is even occasionally in continuous layers of 2 or 3 inches' thickness, extending for several yards."

"*The base of the formation*, especially near the Delaware, is a mass of coarse pinkish and grayish sandstones, composed of rather angular fragments of quartz, felspar, and a little mica, the constituents of the neighboring gneiss, these graduate upward into the soft red argillaceous sandstones." West of the Susquehanna this *bottom conglomerate* is made up of fragments of Valley limestone and Potsdam sandstone, some of them 6″ thick, in a cement of brownish red clay.

The *top conglomerate* or Potomac marble consists of water-worn pebbles (from the size of a pea to that of a man's head) of gneiss, Potsdam sandstone and Valley limestone in a calcareous, red clay cement.

On the Schuylkill the formation presents very little departure from its typical character on the Delaware, the great mass being red shale and soft red sandstone, with occasional beds of more sandy grits and a few of siliceous conglomerate. Perhaps there is on the whole a larger proportion of grey feldspathic sandstone in the series, (some of them building stones,) differing little in composition from the red and brown sandstones, except in that the ce-

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narrow, overlapping, wedge-shaped strata, like many estuary formations, where we may witness in the circumscribed extent and constant alternations of the smaller sub-divisions of the deposit the ever-shifting operation of river currents and of the still more inconstant tides. (Geol. Pa. II, 675.)

ment is a whitish clay (decomposed feldspar) and not red shale. In these grey rocks occur the bluish coaly shale layers, lignite and fibrous charcoal. In Lancaster county by Litiz, Manheim, Mount Joy and Elizabethtown these grey beds form almost a continuous belt. (Geol. Pa. II, 675.)

The boundary line of the Mesozoic formation in Chester county is thus described by Prof. Frazer: —

"Passing in a gently meandering line, generally following the road from Valley Forge in Schuylkill township to Pickering P. O. in Charlestown township, for two thirds of that distance; then branching to the north-westward it cuts the township of East Pikeland in almost equal parts by a line deviating but little from straight. It cuts off the north-eastern end of West Vincent and, following up the creek dividing East and West Vincent townships, it passes through the lower end of South Coventry township a short distance to the south of Pughtown and into Warwick, where having similarly skirted Knauertown, it is prolonged in a narrow strip between a large dolerite region and the mica-schists south of French creek. This narrow strip does not pass the county line but dies away, being cut out by the trap and schists, a very short distance west of St. Mary's. The boundary of the larger mass skirts the above-mentioned doleritic area, makes an abrupt angle at the point of the thin neck which projects north-east of Harmonyville, encloses the latter hamlet, and passes west almost to the county line, when it suddenly turns, being met by a mass of Primal and, altering its course to one east of north for a couple of miles, turns abruptly again and passes into Berks in a westwardly course."

The boundary line of the Mesozoic formation in the lead-mining district west of Valley Forge, is described by Prof. Rogers, in Geol. Pa. 1858, II, p. 675, with great minuteness;

and the local colored geological map which he gives there to illustrate his text is singularly suggestive to the mind of the speculative geologist, apart from its intrinsic value as showing the respective inter-relationships of the different formations: Gneiss, Potsdam sandstone, Valley limestone, Mesozoic conglomerate and metalliferous veins.

The Schuylkill river, after meandering from Reading south-eastward across the whole width of the Mesozoic area, nearly reaches its southern edge at Valley Forge. But here, instead of keeping on through the gap of Valley creek into the Chester county limestone valley, and coming out at Spring mill or Conshohocken, the Schuylkill turns east and flows between Mesozoic hills of considerable height for seven miles to and beyond Norristown; where it turns south and makes its thorough cut across the limestone at Conshohocken, and across the whole gneiss belt to the Delaware below Philadelphia.

Thus a ridge of gently north-dipping Mesozoic beds is left to the south of the river. This ridge overlooks the limestone valley to the south of it. A gap in the ridge at Port Kennedy shows the limestone of the valley underlying the Mesozoic beds, the basset edges of which face the south.* It is plain therefore that the Mesozoic beds once covered the limestone valley entirely across to the South Valley hill, from Paoli to Conshohocken. But when these Mesozoic beds were laid down slanting upon the limestone in the valley, the floor of the valley could not have been at its present level, but must have been much higher. It has been reduced to its present level by erosion during the long Cretaceous and Tertiary ages, since the elevation of the Mesozoic deposits and the consequent draining away of the waters of the Mesozoic estuary.

But during this long course of time the Mesozoic strata must also have been suffering erosion. Limestone erosion, being chiefly chemical and accomplished underground, is necessarily more rapid than sandstone erosion, which is

*It is interesting to notice the little uplift of limestone on both sides of the Reading railroad at Port Kennedy, at the *north* foot of the Mesozoic ridge.

chiefly mechanical and accomplished at the surface.* Consequently while the Schuylkill drainage was more slowly sculpturing the Mesozoic area into a rolling country, the valleys of which were always getting nearer and nearer to sea level, the limestone area was being undermined beneath its Mesozoic covering, myriads of caverns large and small being formed, which, falling in one by one, let down the Mesozoic strata; underground torrents meanwhile reduced the fragments to sand and mud and in time carried away the whole out to sea.

This accounts for two things: 1. Why there is now not a trace of Mesozoic rocks in the Chester county valley,† nor on any part of the gneiss and sandstone country which we may suppose to have been once covered by Valley limestone strata, that is previous to the deposit of the Mesozoic; and 2. Why the present surface of the limestone valley south of Port Kennedy is overlooked by a bluff of outcropping Mesozoic beds.

**Fossiliferous cavern at Port Kennedy.* The underground erosion of the Valley limestone is beautifully illustrated by the discovery of a fissure cavern, uncovered in quarrying for limestone in 1870. The fissure was exposed for a depth of 40 feet from the surface; how much deeper it goes beneath the quarry floor is unknown. Its width was 15 feet. It was merely the chimney connection of some cavern at a greater depth with the surface above. Into this chimney had been carried by the drainage waters the sand and mud wash of the Mesozoic hill slopes; and with the sand and mud was washed into the fissure plants and animals of many kinds, mammals, reptiles, birds, insects, and leaves.

Of the 30 species of vertibrate animals examined by Prof. E. D. Cope (see Proc. Amer. Philosoph. Soc. XII, p. 15, Feb. 3, 1871) there were serpents (mostly harmless) and tortoises of several species. Among the birds were a turkey and a snipe. Among the rodents were beaver, rabbit, mice, &c., (*hesperomys, fiber, sciurus,* and *lepus.*) Among the ruminants were several *tapirs* and a small horse. Among the carnivora was a cat of large size, (panther?) and a large bear (*Leidy's Ursus pristinus*) entirely distinct from the cave bear or living species of Europe and America. Three species of *sloths* were found, mostly gigantic; one was new and named by Prof. Cope *Megalonyx wheatleyi*; two were *Mylodons*, and one of these was probably new. Teeth and tusks of a mastodon (*Trilophodon ohioticus*), which had fallen into the fissure or been swept into it, were also found. None of the bones were gnawed, and the fissure had never been used by or known to the aborigines or predacious beasts, being completely concealed until exposed by the quarrymen.

† Mr. Hall however thinks that the materials filling an ancient water course at King of Prussia are from broken up Mesozoic strata.

There is no Potsdam sandstone seen along the south foot of the ridge, where the Mesozoic lies on the limestone. Why? If the valley were *here* (at Port Kennedy) a synclinal, the Potsdam would come up and form a ridge along the south bank of the river. In other words the ridge would not be Mesozoic but Potsdam. The limestone must certainly therefore turn over and go down northward under the Mesozoic country north of the river (Wetherill, Shannonville, Perkiomen, &c.;) and the steep slope at which it thus descends has determined the steep north dip of the Mesozoic dumped (from the south) upon it.*

This supposition is confirmed by what appears at Valley Forge.

At Valley Forge the west end of the Mesozoic ridge (of Port Kennedy) is a mass of Potsdam sandstone. The only Mesozoic there is a narrow strip at the north foot of the ridge, (here called Mt. Sorrow,) along the south bank of the river. Moreover, the ridge is broadened to double its width at Port Kennedy, and is also much higher. In fact we have two anticlinal axes of Potsdam, nosing down eastward under the limestone of the valley. As the limestone laps round the southern anticlinal and forms a little cove at the east foot of Mt. Sorrow; so it must lap round the northern one, beneath the Mesozoic ridge, and so descend steeply beneath Lower Providence township north of Valley Forge.

For half a mile east and a little more than half a mile west of Valley Forge, the Mesozoic beds rest upon an eroded ancient surface of Potsdam sandstone. The junction may be seen at the abutment of the mill dam 800 feet south of the river bank at Valley Forge. The last place going west where the Mesozoic lies upon Potsdam is at the brook, west of the Baptist church, ($\frac{1}{2}$ mile W. of Valley Forge,) and 700 feet south of the road to Pickering bridge.

From this point westward the Mesozoic bottom grits and conglomerates rest upon gneiss; for the Potsdam has been eroded from the gneiss north of a line which starts here and runs south-westward, whereas the edge of the Mesozoic ranges off west north-westward. The triangular area thus

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*See foot note respecting the limestone on the railroad, above, p. 186.

left between the Mesozoic and the Potsdam is the sharp east end of the northern gneiss region of Chester county, itself much eroded (but how much cannot be told) since it lost its covering of Potsdam.

It is impossible to conjecture the ancient height above sea level of this gneiss region; but the steepness of the Mesozoic beds on its northern flank suggests that it was a high mountain country with steep slopes towards the north.*

It is impossible to say whether it was ever entirely covered with Potsdam or with both Potsdam and Valley limestone; but it is quite certain that if either or both of these formations covered it they were entirely swept from off it *previous* to the formation of the Mesozoic estuary; otherwise 1, the Mesozoic bottom grits and conglomerates would not be composed of gneissoid materials, but be a limestone breccia; [and 2, strips of these formations would appear along the edge of the Mesozoic area. Mr. Rogers thinks that part of the materials of the grits is Potsdam; if so, there must have been patches of Potsdam left in the higher parts of the mountain mass up to the beginning of the Mesozoic deposits, and these patches have subsequently disappeared in the long process of the erosion of the gneiss region down to its present low elevation in regard to tide.†

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* In speaking of the Mesozoic border west of Valley Forge Prof. Rogers expresses the following opinion: "It does not appear that the red sandstone formation originally extended more than a very trivial distance south of its present conglomeritic and sandstone margin; for no wide denudation of a region so irregular could have shaved off the whole southern border so evenly as to stop over so long a line just at the base of this thin conglomerate. Undoubtedly this south edge was greatly eroded and wasted in the district further west: but not in this tract from Valley Forge creek to the neighborhood of Charlestown, where the south barrier of hills was in fact too adjacent to give space for the waters of the formation to spread beyond the limits it there occupies." (Geol. Pa. II, 677.) That would depend, however, on many considerations. The erosion problem is very complicated.

† Speculations of this kind are not useless; for in the first place they form an essential and most useful part of the discipline of the geological mind; and secondly they lead to practical results. In this instance they lead directly to the conclusion that deep shafts at Paulding's bridge, Lumberville, Phœnixville, at on other places on the Schuylkill would inevitably penetrate an underlying ancient surface of Valley limestone. How deep these shafts would have to be must of course depend on what value we assign to the dip of the Mesozoic strata between the edge of the gneiss and the river, as seen along

For it must be remembered that the gneiss region of northern Chester not only has a less elevated surface than the Potsdam crest of the North Valley hill, but a less elevated surface than the Mesozoic hill country between it and the river.* Its erosion was easier, owing to the molder-

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Pickering and French creeks. From the edge of the gneiss square across to the mouth of Pickering creek is 1¼ miles=say 6,500 feet, which at an average dip of 20° (if normal and not false bedding) would give a depth of say 2,300 feet for the surface of limestone beneath the river at the mouth of Pickering creek. But as the dip is not strong at Valley Forge and Port Kennedy, and is in a north-north-west direction, the actual depth may not be half that given above.

**Elevation above tide of the Mesozoic country east of French creek, along the Ridge road.*—Mr. E. B. Harden, in 1882, determined by aneroid a number of points along the ridge road from Phœnixville through Vincent, Bucktown, and Coventry, Harmony and St. Peter's, and St. Mary's to Springfield Station, in West Nantmeal township, near the Berks county line. (The elevations are only approximately correct, the probable maximum error being 10 feet.)

0. French Creek railroad station, (*true elevation*,)	A. T. 128′
1. Crossing of Schuylkill road and the road to Snyder's mill, in East Pikeland township,	212′
2. Ridge road ¼ mile before reaching E. Vincent township line,	273′
3. Ridge road at E. Vincent township line,	282′
4. Ridge road at D. Wismer's lane, ½ mile beyond E. Vincent township line,	405′
5. Ridge road ½ mile south of Vincent P. O.,	393′
6. Ridge road at Vincent P. O. road crossing,	399′
7. Ridge road ¾ mile N. of Vincent P. O., in E. Coventry,	448′
8. Ridge road forks at L. E. Fulmer's, in E. Vincent,	493′
9. Ridge road cross-roads at Davis Frock's, in E. Vincent,	467′
10. Ridge road S. Coventry township line,	528′
11. Ridge road, Bucktown cross-roads, S. Coventry,	418′
12. Ridge road, Lewis Stubblebine's, S. Coventry,	377′
13. Ridge road, north to Coventry school No. 1, S. Coventry,	370′
14. Ridge road, lane before reaching Rock run,	363′
15. Ridge road, ¼ mile beyond Warwick townsnip line,	472′
16. Ridge road, Seventh Day Baptist grave-yard, Warwick,	476′
17. Cross-roads, (Jacob Root,) 1¼ mile N. of 16,	649′
18. Road; half way between 17 and 19,	648′
19. Harmonyville cross-roads, Warwick,	582′
20. On N. branch of French Creek road, ¼ mile N. of Knauer & Kime's forge, and 1½ miles N. of St. Peter's,	525′

ing process to which its feldspathic rocks have been for ages subjected; and owing the to lack of homogeneousness in the whole mass.

Mr. Rogers' description continues substantially thus:

From the west abutment of the Valley Forge dam, the edge of the Mesozoic ascends a little slope of Primal slates, parallel with the road leading from Valley Forge westward, and never more than a hundred feet from it, (to the south,) until it gains the general level of the country at the north foot of the North Valley hill. It passes 250′ south of the Valley Forge hotel. At the brook west of the Baptist church it is 700′ south of the road. Here the gneiss appears, as already said.

The line now undulates westward and then north-westward, over the hill and the next brook, a little below Vanderslice's machine shop; swings south of the next knoll; crosses the main Pickering and Valley Forge road; re-crosses the road a few hundred feet further on, (just west of the abortive Napoleon mine shaft); and ranges on south of the road, 250 feet south of Krause's corner; and by the north margin of the meadow, (south of W. Miller's); this it follows, nearly touching Friends' meeting-house, to the junction of the Pickering-Paoli and Rapp's roads.

From this place to Wheatley's gate it is marked by a line of conglomerate knolls; thence by the base of the knoll north-west of his garden, and by the north slope of the hill on which stands the *Wheatley lead mine* office.

Swinging always northward down the ravines, and returning southward over the divides, past the *Chester County lead mine*, it crosses Brookdale brook, and ascends to the stack of the smelting works; then through the fields next north of the *Montgomery lead mine* to Kinsey's mill.

West of Pickering creek, it runs north of the *Charles-*

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21. French creek falls, ...	474′?
22. Ridge road at St. Peter's, (Knauertown,) at road forks just west of the grist-mill foot race, ...	370′?
23. Ridge road at forks at Warwick (St. Mary's) iron mine, ...	640′?
24. Ridge road ——— ———, ...	570′?
25. Ridge road, Springfield R. station, (*true elevation,*)	637′

town mine shaft, near the office, and then along the west bank of the next ravine to the *Buckwalter experimental opening*.

Crossing the road, and through the north-west corner of J. Davis' field (north-west of his house,) it is seen on the road a mile north-north-east of Charlestown.

Here a dyke of coarse feldspathic granite runs just south of the Mesozoic edge.

Most of the distance above described the Mesozoic edge is more or less a conglomerate of quartz and sandstone pebbles, from grains up to hens' eggs, in a cement of red clay shale; but in some places too fine to attract attention as a conglomerate, or to influence the topography. But between the Baptist Church brook and the Wheatley mine, (especially between the *Pennsylvania mine* brook and the Napoleon mine,) may be seen *two massive conglomerate beds* forming by their outcrops (200 feet apart) two lines of little knolls or ridges. Along the under one runs the road to the Friends' meeting-house.*

They are almost identical in composition, being evidently derived from the older formations (especially the Potsdam sandstone) of the North Valley hill. "Much material of the adjacent gneiss, its granite veins inclusive, enters into the substance of all these lower beds of the red-shale series.

Mineral veins along the edge of the Mesozoic west of Valley Forge.—The elaborate description of these interesting exhibitions by Prof. Rogers, written in 1853 and published in 1858 (Geol. Pa. II, 699,) will be given in another place in this report. Some of these veins are confined to the gneiss, others penetrate the Mesozoic border. It is remarkable that the metalliferous character of the veins seems to be determined by the rock which they cut.

The trap dykes of Pennsylvania, New Jersey, New England, and the southern Atlantic States, are not confined to

* "The two evidently suggest two earthquake concussions, with a pause between them, early in the formation of the red sandstone deposits." (H. D. Rogers, Geol. Pa. II, 677.)

the Mesozoic formation, for they cut tranversely all the formations from the gneiss up to the sub-carboniferous. But the principal exhibitions of trap are certainly, for some unknown reason, confined to the areas occupied by Mesozoic rocks, both in the Connecticut Valley, in Middle New Jersey, and in south-eastern Pennsylvania. In the midst of the open rolling country of red shale and sandstone rise high isolated hills of trap, the eroded outcrops of outbursts of igneous rock along cracks which go down to great depths beneath the floor of older rocks to some profounder reservoir of lava, now extinct, but similar to that which at the present time underspreads the western part of the United States, feeding active volcanoes and geysers, and producing earthquakes and fractures of the crust of the earth. Ancient volcanoes and geysers do not seem to have existed on the Atlantic border, but outbursts of lava took place through and between the layers of the Mesozoic strata, and these now constitute the trap hills of the Mesozoic region.

The composition of the trap is sometimes more acid, sometimes more basic; it is sometimes a diorite and sometimes a dolerite. Its old name was *basalt*, and gigantic rudely prismatic columns can be discerned in many of these hills. Prof. Rogers calls it (p. 671) "a union of augite, feldspar and titaniferous iron," the augite predominating. "In some dykes, however, the rock embraces much hornblende, replacing the augite . . a true greenstone trap . . but this is less common. It is of all degrees of relative fineness of crystallization, from a coarse aggregate . . to an almost homogeneous mass." Its few minerals (chiefly amygdaloidal) "exist near the borders of certain of the larger dykes, or more properly in immediate contact with the altered red shale . . *epidote*, *prehnite*, *zeolite*, *stilbite*, *analcime*, and *datholite*."

Omitting from this report Prof. Rogers' chapter on *Trap dykes* (Geol. Pa. II, 684 ff.) which takes a range far beyond the limits of Chester county, it is only necessary here to repeat his observations of the fact that *trap* appears in the most noted iron mines, such as the Warwick mine in northern Chester, the Jones' mine in southern Berks, the Cornwall mine in Lebanon, and the Dillsburg mines in York county.*

It is remarked by Prof. Rogers, (Geol. Pa., II, 699,) that greenstone trap dykes are invariably "small and obscure" in the metamorphic (gneissoid) districts of southern and northern Chester, but extend so as to cut the *Primal slates* and *Valley limestone* formations; whereas the dykes or veins of granite are never seen except in typical gneiss rock. Hence it might be inferred that the granite injections all took place in the most ancient ages, previous to the Primal deposits. But, he adds, there is some reason to doubt the accuracy of this generalization; for, dykes of rotten granite occur in gneiss near Yellow Springs in contact with the Mesozoic red sandstone and iron ore, apparently occupying fissures of Mesozoic age, isolating patches of the red sandstone from the main body. The question in these instances, is whether the "rotten granite dyke" be not really portions of the Lower Primal slate formation, formed out of and imitating the gneissic mother rock.

The insignificant size of the *trap dykes* in the gneiss regions, contrasted with the huge outbursts of trap in the Mesozoic country, is explicable by the fact, that the gneiss country offered no facilities for wide fissures, whereas, the the Mesozoic strata could be lifted like the lid of a box and allow of any quantity of outflow. But another explanation also is at hand; for, some of the Mesozoic traps were evidently overflows, happening after the lower part of the formation only had been deposited, so that the upper strata were deposited afterwards upon the trap overflow. This is proved in well known localities by the fact that only the Mesozoic sandstones and shales *beneath* the trap are baked and altered, while those *overlying* the trap are in their usual condition.

The lead and copper lodes of the Pickering creek, at the

* The Jones' iron mine will be described in the report of Berks county; with an illustrative map, surveyed and drawn in 1882, by J. H. and E. B. Harden.

edge of the Mesozoic formation west of Valley Forge, are of an age still later than that of the *trap dykes*.*

This is proved by the fact that the *Wheatley and Brookdale lead bearing lode* (see local map) cuts no less than three of the small trap dykes of that district.

The trap is fine grained and bluish, and the direction of the trap dykes approximately east and west. Mr. Rogers' description of these three dykes, (G. P., II, 703,) and his deductions from the data, are well worth recording:

"*Dyke No. 1.*—From the engine-shaft cross-cut, S. W. in the 10-fathom level 399 feet, there is a trap dyke (No. 1) ending against the lode on its N. W. side or foot wall; it is about 3½ feet thick, its course is E. and W., and its dips N. about 18 inches per fathom. Between this N. part of the dyke and its S. half, which abuts in like manner against the S. E. side or hanging wall, there is a space of 56 feet. This has the same course, but its dip N. is not more than 12 or 15 inches per fathom.

"*Dyke No. 2.*—There is another smaller dyke composed of close-grained trap; it also abuts against the lode on its N. W. side about 93 feet from the S. W. half dyke of No. 1, or 555 feet from the engine-shaft cross-cut. This dyke is about one foot thick; its course is about N. 70° W., and it dips almost perpendicularly. The other part of this dyke meets the lode on its S. E. or opposite side, at a distance of 18 feet, presenting the same nearly vertical dip, and holding about the same thickness as its counterpart.

"*Dyke No. 3.*—Another dyke, 3 feet or more in thickness, occurs at a distance of 30 feet from the S. E. half of dyke No. 2. As this lode has not yet been driven on this level beyond the dyke, or even entirely through it, it is not possible to state definitely its dimensions, or even its course and dip, though the latter appears to be N., like the other two dykes above described. It would seem to be heaved, but to what extent remains to be seen hereafter.

"Adverting to the very different distances to which the

* But earlier than the Cretaceous age, for the Cretaceous rocks of New Jersey overlap the new red and its dykes; and no minerals are found in the Cretaceous.

two dykes, Nos. 1 and 2, are heaved in this level—viz: 56 feet and 18 feet respectively—it is obvious that the displacement of these divided portions cannot be the result of an exclusively horizontal movement of the walls or cheeks of the fissure filled by the lode, but must be due, in part, at least to a vertical dislocation or shifting. The conditions of the case seem plainly to indicate that the throw of the N. W. side of the fissure has been upward and forward towards the N. E., or that of the S. E. side downward and backward towards the S. W. The exact direction and amount of this oblique displacement of the walls of the lode cannot be computed from the limited data at present furnished by the mine. It seems, however, to have amounted to at least some 3 fathoms in a horizontal direction, and to not less than 12 or 15 fathoms in a vertical one. So heavy a dislocation or throw, when viewed in connection with the great length of the vein, is certainly a very encouraging feature; for it is plain that a crack, whose sides have been so much displaced, cannot pinch itself to very small dimensions, but must remain the same open well-defined fissure which we see it in the mine for a great depth beneath the present workings. Thus the trap dykes, or cross courses, by disclosing to us an extensive displacement of the cheeks of the vein, confirm in an interesting manner the inferences already derivable from the lode itself, that, compared with the others of its district, it is an injection of mineral matter of more than ordinary regularity, extent, and richness."

Pickering creek mineral veins.

(*Detailed description by Prof. H. D. Rogers, 1853.*)*

"It will be seen, upon consulting the map of the mining district of Montgomery and Chester counties, that the metalliferous lodes or veins extending from the Perkiomen mines in Montgomery county to the Charlèstown mines in Chester county occur not far from the boundary which separates the gneissic rocks of this region from the Middle Secondary formation of red shale and sandstone. Some of

*Geol. Penn. II, 699 ff. 1858.

them would seem to lie entirely in the one set of strata, and some of them in the other; while others again, especially the interesting group of the Pickering creek veins—on the economical prospects of which I propose to venture some opinions—are partly within the gneiss and partly within the red shale, penetrating the latter, however, to apparently a trivial extent. It would seem to be a pretty general fact, that such of these veins as are confined entirely or chiefly to the gneiss bear *lead* as their principal metal, whereas those which are included solely within the red shale are characterized by containing the ores of *copper*. But the *zinc* ores, viz: zinc-blende and calamine, prevail in greater or less proportions in both set of veins, existing, perhaps, in a rather larger relative amount in the copper-bearing lodes of the red shale. Thus the Perkiomen and Ecton lode, the United Mine lode, the Shannonville South lode, a small lode on French creek, a lode at Port Kennedy, and the Morris lode near Phœnixville, are genuine *copper* veins, and they are all, without exception, in the red-shale formation.

"On the other hand, the Wheatly and Brookdale lode, the Chester county lode, the Montgomery lode, and the Charlestown lode, with other adjoining ones of the same group at present more imperfectly developed, all lying within the gneissic rocks, or if extending into the red shale not explored beyond its mere margin, are equally genuine *lead* veins. This interesting general fact is not presented, however, as an invariable law, unattended by exceptions, for it must be observed that several of the lead veins of the gneiss actually enter the red shale; two of them, the Wheatley and the Chester county lodes, carrying their ores of lead and the usually accompanying vein-stones into this rock, while some of the others enumerated are traceable still farther within its boundary by their characteristic surface-fragments. Nevertheless, in all these cases the red-shale formation which they penetrate is a very thin and superficial capping, or unconformable covering to the gneissic strata, within which, even here, the chief body of the veins must be contained below this shallow depth. Thus, even in these instances, the exceptions to the rule are more apparent than real. But partial deviations from the law, of another sort, are met with; some of the lead veins of the gneissic strata contain traces more or less abundant of the ores of copper, and, more strikingly, very considerable proportions of lead ore are occasionally associated with the copper ores, in the copper veins of the red shale, especially in the lodes of the Ecton and United mines. Yet even in these last-mentioned instances, which are the most conspicuous exceptions to the general rule hitherto brought to light in the district, the proportions of lead ore to copper ore are quite subordinate, when estimated for each entire lode.

"The *gneissic strata* of the tract embracing this group of lead-bearing veins seem to differ in no essential features from the rest of the formation ranging E. and W. through this belt of country. Here, as elsewhere, they consist consist chiefly of soft, thin-bedded micaceous gneiss, a more dense and ferruginous hornblendic gneiss, and a thick-bedded granitic gneiss, composed not unfrequently of little else than the two minerals, quartz and feldspar.

"A soft, white, and partially-decomposed granite is a very frequent associate of the stronger *lead*-bearing veins, particularly in their more productive portions; but this material belongs, in all probability, not to the ancient granitic injections of the gneiss, but to those much later metalliferous intrusions which filled long parallel rents in that formation with the lead ores and their associated minerals. It appears to be, in fact, of the same date of origin with these metalliferous lodes, and may be viewed as derived in part or altogether from the fusion of the intersected gneiss, by the intensely hot mineral matter of the vein brought into close contact with the walls of the fissure. The melted constituents of the gneiss have thus floated up along the sides of the true vein, and re-crystallized, upon cooling, in chief abundance upon the exterior of the lode. Soft granitic matter of this sort very frequently adjoins the hanging walls of the less steeply pitching lodes of magnetic iron-ore in New Jersey and New York; and it would naturally tend to place itself in this position, from its superior lightness compared with the metallic matters.

"The gneissic strata and their granitic injections throughout this district, display a softened, partially decomposed condition, extending in many places to a depth of several fathoms. This rotted state does not, however, pervade these materials to as great a depth as it does in the belt of gneiss lying S. of the Chester county valley and nearer the level of the tide. To its influence we must impute the fertility of the soils resting on the formation, and the soft lines of the landscape. Its origin is due, in part, at least, I think, to the action of the sea-water, which once evidently rested over all this S. edge of the low Atlantic slope of the country, dissolving by chemical forces the more soluble ingredients of the feldspar, hornblende, and mica.

"Immediately adjoining some of the mineral veins at the Wheatley and Chester county lodes, the gneiss is softened and decomposed to a very considerable depth, and, in some places, in a very thorough manner; the more micaceous beds being converted into a crumbling, purplish-red, unctuous, and clayey material, easily crushed in the hand, though taken from a depth of many fathoms. This condition, which has much facilitated the cutting of the upper adits of these lodes, is the result, in all probability, of a chemical influence exerted on the materials of the strata by some of the elements which belong to the veins, or which passed up through the fissures they fill at the time of their injection. Highly-heated steam and other volcanic vapors have manifestly been the agents of many of the changes we witness in the walls of our igneous veins. At the same time, it must be borne in mind that, near the surface, the penetration of external water and its carbonic acid, and free oxygen along the sides of the lodes, may have assisted this decomposition; and there can be no doubt that these elements, thus introduced, by leading to chemical changes and replacements in the constituents of the lodes, have caused the formation of several of the minerals we find—the carbonates and sulphates, for example, which are usually met with in the cavities and nests of the veins.

"*The dip of the gneiss* throughout this district is generally about S. 20° E., and seldom at any high angle, the most common being 30°—40° ; but this direction and inclination are, in some cases, much affected by contact with the veins. These *cut* or intersect the beds of the gneiss, both in strike and dip, even where they seem, by the violence of the disruption at the formation of the vein, to have twisted the strata from their ordinary bearings. This intersection or cutting shows these to be true lodes.

"Of the *general relations of the mineral veins* of the district to each other, enough is already known to convince us that these lodes are physically associated as members of one natural group of igneous injections, indicating that this is a genuine mineral region, and that the distribution of its metallic wealth is controlled by definite and ascertainable laws.

"Of the one dozen or more lead and copper lodes of greater or less size brought to light in this quite limited region of five or six miles in length, and two or three miles breadth, the greater number are remarkably similar in their course, ranging N. 32°–35° E. and S. 32°—35° W. ; and what is equally worthy of note, they dip, with scarcely an exception, towards the same quarter, (S. E.), though in some instances so steeply as to approach the perpendicular. Those which do not observe this direction seem, as far as traced, to range N. 52°—54° E., and S. 52°—54° W., and by their mutual parallelism to each other to constitute, as it were, a second subordinate group or system of veins. There are one or two other lodes, such as the *counter-lode* of the United mine, which range at even a less angle to the meridian than the first or principal set, namely about N. 26° E.

"The point of chief interest is the wonderfully close parellelism of the more numerous group, embracing the larger and more promising veins of the district.

"There is no marked difference in the general character of the vein-stones of the several mineral lodes, nor any features to distinguish as a class those of the red shale from those of the gneiss, nor, again, those observing the normal direction of N. 34° E. from those of the more exceptional direction of N. 53° E. Yet each vein posesses certain special subordinate characteristics in both its non-metallic minerals and its ores, and even in its surface vein-stones and gossans, by which the initiated observer may recognize its individuality.

"The predominant material in all these lodes is quartz, then sulphuret of iron; next to this, perhaps, the sulphate of baryta; though this is a much more variable ingredient, being scarcely seen in the Wheatley and Chester County veins, while in others, as in the Charlestown, Morris, and United mines, it is in great abundance. Besides these there occur frequently the materials of the walls of the veins, but in a more or less altered condition. Such are the soft, white, felspathic granites in some of the lead-veins, conspicuous, for example, in parts of the Wheatley mine; and he altered shale and sandstone fragments involved with the ore in the Morris lode. These veins are recognized and traced on their "backs" or outcrops by fragments of indestructible vein-stones, chiefly cellular quartz and sulphate of baryta, and by their gossans or masses of pulverulent oxide of iron and ochreous earth, interlaced with quartz, or filling cavities in the lumps of this mineral; and still more definitely by the presence of the metallic ores, sometimes well preserved in the cavities or in the body of these fragments; or oftener only in stains and surface coatings of the phosphate of lead or the carbonate of copper.

"The different lodes differ more, perhaps, in the amount and distinctness of the gossan which they show on their backs and in their higher levels, than in almost any other particulars. In this excellent indication of a good and remunerative metalliferous vein—an abundance of soft brown gossan—perhaps none of the lodes of the region will compare with that of the Wheatley mine. This material, the product evidently of the decomposition of the sulphuret of iron of the vein, often contains, in this Wheatley lode, especially at some depth below the surface, a very appreciable trace of silver, derived, most probably, from the decomposition of argentiferous galena, which is one of the characteristic ores of the vein. Sundry assays of its gossans show an average proportion of about ten ounces of silver to a ton of the material.

"The metalliferous and other minerals found in these veins form quite a numerous list.

"Selecting the Wheatley lode as presenting, perhaps, the greatest diversity of species, and as that which has received altogether the closest study, we find the mineralogy of these veins represented by the following large and interesting catalogue: Sulphate of lead, carbonate of lead, phosphate of lead, arseniate of lead, molybdate of lead, chromate of lead, chromo-molybdate of lead, arsenio-phosphate of lead, sulphuret of lead, antimonial sulphuret of lead and silver, sulphuret of zinc, carbonate of zinc, silicate of zinc, sulphuret of copper, green malachite, blue malachite, black oxide of copper, native copper, oxide of manganese, native sulphur, native silver, quartz, cellular quartz, oxide of iron containing silver, hæmatite iron, brown spar, sulphate of barytes, iron pyrites, and two or three other species.

The Wheatley lode and its mines.

"A prolongation of the Wheatley Vein, entitled the "Brookdale lode," is really but the extension of the first-named vein, as is apparent from its lying precisely in its course, the line connecting them not deviating, in fact, the amount of half a degree in a distance from the N. E. end of the Wheatley levels of more than 3,000 feet to the engine-shaft on the back of the Brookdale portion. It is furthermore confirmed by the correspondence in the direction of the dip of the two veins, but especially by the close agreement, amounting to identity, between the vein-stones and ores of the respective lodes.

"This remarkably regular silver-lead vein, already one of the most extensive, as respects its developed length in the country, has been opened and mined at intervals along a range of about 3,072 feet. It is first approached from near the water level, from the S. W. side of Pickering creek, by an adit cross-cut of 410 feet through the Red shale; the distance from this point, where the adit turns into the lode to the cross-cut leading from the vein to the main or engine shaft, is 540 feet; thence along the vein to the most western point now reached in the Wheatley mine, which is, in the 10-fathom level, 571 feet; making a total length here wrought to the date of the 1st of May, 1853, of 1,111 feet. The main adit level, including the part in the red shale, is 1,279 feet long. Between the Wheatley and Brookdale engine shafts the distance on the lode is 2,076 feet, and at the Brookdale mine the lode has been opened by an adit level a further length of 456 feet, making in all the developed length already specified of 3,072 feet. That the lode is prolonged several hundred feet beyond the present termination of the adit of the Brookdale mine, is evident to any careful observer; for the surface is marked in the vicinity of the course of the vein for this space, by lumps of cellular quartz, containing the well-known gossan of the vein, and its distinctive ores and minerals. It is certainly an encouraging feature in the vein that it thus so well preserves all its characters over so considerable a length. Although there intervenes a space of about 1,501 feet between the S. W. workings of the Wheatley mine and the N. E. openings of the Brookdale, within which the lode has not yet been sought for nor proved, there cannot be much doubt that it maintains itself continuously through this interval, and is a regular persistent vein.

"In width this vein varies from 1 foot to 2 or 2½ feet, its average size in the Wheatley mine being about 18 inches, and in the Brookdale adit nearly 2 feet. Thus far it gives all the indications of being about as productive in ore in the latter mine, at an equal depth, as it is in the former. While the Brookdale end is somewhat thicker than the other, it is rather more full of quartz; yet the adit there, which is only some 30 feet below the surface, and is at present rather more than 456 feet long, presents for 400 feet what miners would call a "kindly lode for ore," with quartz, gossan, phosphate of lead, carbonate of lead, and galena, growing somewhat poorer, however, farther towards the S. W. end. The Brookdale shaft, descending on the lode, is only 75 feet deep as yet; but the lode seems gradually to improve as the sinking advances.*

"The dip of the lode in the Wheatley mine is about 2½ feet to the fathom, or 68°; while it is steeper in the Brookdale end, being there about 18 inches per fathom, or 76°. Its mineralogical characters have been sufficiently described already, when alluding to it as the type of the more promising lead-bearing lodes of this district. It may be well enough, however, in this place, to call attention to what has been said under the head of "General Remarks" upon these veins, respecting the prevalence of a soft feldspathic granite on its walls, a soft rich gossan in its upper levels containing silver, and the gradual reduction in the proportion of the phosphate and carbonate of lead, with a corresponding increase of that of the galena in descending from level to level in the Wheatley mine. This last fact, showing a progressive replacement of the more easily vaporized ores—condensable only in the upper cooler parts of the vein—by other ores requiring a higher heat to sublime them, gives us, as already intimated in a former statement, a right to anticlpate a somewhat further augmentation in the quantity of galena as the mine descends. By indicating the energy of the igneous action which attended the injection of the metalliferous materials in the fissure, these more readily sublimated compounds are in themselves an assurance of the probable permanency and constancy in size of the lode. That this vein is the product of true igneous or volcanic agency from a deep source within the earth, is not only clearly implied by all that has been here stated of its geological and mineralogical features, but is plainly demonstrated by the occurrence of pure volcanic or crystalline sulphur in the cavities of the less compact masses of the galena or sulphuret of lead. Were a conclusive proof of an igneous origin really needed, it would be furnished, I conceive, by this interesting fact. Other and equally striking evidences of the force with which the vein was injected will

*At date of August 1, 1853, the shaft was down 110 feet; and a level, at 90 feet depth and 20 fathoms long, exhibited a much richer condition than the adit-level above.

present themselves in the cross courses of trap-rock, intersected and displaced by the lode.

Extent and condition of the Wheatley mine in 1853.

"*The Adit-Level.*—The adit or water level lies at an average depth beneath the surface of about 8 fathoms. Its total length is 1279 feet. Of this space, 410 feet are through red shale from the adit mouth to the lode. From this oblique cross-cut it is 540 feet long the lode to the short cross-cut at the engine-shaft. Thence to the W. whim-shaft it is 194 feet, and beyond this the adit extends 135 feet farther.

"*The 10-Fathom Level.*—This level has a total length at the present date, May 1, 1853 of 935 feet from the end of the engine-shaft cross-cut to its present S. W. terminus. It has now been driven 604 feet; and from the same point to its N. E. end it is 331 feet long. It extends, therefore, about 275 feet past the S. W. end of the adit-level.

"*The 20-Fathom Level.*—Up to the same date, the 1st of May, this level had been driven S. W. from the engine-shaft cross-cut 465 feet, and N. E. from the same point about 95 feet, being a total length of 560 feet.

"*Of the Shafts and Winzes.*—There are five external shafts and six shorter interior ones — called winzes by miners—connecting the different levels.

"*The Engine-Shaft.*—The main shaft of the mine, by which all the water is lifted, and a portion of the ore also, has a present depth of 234 feet. It is perpendicular, and enters the gneiss rocks at a point 122 feet S. E. from the lode at the surface. At the adit-level, its distance from the lode, in consequence of this being nearly perpendicular in its upper portion, is still 120 feet; opposite the 10-fathom level its distance is 103 feet, and at the 20-fathom level the space is 76 feet. On the assumption that the present very regular rate of dip of the lode will continue, the shaft will be off from the 20-fathom level—not yet quite reached—about 51 feet, and 26 feet from the 40-fathom, and only 1 foot from the 50-fathom level, a little beneath which it will enter the lode. This shaft is, in regular-dipping gneissic strata, penetrated here and there with injections of granite and sienite.

"*The S. W. whim-shaft*, 194 feet S. W. from the engine-shaft, descends in the lode, and has a depth of 174 feet.

"*The N. E. whim-shaft*, 311 feet from the engine-shaft, is not in the lode, but in the gneiss rocks, and is so placed that it will cut the lode at the 20-fathom level. Its present depth is about 100 feet.

"*The two adit-shafts* meet the lode at the adit-level, and are only for ventilation. They both are to the N. E. of the engine-shaft: the *first* at 201 feet from it, with a depth of 57 feet; the *second* at 530 feet from it, having a depth of 40 feet.

"*Of the winzes* within the mine, there are two which descend from the adit-level to the 10-fathom level; one of them situated to the N. E. of the engine-shaft cross cut, and the other to the S. W. of it.

"The other four descend from the 10-fathom level to the 20-fathom level; and of these, one is N. E. of the engine-shaft cross-cut; one lies between this cross-cut and the W. whim-shaft, while the remaining two are to the S. W. of this whim-shaft.

"*Note.*—Subsequently the 10-fathom level has been extended 72 feet, and the 20-fathom level 168 feet.

Product of the mine in ore.

"I will now present some notes of the past productiveness of the mine, with my views of its prospective yield.

"Good ore has been extracted in stoppings even between the surface and the adit-level: for example, near the engine-shaft cross-cut, for a length of about 40 feet. In the next lift, or between the adit-level and the 10-fathom level, the mine has yielded good ore in three stoppings: one, N. E. of the engine cross-cut, 40 feet long and 30 feet high; another, just S. W. of the cross-cut, 80 feet long and nearly up to the adit-level, or about 55 feet high; while the third or largest was both N. E. and S. W. of the W. whim-shaft, and had a length of 214 feet, and an average height of some 36 feet.

"In addition to this portion already taken out, I would observe that there was in 1853 a mass of ore still above the 10-fathom level, at its extreme W. end, some 35 feet in length.

"Between the 10-fathom and the 20-fathom levels there has been very little ore removed as yet, the chief piece of stopping being a little S. W. of the engine-shaft cross-cut. Another mass, about 50 feet long and only 9 feet high, has been taken chiefly from the S. W. of the whim-shaft; and there is yet a third stopping, on the main lode at the S. W. end of the 20-fathom level, 45 feet in length, but carried up at present no more than some 12 feet on an average.

"In the portions of the main lode which seem to promise a profitable future yield, there remains some ore above a long stopping near the W. whim-shaft above the 10-fathom level. The ground S. W. of this old stopping is dead, and beyond it we find 36 feet of good stopping-ground to the present end of the level.

"From the 20-fathom level on the N. E. end, N. E. of the engine-shaft, occurs a piece of good ground, almost 40 feet long, near the winze S. W. of the engine-shaft cross-cut. This first piece is 66 feet long between the cross-cut and winze. A second piece, beginning 50 feet N. E. of the whim-shaft, and extending for some 250 feet to the present end of this level, though in places quite lean, will pay well for stopping. At the S. W. end of the workings, the lode appears of average richness. On the 10-fathom level there is a cross trap-dyke 3 or 4 feet thick, and beyond this the vein is resumed, but is at present thin, being only just at the dyke. The 20-fathom level is not as far forward within 150 feet. It ends in a very fair lode, and has very recently increased both in size and richness, the ore part being estimated to be 2 feet thick, and to yield 3 tons of ore per fathom.

Branches from the main lode in the Wheatley mine.

"An interesting and encouraging feature in this vein, betraying the energy and extent of the rupturing and injecting force, is the presence of several branch lodes which fork off at an acute angle from the main mass, and for the most part, re-enter it again at a similar obliquity, insulating at the same level, at least, a thicker or thinner mass of the adjoining rock. These enclosed "horses," as the miners call them, are sometimes entirely insulated in certain mines, sometimes only partially so. In the Wheatley lode, the principal one points off to nothing upwards, and feathers off in both directions horizontally, by the branch veins running into the main lode upwards as well as horizontally; but whether it is thus surrounded in the downward direction cannot be known, since it is growing progressively thicker from level to level descending. That this branch lode will eventually enclose the "horse" in the downward direction, seems altogether probable, from its appearing to be so essentially a true branch shot upward and laterally from the main injection of ore.

"The branch veins, as now developed, are—

"*First.* A branch vein or offset from the main lode, which turns out and re-enters it, insulating a horse. This branch at the 10-fathom level is 80 feet between its two junctions with the main lode, and at this level it recedes 9 feet at the thickest part of the horse. The horse contains strings of phosphate and carbonate of lead. This branch joins the main lode about 20 feet above, back of the 10-fathom level. It dips steeper than the main lode, underlying not more than 6 inches in a fathom; for, at 16 feet below the 10-fathom level, the cross-cut to it is 12 feet long, and it will be 20 feet at the 20-fathom level.

"This branch yields good ore throughout, chiefly galena. Its average thickness is about 9 inches, and it is richest where the horse is widest, and thins at its junction with the main lode.

"Opposite this branch the main lode contains galena and phosphate of lead as on the 10-fathom level—good ore, say about 13 inches in thickness.

"There is another branch also on the N. W. or underlying side of the lode, visible in the 10-fathom level, but opened and mined from the 20-fathom level. It has been mined 60 feet from the S. W. point of the horse N. E. to where the workings now are; but it has not been worked round into the lode.

"This branch, like the other, is nearly perpendicular, underlying not more than 9 inches per fathom. The horse, at the thickest, is about 12 feet, and at the present end of the workings, 5 feet thick, the branch now approaching the main lode.

"The horse is streaked with thin veins, and has chunks and strings of galena, carbonate of lead, &c. There are symptoms of other branches or turn-outs of the vein, some of them on its S. E. side; but these two, here mentioned, are the ouly ones now working.

"These branches, it will be seen, promise to contribute quite a considerable auxiliary amount of ore to that derived from the main lode, and they deserve to be very carefully sought and pursued.

"Of the other or productive half, a careful study of the Wheatley mine induces me to believe that the average yield in good ore, calculated to the square fathom, is from 1¼ to 1½ tons.

"It is in the power of any person, from these data, and from the other elements of length and depth already presented, to estimate for himself, on the reasonable assumption of a permanency in the averages I have ventured to give, the total future yield of the whole lode, embraced between the limits within which it has been opened, and is now being wrought, in the Wheatley and Brookdale mines.

"In support of the general accuracy of my estimate of February, 1852, of the quantity and aggregate value of the ore then accessible in the mine, I beg leave to mention, that I learn from the books of the company, that the quantity of marketable ore actually extracted from those workings and sold, proved to be almost exactly what I at that time computed it, as it lay unbroken in the mine.

"*The Brookdale lode*, or, more strictly, the Brookdale end of the Wheatley lode—for every indication implies that the two mines are situated on one and the same metalliferous vein—has been already sufficiently described in referring to the features of the whole under the name of the Wheatley lode. There would seem to be very little room to doubt that this assumed continuity of the vein really exists; for though both the Wheatley and the Brookdale portions, in certain sections of their length, deviate considerably from the direction of the line joining the most distant shafts, yet the vein appears to return again to this general average course, the departures being neither very wide nor long. The same undulation in its course is noticeable at the Brookdale end which we witness in the Wheatley portion. Though the actual distance on the lode between the S. W. end of the present workings in the Wheatley mine, and the nearest positively proved point in the Brookdale mine, is about 1308 feet, yet the coincidence in direction in the surface vein-stones, and in the ores, and all their accompaniments, is so striking as to convince every attentive observer that the two mines are seated upon one and the same lode. Referring to the general statements given in the preceding sketch of the geological and mineral features of this vein, and its relations to the other veins of the district, I proceed to offer a few notes and observations respecting the Brookdale mine.

"The length of lode opened by the adit-level is about 456 feet, but there are decided indications on the surface along the course of it, even a few hundred feet beyond the point at which the adit at present terminates, that the vein still continues. The lode through much of the Brookdale ground or sett, outcrops near the bed of the little transverse valley which descends N. from a range of higher land; as a consequence, the adit-level is not deep beneath the surface, being nowhere lower than 6 fathoms, and, on an average, only 4 fathoms.

"In this adit-level, the lode is stained with spots of carbonate and phosphate of lead, and with galena, for a length of about 400 feet, or within some 60 feet of the end of the level. The gossans, vein-stones, and ores of the Brookdale mine are identical with those of the Wheatley, and it exhibits in its hanging wall precisely the same variety of soft white feldspar and quartzose granite which distinguished the same wall of the latter, and which I have so very often noticed to be the accompaniment of our richest metalliferous veins.

"Above this adit, several tons of marketable ore were procured at no greater depth than some 20 feet; and below this level the vein steadily improves in richness in the shaft.

"On the whole, the indications of a productive vein in the lower levels of this mine seem encouraging; but to open the lode satisfactorily, a powerful pumping-engine is indispensable. The position of the vein so near the bed of a ravine will render this mine a wet one; and although the present excellent engine of 60 horse power will be competent to the drainage of the first upper levels, it can never grapple with the burden of water to be lifted when the workings grow deep and extensive."

Granite, greenstone, and augitic trap dykes penetrate the gneiss in various parts of northern Chester; and with them occur veins of magnetic iron, and copper and zinc ore, which will be described in the following township report, on pages to be found by reference to the "Index to Chester county."

The *granite* injections are for the most part a coarse binary mixture of white opaque feldspar and quartz, tending to surface decomposition. The dykes are narrow, with nearly parallel walls and ramifying veins, sometimes cutting the gneiss rocks perpendicularly; in other cases running between and dying out in tortuous branches among the contorted layers. A somewhat common variety consists of quartz, greenish semi-translucent feldspar, and a small proportion of hornblende. The white feldspathic granites seem most to abound in southern half of the district where the gneiss rocks resemble them. The hornblende augitic variety (with its minerals) prevail in the northern part, where the mother rocks are also more of this kind. The prevailing direction of the granite dykes is N. 55° or 60° E., and the dip, where not vertical, is steeply S. E.

The *trap dykes* are narrow, closely crystalline, fine-grained, bluish, hornblendic in all directions, but usually E. N. E. Small trap dykes are common in Vincent and East and West Nantmeal. The two high hills near Warwick furnace are the largest masses of trap in the township. (H. D. R.)

Fossils of the Mesozoic red shale and sandstone.—In the Connecticut valley immense numbers of foot-prints, mostly of three-toed animals, have been found in the quarries, and preserved in the great museum at Amherst, and in other lesser collections. These animals were at first supposed to be birds, and a few of them gigantic batrachians (frogs); but subsequent discoveries in many parts of the world, and especially in the western territories of the United States, have proved them to be large sauroid (lizard-like) animals with certain bird-like features. The foot-prints are pictured in a quarto memoir by the late Dr. Hitchcock, Geologist of Massachusetts and President of Amherst College. Some of these foot prints may have been made by early forms of *birds*, such as are known to have lived in that early age, and to have had their mandibles set with fine teeth; but the majority of them were undoubtedly made by *reptiles*, some of which were furnished with wings. This is proved by the sudden commencement and termination of the rows of foot prints, showing that the creatures alighted on and again rose from the shore mud into the air.

In Lehigh county, Pennsylvania, saurian bones were found, described by Dr. Isaac Lea, under the name of *Clepsisaurus pennsylvanicus.**

At Phœnixville, while the tunnel was made, many fossil bones, teeth, and plants were thrown out, and collected by Mr. Charles M. Wheatley. Prof. Rogers found here a tooth, which he figures, Geol. Pa., II, page 693. Dr. Lea supposed this tooth to have belonged either to a *Clepsisaurus*, or to another lizard called *Centemodon sulcatus*, found in New Jersey.†

Clepsysaurus Leai was afterwards found in Pennsylvania.

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*So named because of the resemblance of the vertebral bones to an hour-glass.

† Proc. Amer. Acad. N. S., Philada., June 2, 1857, Dr. Leidy's discussion of the *non-thecodont* character the teeth of *Clepsisaurus*, &c., is to be found in Proc. A. Acad. N. S., Phil., June 9, 1857.

Ganoid fish scales have also been found at Phœnixville. Several species of *Catopterus* occur in other States; and an *Ischypterus* in New Jersey.

In Virginia Prof. W. B. Rogers, in 1842, found other fossils, which he communicated to the Boston Soc. Nat. Hist., in 1854.

In North Carolina, Dr. Emmons found other reptiles which he named *Rutiodon Caroliniensis*, *Palæosaurus Carolinensis*, and *Palæosaurus sulcatus*.

Another reptile, *Bathygnathus borealis*, was found in Prince Edward's Island.

Prof. Frazer found large bones in York county, which Prof. Cope pronounced reptilian.

Of small crustaceans, several species of *Cypris* and *Estherea* have been found in Pennsylvania.

No *mollusks* (shells) and no *radiates* (star fish) as Prof. Dana says (1880) have been found in our eastern Mesozoic rocks; a fact which points to their having been fresh or brackish water deposits.

The only fossil *insect*, a larva of some Neuropterid (Ephemera?) about three quarters of an inch long, was found in the Connecticut river valley; but Prof. Hitchcock named nearly thirty species of unknown animals from rows of small foot tracks, the impressions of which have been left in the soft red shales. Some of these tracks may have been made by the larvæ of insects; others by the small crustaceans.

Plants are numerous at one or two horizons in the Mesozoic formation; referable to *Equisetes* (horse-tails); *Zamites*, therefore Triassic; with lignitic fragments of conifers.

Plants have been recently found by Prof. Cook in the lower part of the formation in New Jersey which have a Permian aspect.

Recent memoirs, by Prof. Fontaine of the University of Virginia, and by Prof. O. J. Heinrich, on the Mesozoic of Virginia and its fossil plants, throw a flood of light upon its constitution, showing clearly that it can be divided into sub-formations.

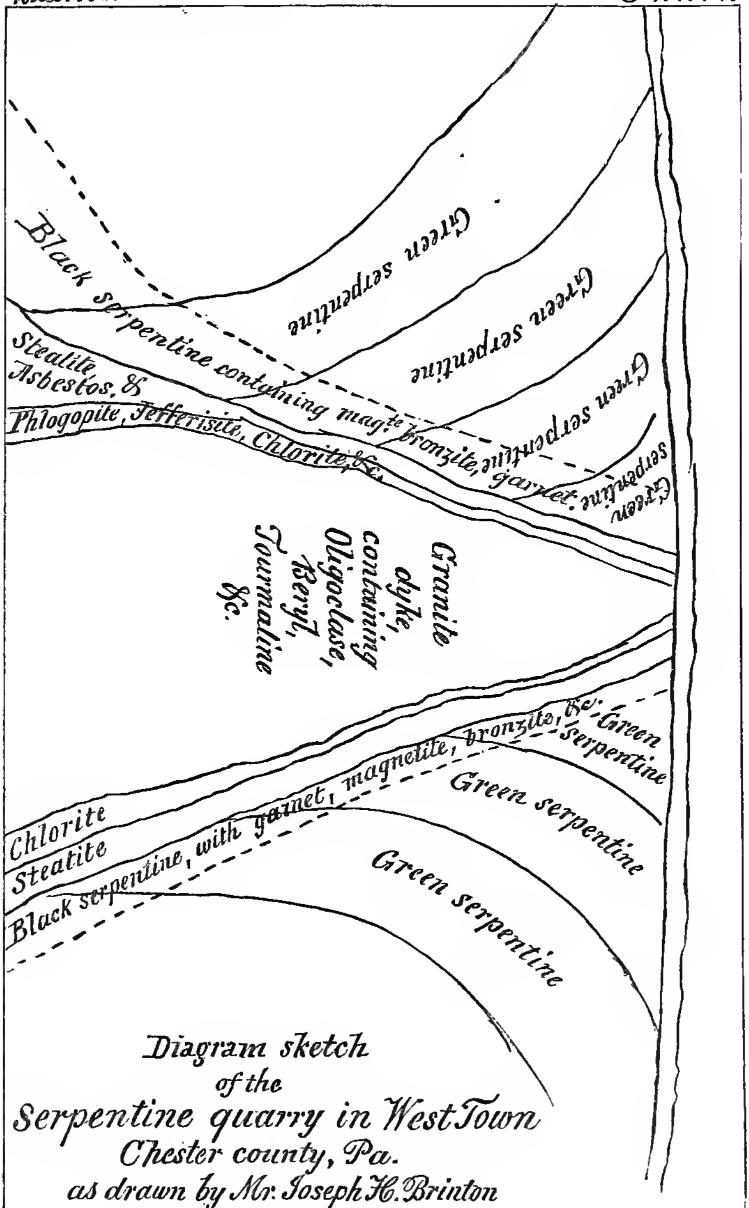

Diagram sketch
of the
Serpentine quarry in West Town
Chester county, Pa.
as drawn by Mr. Joseph H. Brinton
to explain his views.

CHAPTER III.

*Geological notes in the several Townships of Chester county.**

BY PERSIFOR FRAZER.

Preliminary Remarks.

Varieties of Rock in Chester County.

There are nine distinct groups of rocks recognizable within the limits of Chester county, but it is not easy to arrange them in any exact chronological scale at present, owing to certain vexed questions of structure to which allusion must be continually made. So far as they have been made out they are as follows, beginning at what are presumed to be the lowest:

a. Certain syenites and feldspar porphyries, which by an unusual paragenesis occur frequently together. The feldspar porphyry is a coarsely crystallized rock, made up of potash feldspar and white or sometimes amethystine quartz, and also occasionally containing enough mica to entitle it to be called a coarse porphyritic granite.

The syenite is a dark compound of hornblende and white feldspar, having in the ruts of the roads which cut through it iron stains, weathering into the familiar "nigger-head" bowlders, and producing also an impure clay. Some rocks

* Most of the observations recorded in the following pages were made in 1879.

resembling this syenite have been analysed by Dr. Genth and found to contain labradorite and audesite with pyroxene. They will be alluded to in another place, but the occurrence is interesting.

b. Next to these come their imitations—often difficult to distinguish from the originals, and where the juxtaposition of syenite and feldspar porphyries has in all probability been inferred. Thin sections of the gneisses in this area show a marked increase in potash, feldspar, and microcline.

c. Next come the mica-schists, which in one form or another cover the larger part of the area of the county. In the south-east and north-west these rocks are crystallized, and shed their mica on the fields and roads as do the gneisses of the Philadelphia region. Towards the south-west margin of the county the detached mica is also conspicuous, but in the massive rock it is much convoluted and more *crystalline* in character. The only portions which are really argillitic and almost crypto-crystalline are those immediately south of the Chester valley and in the eastern part of the county.

d. Throughout an area widening from the east from one mile near Eagle Station to fourteen miles or more along the Octorara creek and touching the northern outcrop lines of most of the limestone and serpentine patches which extend along this belt, there occur thin mica-schists of more foliated and crystalline character which cannot be otherwise designated and yet are in all probability different in age, as they are in texture, from the true mica-schists of the Delaware and Delaware county border. Part of these are undoubtedly above the limestones which lie in detached masses over the southern part of the county, and part of them are equally certainly below. Some of them are garnetiferous.

e. Within this triangular area just referred to are irregular included areas of more or less chloritic rock, and some of argillitic or hydra-mica-schists. It was intended to separate these areas from the general mica-schist region and from each other; but this attempt, when redneed to paper, had to be abandoned, so impossible to suppose as the results of natural divisions were the boundaries thereby produced. This part of the mica-schist then is distinguished from the coarsely crystalline mica-schist by the fineness of its component parts, the occurrence within it of chloritic and argillitic areas, its proximity to and apparent connection with the largest limestone area, and the abundance of the milk quartz which it contains.

f. Next in order of age come the limestones. The plural number is preferred in speaking of them because it is not certain that they all belong to one age. That they formed most important "benches" in the stratigraphy will sufficiently appear from the frequency with which they have been named already. Limestones generally imply clay; and whatever may be the cause, they are too frequently joined with limonite and other mineral occurrences to permit of the explanation that these connections are merely apparent or fortuitous. Admitting that the limestone of the Chester valley is contemporaneous and in fact continuous with that of the Lancaster deposit, the same by no means follows for the outlying patches of southern Chester county. Their dip is usually south. Some of them are clearly imbedded between crystalline rocks when cropping out at high angles, and sometimes this is the case under the former conditions.

It has been elsewhere said that the freedom of these southern small patches of limestone from magnesia was enough greater than that of the main mass to imply for them a separate genesis.

Towards the east in the Chester valley limestone and very generally in the small basins the limestone is partly highly crystalline, in fact a marble. There are two colors which distinguish it. That of the valley rock is generally blue, striped with thin or thick layers of white limestone; that of the others more generally lighter blue to gray. Both weather alike into irregular pits and honeycomb texture when exposed.

One isolated patch of limestone—the only one observed north of the Chester valley—deserves mention on account of its resemblance to the isolated patches so frequently alluded to above, south of that marked median belt. It occurs near the south-east corner of Honey Brook township, and near to but not actually touching the border line between the mica-schists and the quartzite and sandstones which there form a large peninsula. It forms a narrow strip of small extent.

g. Perhaps before the limestones the serpentine should have been mentioned, especially as this rock, everywhere causing its outcrops to be named "Barrens," has been utilized in Chester county for building stone, and its production has built up a large industry.

The serpentine, originally supposed to be of igneous origin and very generally now assumed to be a separate and distinct formation, allows neither of these characters to be distinctly proven. As a general rule, where exposed it is so fractured and broken as to make the determination of its dip very difficult or altogether impossible. But its strike cannot unfrequently be pursued, in almost straight lines, for miles, though these lines have not always any ascertainable relation with the strike of the rocks near which it occurs. There seem to be two different positions in which it occurs: one as the margin of the chloritic schists, and one among the mica-schists themselves away from any other rock. As an example of the first case it is found in Easttown township, between the argillitic mica-schists, and north of a dyke of trap, on the other side of which however it very soon appears to the westward. Of the second case are the occurrences in East Goshen and Westtown townships.

It is most largely developed in the extreme south-western extremity of the county, in Elk and West Nottingham townships, where it joins the deposit described in the Report on Lancaster county, and crosses the Maryland border and the Susquehanna river, forming the mines of Verd Antique, which has been noticed in a previous volume.

It is difficult to assign an age to this rock on stratigraphical grounds, or to give a satisfactory account of its origin. The hypothesis that it is a layer of magnesian schists altered in place, while the most satisfactory in many respects, does not account for all that may be observed with regard to it.

h. The New Red sandstone or Mesozoic sandstone has been too often described and is too uniform to need extended comment. It covers the extreme northern part of the county, and, as is generally the case in Pennsylvania its dips are in the N. W. quadrant, with moderate strength. Its constituent strata are either brick red or grayish drab with some greenish shales.

Its various layers are minutely set forth in the York county report, and what was said of its character there is applicable here. It is loosely compacted, most frequently arenaceous; it produces a thin and poor soil except for certain plants which thrive on a light soil, well manured; it contains occasional belts more or less spangled with micaceous iron; it carries its usual trap-dykes; and it is divided by numerous cleavage planes. It is not known to contain any valuable deposits in Chester county except the fossil remains found in the cutting for a tunnel near Phœnixville. But on or near the contact of this with the underlying formation many valuable mineral deposits have been found, to be mentioned in their proper place.

i. Next come the trap-dykes, of which there is no lack even in the comparatively small area covered by the New Red in Chester county. These are capricious, of irregular form, and one at least recalls those lens-shaped masses in York county, which seem to have been caused by overflows of molten material pouring up through a rift in the earth's crust much smaller than the area they now cover.

These traps have been collected and thin sections of them have been prepared for the microscope similarly to those of the counties of Lancaster, York, Adams, which have been partially described. They are generally dolerites, which have now and then a syenitic texture and appearance, but contain as a base principally augite, labradorite and magnetic iron ore octahedra, which latter are usually to be found in the road gutter for some distance from the descent from the dolerite areas.

j. Finally are to be mentioned the gravels of various recent periods which have been studied by Prof. Henry Carvill Lewis, first mentioned in some papers included in the published proceedings of the Mineralogical and Geological Section of the Academy of Natural Sciences of Philadelphia for 1877–1879, and soon to be fully described in his special Report on the Glacial Moraine in Pennsylvania (Z).

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1. North Coventry.

This township is the extreme northern of Chester county, and lies on the bank of the Schuylkill river opposite Montgomery county and Pottstown. The hills which border the river and which run into Berks county on the N. W. are comparatively high masses of more or less disintegrated loose friable sand very generally deprived of coloring matter by constant leaching of the rains, and from this fact do not closely resemble the typical Mesozoic or *Red* sandstones, but present to the eye an uncultivated area of yellow sand over which for the most part spreads a scanty vegetation of stunted pines.

There is an outcrop of red-shale on the river road about 450 meters (or yards) west of the residence of Jacob Neiman on the township map. It passes south from the river along the western border of the township from Lewis Bachman's to and beyond the German Reformed church; and this is true also of that portion of this formation further east, where rocks of the same character occur from a little south of Henry Ecker's to John Haldeman's, within half a mile of the E. Coventry line.

There is no part of this township in which other rocks than those characteristic of the Mesozoic formation occur, although it is necessary to include under these the doleritic *traps* of which a narrow tongue from the large mass in the adjoining township of Warwick penetrates the extreme southern and western border, on the place of David Smith.

Nothing of interest was observed with reference to these Mesozoic rocks in North Coventry, which have the well known dip, strike and physical characteristics of the members of this formation.

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2. *South Coventry.*

This adjoins North Coventry on the south from which it is separated partly by Pigeon creek and partly by artificial boundaries. The same Mesozoic rocks just described continue south over the greater part of the township down to French creek, which forms the boundary between them and the Azoic series alluded to already in a previous page.

In the northern part of the township these rocks are yellow and red sandstones and shales, showing wherever exposed in place the dip usual to this part of the Mesozoic sandstones; but towards the S. W. margin of the formation there occurs at many places large numbers of fragments and débris of the older and adjacent rocks including the quartzites, and the rock of doubtful signification called alternately conglomerate, feldspar porphyry, &c. Besides this there are small detached collections of dolorite fragments, suggesting the presence of a dyke, of which the course and features are hidden beneath the soil.

Near the place of John Reagan a coarse quartzose *gneiss* appears to dip S. E. at a moderate angle; and this is the character of the material and its position north, on the same road, past Richard Williams and Joseph Reignor, to the intersection of a road leading into the adjoining township of East Nantmeal. About 700 yards west, on this road, occurs coarse rotten gneiss, with a considerable quantity of *kaoline*, which seems to dip ±40° to the N. E. All this is in the extreme southern corner of the township.

[A *plumbago vein* runs through the gneiss, three quarters of a mile north of Reagen's, or a quarter of a mile southwest of Pughtown, of which Prof. Rogers says, in the final report of 1858:

"Near the junction of Beaver creek with French creek, or a short distance to the S. W. of Pughtown, there is a vein of impure plumbago on the farm of Jesse Hawley. It occurs between beds of gneiss, is about 3 feet in thickness, and dips with the strata to the S. E. about 45°. The plumbago is pulverulent, and mixed somewhat with foreign matters, especially oxide of iron, oxide of manganese, and some of the minerals of the gneiss, in a state of disintegration. The excavation exposing it is a very superficial one, being merely a drift, of the length of a few fathoms, penetrating the vein at the water level. After being mined, the material is broken, screened, and washed, when it is packed and sent to West Chester, there to be converted into a fireproof mineral paint for railroad cars, houses, barns, and other structures. This paint is prepared dry, and also ground in oil. It has been found very useful in resisting atmospheric exposure, though it has been employed as yet to a very limited extent."

The occurrence of veins of plumbago like this one, and the two others to be mentioned in West Pikeland and Upper Uwchlan townships stand for what they are worth in evidence of the Laurentian age of the gneiss.]

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3. East Coventry.

This lies immediately to the eastward of the two townships just described and wholly within the Mesozoic rocks. It is separated from Montgomery county by the Schuylkill river. What has been said above will apply to the rocks of this township.

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4. East Vincent.

This lies S. E. of East Coventry township along the right bank of the Schuylkill and wholly within the Mesozoic series.

French creek which forms its S. W. boundary separates very sharply these rocks which make up its entire area from the Azoic rocks. A large part of the western half of this township is covered by loose sand.

The river shore of the township is broken by two short curves of the stream, which make a narrow point of land pointing nearly due north, indicating the place where the river, having encountered a layer of more than average resistance, alters its course by 180° and descends again nearly due south to the borough of Springville, which forms the eastern edge of the township on the river. This same topography is repeated, once above, and twice below this point, between it and Valley Forge.

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5. *East Pikeland.*

This adjoins East Vincent but unlike the latter it is divided into two parts by a line of which the general direction is N. W. and S. E.

The upper (N. E.) and longer portion is composed wholly of the Mesozoic sandstones and shales; the lower (S. W.) part wholly of the Azoic series.

The line of demarcation crosses the township line near Gottlieb Keebler's house in West Vincent township, and after curving N. E. to Kimberton station on the Pickering Valley R. R., turns S. E. near Samuel Bartollett's house, crosses a branch of French creek and the road between Kimberton and Pickering P. O., and runs nearly parallel to and a short distance S. W. of the road till it passes the border into Charlestown township.

For a part of this distance the Mesozoic measures are represented by gravel and the Azoic covered by an abundance of milk quartz and quartzose sandstone fragments.

[The *Raby mine* of brown hematite iron ore, situated one mile south-west of Kimberton railroad station, and an eighth of a mile off the railway line to the north-west, is owned by the Rev. Mr. Raby. Several hundred tons of ore have been stripped, most of it going to S. Tilton's Plymouth furnace, at Conshohocken. The mine is still worked, (Nov. 1882,) yielding about six tons per day. The washing is done by horse-power.]

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6. *Schuylkill.*

This joins East Pikeland on the S. E. and along the river in its descending course. The upper part of the township is covered by the Mesozoic series and includes a locality in the vicinity of Phœnixville celebrated for the discovery by Mr. Charles M. Wheatley of many mineral species and fossil forms, most of the latter having been studied and classified by the labors of Prof. E. D. Cope. The Reading R. R. cuts through a long hill by means of a tunnel about half a mile long and between certain beds in this tunnel were found the fossils just mentioned.

The southern margin of the Mesozoic is a waved line which divides it from the Azoic to the south and meets the river at a point a short distance south of Valley Forge.*

The direction of dip of the Mesozoic shales at this point forms a curious exception to the ordinary rule of N. W. dip. It is E. 30° S.–45°; but inasmuch as this is on the extreme border line of the formation it may easily be ascribed to a sagging or bending downward of the upturned basset edges of the rocks where they have been left unsupported by the crumbling of the underlying rocks.

This line passes near the house of John Kane in Charlestown, and runs a little north of east, again descending near the residence of John Christman, and nearly through the "Chester County mine," skirting the mine of the "N. Y. and Boston Silver Lead Co.," crossing a branch of Pickering creek in a direction a little north of east and close by the school-house; it follows very closely the Valley Forge road to its last deflection northward, and maintains its course straight across the long Valley Forge dam.

The southern boundary line between the Azoic rocks and those of evident Potsdam age is much more irregular and waved. It enters the township near its extremest southern

* For a minute description of this border see pp. 183 and 191 of this report.

corner, and runs N. E. for over a mile at an acute angle with the State road, which it crosses and bends southward slightly till it passes a fork from the State road leading to Valley Forge. It then runs N. E. nearly parallel to the fork, leaving a high and rather abrupt hill, of which the top is mainly composed of a yellow sand, while the contiguous Azoic rocks are represented by pink and blue crystalline quartz fragments (conglomerate) and hornblendic gneiss, (or syenite.)

After following this road to a point a short distance west of Wm. Rossiter's house the boundary line again turns south, passing near the residence of Jas. McGivene, when it bends again northward, and after a few similar waves joins the boundary of the New Red west of the Baptist Church.

These waves are formed by the interlocking noses of hills of Potsdam and hornblendic gneiss or quartzose conglomerate. From the N. Y. & Boston Silver Lead Co.'s mine on the west to John G. Crawford's house, and thence east to the Forge dam, the Azoic measures are composed of successive alternations of hornblendic gneiss and quartz conglomerate or feldspar porphyry.

[There is nothing of importance to remark about three fourths of the township occupied by Mesozoic rocks. But the border of this Mesozoic area is made extremely interesting by the range of lead and copper mines east of Pickering creek, of which the old *Wheatley mine* (now the *New York and Boston Silver Lead Company's mine*) is the principal. These have been minutely described on pages 196 and following pages of this report, as they were to be seen in the years of their most active exploitation, where their character and value could be best studied.

The local map to illustrate this range, constructed for Prof. Rogers, will serve as a useful and suggestive illustration also of the great defects of our maps. Let the reader compare it with the township map of Schuylkill in the Chester county atlas, and he will be astonished at the incongruities.

The gneiss area south of the Pickering creek mineral range has also been sufficiently described on pages 160 ff; and the strip of Potsdam sandstone along the southern border of the township on pages 151, 152, of this report.]

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7. *Charlestown.*

This lies west and a little south of Schuylkill, and like the latter has representatives of the three principal formations hitherto described within its borders.

The line which divides the Mesozoic sandstone (of which there is only a very small strip in Charlestown township) from the Azoic rocks passes the township's eastern border a little north of its crossing by the State road,* and after two narrow and deep folds near Buckwalter's house, passes in a sinuous line west of George Snyder's and Jacob Wagoner's houses and crosses into East Pikeland half a mile north of Joseph Wagoner's house.

The southern border of the Azoic measures follows with a very curved line the general direction of the Chester valley; but there is a constant deviation from the line of the axis of this valley which is constantly restored, so that the trace on paper resembles a series of curves of which the N. E. faces are more nearly normal to the Chester valley axis than the N. W. faces. In fact if this structure were represented on a sufficiently large scale it would represent a series of anticlinal axes, oblique to the axis of the Chester valley, but parallel and in echelon with each other, the whole giving the most patent exhibition of *nonconformity*.

The Potsdam rocks which form the lower edge of the township are mainly white quartz and very strikingly dissimilar from those against which they abut.

The Azoic rocks are either the quartz conglomerate (feldspar porphyries) previously mentioned, or hornblendic gneiss (or syenite.) The manner in which these alternations take place may be better understood by following out a course along designated roads.

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* Which follows the left bank of Pickering creek.

Commencing for this purpose then with the short road on which are the houses of John H. Tholen and Simon Smith in the south-eastern part of the township, this road is mainly filled with quartzose sandstone, except at one point a short distance east of the house of Jos. M. Faulkner where a very small area is filled with the conglomerate holding bluish quartz—evidently the point of a small wave of the Azoic measures penetrating south into the area of the Potsdam.

From Charles Warren's house (on the road forming the eastern boundary of the township) north to near the house of Thos. J. Grover the fragments of Azoic rocks are almost exclusively confined to the conglomerate with tinted quartz.

Here they appear to change to hornblendic gneiss to and west along the White Horse road to J. S. Rapp's, and thence south about 300 yards.

South of this point to Faulkner's the predominating rock is the "conglomerate."

Between the two formations, north of Faulkner's house, milk quartz and sand occur.

Pursuing the White Horse road further westward the gneiss and syenite seem to disappear near the house of Henry Frock, and the conglomerate with blue quartz to take their place, as if a dying anticlinal of the dark rocks crossed the border from Schuylkill county as a nose barely reaching and enclosing this part of the White Horse road.

All the rocks observed between this road and the Tredyffrin township line, and as far north as Mrs. Margaret Hartman's house, belongs to the class of which the oft-mentioned conglomerate is the type; but about the neighborhood of her house and that of James Weedon's, fragments of syenite are seen, which a short distance to the north are mingled with dolerite fragments. No conglomerate is visible from here in a north-east direction, through the town of Charlestown to the northern boundary of the township.

From the locality above referred to, viz: the residences of Jas. Weedon and Mrs. Hartman, north to the Mennonite grave-yard (about 1 mile) and westwardly and northerly over the rest of the township, the conglomerate is the predominant rock, except for about a mile and a quarter S. W. from the East Pikeland line, along the West Pikeland border, and ¾ mile S. E. from this line, where coarse, crystalline gneiss, syenite, and dolerite fragments are found.

Near Amos Reese's house, on the line between Charlestown and East Pikeland, the walls between the fields are of fresh stone resembling dolerite in fracture and weathering; like *orthofelsite porphyry* in the white blotches on a dark ground; and like syenite in the glistening of the minute black spots of hornblende. The feldspar seems to be plagioclase.

[In the eastern corner of this township we have an area which seems to throw light on a difficult question in Pennsylvania geology, viz: how the two great formations of the South mountains west of the Susquehanna river are represented in the Schuylkill country. The South mountains do not show the fundamental azoic gneiss or syenite rocks any where at the surface, because these are covered by a great thickness of *Huronian rocks*, on which rest at least two thousand feet of *Potsdam sandstone.* The thinness of the *Potsdam* in Chester county has been noted; and also the fact of its often resting directly upon the gneiss. The question arises in all such cases: where is the *Huronian formation,* which in Adams and Cumberland counties comes between the Potsdam and the floor of the gneiss? The only answer—a very doubtful one—is furnished by the strip of conglomeritic porphyritic petrosilex rocks described in the above notes to Charlestown township as intervening between the Potsdam quartzite sandstone of the North Valley hill, and the tongue of hornblendic gneiss along the White Horse road.—J. P. L.]

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8. *West Pikeland.*

This lies S. W. of East Pikeland and N. W. of Charlestown. It is principally filled by the feldspathic rocks so often mentioned and its rocks are azoic only. There are a number of *kaoline mines* here of which the origin is to be ascribed to the weathering of the abundant feldspar. There are also numerous *iron mines* along the line of the Pickering Valley R. R., which bisects the township, the geological relations of which seem to be the same as those of the townships to the west and north-west.

On the road which crosses the S. E. line of the township near its middle point, and passes through the Chester Springs to the Vincent Baptist church, on the north-west line, the rocks are principally quartz or gneiss.

The same is true S. W. of this road, except that the bedding becomes more obscure and the fragments resemble rather those of a feldspathic granite, whose weathering leaves a rich red soil.

[The *brown hematite iron-ore mines* of this township, as seen by Prof. Rogers in 1853'4 are described in foregoing pages 168 to 174; such as the *Fussel*, the *Prizer*, the *Tustin*, the *Stiteler*, the *Latshaw*, the *Fegley*, and the *Jones*. Some of these mines have been worked at intervals ever since. The *Orner* mine has been opened. Exploring pits have been dug in various places in superficial deposits of ore, all of which are probably referable to the same original source, the former spread of the ferruginous Mesozoic shales and sandstones over the surface of the gneiss region, from which they have been almost entirely removed by erosion.

The *Fegley mine*, on the north-east township line, three furlongs north-west of where the Pickering Valley R. R. crosses the line, belongs to Samuel Fegley & Bros. and George Deery; was leased by the Phœnix Iron Company, Feb. 25, 1865. Large excavations were made, but all work in them has been abandoned for a number of years.

The *Orner farm mine* lies half a mile due west of the old Fegley mine. It is owned by the Phœnixville Iron Company, and bids fair to exhibit a large body of ore. *Plumbago* has been found here.

The *Morris Fussel mine*, on the road from Chester Springs to Birchrunville, just one mile north-west of Chester Springs, and within a furlong from the W. Vincent line, was leased by Dr. Morris Fussel to the Phœnix Iron Company, July 16, 1880, but only furnished 250 tons of brown hematite ore, which exhausted the deposit.

The analysis of this ore by Mr. J. Creagh Smith, furnished by Mr. J. H. Harden, is as follows :—

Peroxide of iron,	71.51
Alumina,	2.72
Silica,	11.67
Sulphur,	.08
Phosphorus,	.15

with traces of lime and magnesia ; which gives iron, 50.69. The phosphoric acid was 0.36 ; the volatile matter, 14.55.

A deposit of ore has also been proved at a place half a mile east of the Morris Fussel mine.

South of Chester Springs are the following brown hematite ore deposits :—

The *Isaac Tustin mine*, a quarter of a mile south of Chester Springs, was first explored in 1851, and leased to the Monocacy Furnace Company. It was afterwards, March 18, 1864, leased to the Phœnix Iron Company. Several hundred tons of surface ore were taken from the excavation, which was then abandoned because the ore did not extend to any depth. Mr. McCreath's analysis of this ore is given on page 176 of this report, as analysis E.

The *Prizer mine*, a furlong south-west of the Tustin, was formerly worked by the Phœnix Iron Company, who leased it in July, 1856. Latterly it was leased by the Monocacy Furnace Company, who took out a large quantity of ore from it, but abandoned it for just the opposite reason from that which caused the abandonment of the Tustin mine ; the ore here lying deeper than they found convenient to strip. It is now owned by Stiteler. McCreath's analysis of this ore is given on page 176, above, as analysis D.

The *Jacob B. Latshaw* mine is an abandoned excavation half a mile due west of the Tustin mine, and west south-west from Chester Springs, a furlong north from the Latshaw residence. Two or three thousand tons of ore were taken from it by the Phœnix Iron Company, after their lease of it October 18, 1873.

The *Harvey mine*, on the Jones' estate, is seven eighths of a mile south-west by west of Chester Springs. The road from Moses' grist-mill north-west to Nantmeal bends around it a furlong west of the Latshaw residence. It belongs both to the Enoch Jones' estate and the Phœnix Iron Company, the dividing property line passing through the center of the excavation. About 1,000 tons of ore were taken out in 1881 by James Harvey, lessee from the Jones' estate. Mr. McCreath's analysis C of this ore will be found on page 176 above.

Exposures of *azoic slates* occur in this mine, dipping towards the south-east. These possess a high geological interest for any theory of the origin of these brown hematites in the gneiss region at a distance from the border of the Mesozoic region, as they throw some doubt upon Prof. Rogers' theory that the ores come from Mesozoic rocks which have been removed by erosion. It is possible to imagine these slates the representatives of his Primal slates. It must be remembered that the brown hematite deposits along the north flank of the Reading and Easton hills and in the included vales of the South mountains have originated from slates mostly overlying the Potsdam sandstone.

In Prof. Rogers' description of this Harvey mine, which he calls Latshaw mine, (see page 172 above,) he points to the fact that the Tustin, Prizer, Harvey, and Stiteler mines lie along an east and west straight line, which he considers a line of fracture, in the jaws of which a strip of Mesozoic rocks have been caught, and the ores deposited by segregation.

The *Stiteler mine*, owned by the Phœnix Iron Company, is situated a quarter of a mile east of the Conestoga turnpike, five eighths of a mile from the W. Vincent line, and a mile and a quarter west by south from Chester Springs.

It is about 300 yards long by 200 wide, and is therefore one of the largest open ore quarries in the region, yielding at one time from 5000 to 8000 tons of ore annually; but is now abandoned.

In 1853–4 it was in full operation and was examined by Prof. H. D. Rogers, whose description of it will be found on page 172 above.

The *Acker* (*Enoch Jones*) *mine*, a quarter of a mile due south of the Harvey (Latshaw) mine, was formerly worked by the Phœnix Iron Company, under a lease dated Jan. 1, 1863. Large quantities of ore were taken out. The deposit is now worked by Mr. Acker for the Monocacy furnace. The yield of late, that is, in the summer and autumn of 1882, has been from 20 to 30 tons per day; and the old Phœnix Iron Company's hole is being pumped out for further exploration, as the present surface workings do not promise a sufficiency. Prof. Rogers examined the mine in 1853–4, before it was well opened up; but his description of it then is interesting; see *Jones mine*, page 173, above.

The ore from all these mines is carted one, two or three furlongs to the Pickering Valley railroad which follows the right or south bank of Pickering creek, and then crosses the divide and descends French creek to Phœnixville where it joins the Reading railroad.

The *Chester Springs Plumbago mining and manufacturing* company's mine, is situated in the eastern quarter of the township, a quarter of a mile due west of the Mt. Vernon school-house, just a mile due south-east of the railroad bridge over Pickering creek. All that can be said about this is that the company are prospecting with a reasonable hope of finding a workable vein. No good reason can be assigned why valuable graphite beds should not be numerous in the Laurentian gneiss of Pennsylvania, as well as in the Laurentian gneiss of Canada.

A *Kaolin* deposit has been exploited in the north corner of the township just three quarters of a mile in a straight line due north from Chester Springs. This porcelain clay bed is of course a surface concentration at the outcrop of a band of very feldspathic gneiss.]

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9. *West Vincent.*

This township shows on its extremest N. E. border where two right angled bends of French creek give the lower branch of that stream a direction nearly parallel to its upper course, but about ¾ mile N. E. of it a band of Mesozoic rocks connected with the beds which cover the northern part of the county. The rest of the township is entirely covered by azoic rocks, among which the feldspathic granite predominates, but is replaced by hornblendic gneiss and syenite fragments for ¾ mile south of Birchrunville; and for half that distance east and west of the covered bridge over French creek, from near Stauffer's mill, to the road leading to Robert Grier's residence.

[The *John Mosteller mine* of brown hematite iron ore, situated a furlong south of the Eagle and Kimberton road, exactly one mile a little south of east from Pughtown, is leased by the Phœnix Iron Company, mining and washing surface ore at the rate of about 15 tons per day. Mr. J. C. Smith's analysis of this ore, Sept. 22, 1880, gave:—Silica, 23.07; Phosphoric acid, 1.06; Iron, 41.64; Phosphorus, 0.46.

The *John B. Stauffer mine* of brown hematite, situated three eighths of a mile south-west of the Mosteller, and seven eighths of a mile south-east of Pughtown, was leased by the Phœnix Iron Company, Oct., 1880, and then abandoned. They exhausted the deposit by taking out about 4000 tons. Mr. McCreath's analysis of the ore is given, as analysis A, on page 176 above.]

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10. East Nantmeal.

This lies south of the South Branch of French creek and is covered exclusively by Azoic rocks. The feldspathic granite from South Coventry township extends a short distance over the border where it is replaced as is that from West Vincent more immediately by coarse sand followed by syenites and coarse hornblendic gneiss.

These rocks impart their character to the entire area of the township and are indeed the only rocks observed therein except some loose fragments of dolerite near Franklin Seidel's near Marsh creek, three fourths of a mile south east of Marsh P. O.

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11. *Warwick.*

This is one of the most interesting townships in the county on account of the great variety of the rocks exposed within its area and also because of the important iron ore mines which it contains.

Two areas of Mesozoic rocks cross it from the main body of that formation westward.

One is a very narrow strip bounded on the south from Knauertown eastward, by the north branch of French creek and on the north by the great outburst of trap which covers about a third of the whole township.

This thin strip penetrates with a width of barely a hundred meters (or yards) almost to the extreme western limit of the township, but is cut off and obscured by the Potsdam a short distance west of St. Mary's (Warwick P. O.) and of the house of D. B. Mauger, a quarter of a mile south west of the forks of the road, at the west end of St. Mary's.

The other belt of Mesozoic measures fills the entire area of the township north of the North Branch of French creek (west of Harmonyville) which marks its boundary all the way to and into Berks county.

This great area of trap is of irregular lenticular shape and is not itself perfectly uniform as to character. The southern half appears to be doleritic—typically so; the fragments often being of great size; but whether large or small they exhibit the rough striation on a conchoidal surface so characteristic of dolerite and are in general very little weathered.

The northern half of the area however is more syenitic in character and shows in places very well-defined syenite, as do the large areas of similar igneous rock in Adams and York counties.

This is especially to be observed of the fragments in the bend of the North Branch of French creek from Jacob Churk's to Wm. Swinehart's, two miles north west of Knauertown.

The feldspathic granite or conglomerate rock is found in the neighborhood of the Hopewell iron mines, in the extreme west, in juxtaposition both to the syenite and to the quartzose rocks of the Potsdam sandstone, all of which come together in this vicinity.

Near the house of Eliza Robinson, and nearly two miles west of Knauerton, is found a crystallized rock containing pegmatite, and a dark green mica (not certainly determined), together with muscovite.

Along this road to St. Mary's P. O. the rocks show signs of being crystallized, but not without inducing the suspicion that they may be débris of the old crystalline rocks compacted together during the Trias-Jura period. Pegmatite is found everywhere abundantly.

Half a mile south of Knauerton the rocks are composed of crystals of a green mineral, not determined, and Pegmatite. The weathering and fracture of these rocks resemble those of re-compacted Mesozoic measures, and again, as so often in this region, suggests the possibility of the experience of Mr. Heinrich of the granites of the Midlothian coal basin in Virginia being repeated here. The appearance is much as if the Mesozoic estuary had broken up the older rocks which formed its basin, and recemented them, without much decomposition, so as to form in many respects similar rocks.

The Hopewell mines are situated in the extreme western part of the township.

The *Hopewell Middle mine*, under the charge of Captain Wm. Gay, of Pottstown, was running Oct. 1, 1879. At that time the old workings were entirely abandoned. The new mine was 150 feet deep, and worked by drifts and slopes. There were four levels. They commenced sinking the shaft in December, 1877. There were only five men at work in the shaft. The water was not troublesome, and was easily managed by one Cornish pump. The "vein" of ore was said to be 40 feet thick, with no bottom to it yet found. But this is in all probability a measurement diagonally across it, as it is said to average 10 feet thick.

The ore lies in "hard blue rock" or rather between a *hanging wall* of the conglomerate with blue or amethystine quartz and a *foot wall* of syenite or dolerite, the hard blue rock referred to. The ore resembles quite closely the Cornwall ore, and is to some extent magnetic.

The dumps around the mines show a great deal of epidotic rock mixed with a great deal of micaceous iron ore, dolerite, and syenite fragments. The latter come in from about half a mile west of here.

The Hopewell or Middle mines belong to the Pottstown Iron Company since about 1873. They had been actively working them for three years, to December 1880. The ore is said to lie in bands like veins, the foot wall dipping 35° to the W. 20° N.

The outcrop was worked out by open cut for about 200 feet E. 20 S. of the present shaft. This was done by the original owner, Mr. Hopewell, and prosecuted until the workings got too deep to continue by open cut. He then sunk a shaft about 100 feet W. 20° N. of the outcrop cut. This is now covered by the dump.

The Pottstown Iron Company then sunk the present shaft, which gets through the ore at a depth of 150 feet. The ore is here about 12 to 14 feet thick, dipping 35°, but swelling and pinching; in the main averaging about 12 feet. Most of the ore goes to Pottstown and the rest to Bakelyville, in both cases to the use of the company mining it. The foot wall is hard compact syenite, and the hanging wall is reddish shale.

[The principal ore body is considered exhausted, and the miners are now (Oct. 1882) robbing the old pillars, which yield about thirty tons per day, which is sent by a branch railroad (terminating at Harmonyville) to the Springfield station, and thence by the Wilmington and Northern railroad to the furnace at Pottstown.

The early history of the Hopewell mine is given by Prof. Rogers in his final report of 1858. His observations date about 1854.

"*Hopewell Furnace Ore Pits.*—Proceeding westward along this strip of gneiss, the next and last important mineral injection which we meet with is that of the iron mines of Hopewell furnace. These are situated about one and a half miles N. W. of St. Mary's, or the Warwick iron mine, and near the N. edge of the belt of gneiss, where it is margined by a range of white Primal sandstone, forming a spur in prolongation of the Welsh mountains, called Thomas' hill. This mine has been wrought for very many years. There are in all four ore pits here, only two of which, however, are now wrought; both of the new pits, or those at present worked, are drained by one engine shaft. This ore is a highly crystalline variety of the magnetic oxide of iron, presenting many specimens of beautiful octahedral crystals. The ore is in two veins, both dipping at a moderate angle of about 30° towards the N. W. One of these, the undermost, varies in thickness from 15 to 25 feet; the other overlying vein has an average thickness of some 7 feet. A thick dyke of close-grained, gray trap rock cuts and partially shifts the ore. Its course is about S. E. and N. W., while that of the veins of iron ore is N. about 65° E, or, as usual, nearer E. and W. than the trappean dyke. Unfortunately the engine shaft has been sunk thus far almost entirely within the trap-rock, a mistake entailing great delay and much unnecessary expense. It is designed to intercept the veins or beds of ore at a good depth below the surface in their dip to the N. W."]

The *Warwick large mine* is cut in a gravel made up of loose fragments of syenite granite, quartz conglomerate, and a mud rock, together with sand and clay. The public road runs through the middle of the area occupied by the mine.

The new opening, or *Smith's Warwick mine*, was made in the spring of 1879. It was being worked by the aid of a steam engine of 10 horse power.

[These *St. Mary's mines* are owned in part by the Phœnix Iron Company, the E. & G. Brooke Iron Company, Colonel Smith, and others. The Brooke company are the principal operators, (Oct. 1882.) The mining is done by shafts, and the yield of magnetic ore is about twenty tons per day.

The past history of the famous Warwick Mine is very interesting. Its aspect in 1854 is thus described by Prof. Rogers:

"*Warwick Iron Mine Proper.*—This extensive and interesting body of iron ore, situated just S. E. of St. Mary's Episcopal church, is in reality not a genuine lode or igneous intrusive vein, though the ore derives some of its characters from intrusive igneous action; but it is a bed or deposit at the base, or very near the base, of the middle secondary red sandstone, which here laps upon the gneiss. The explored extent of this bed, hitherto penetrated only near its outcrop, or where the overlying strata are shallow, is already very great, amounting to many acres. The ore deposit observes everywhere a very gentle dip, and seems to undulate in two or three waves across the tract which includes it. A somewhat conspicuous anticlinal change in the dip occurs to the S. and S. W. of the present main engine shaft by which the mines are dried, and there is every indication that the ore basins, both S. and N. of this saddle. Though the basin to the S. of it is intersected, and the ore in one place cut off or thrown out to the surface by the intrusion of a wide dyke of trap rock, there is strong reason to infer that the ore occupies a comparatively wide though perhaps shallow basin N. and N. E. of the engine shaft.

"Besides this intrusion of trap there seem to exist here injections of serpentine and other mineral matters, and at one point, just by the S. W. margin of the ore bed, there exists a very singular intrusion of mineral matter penetrating the ore, and altering, in a remarkable manner, the conglomeritic layers which here constitute the S. E. border of the red sandstone formation. This rock is greatly baked and changed in aspect, includes numerous spheroidal bunches of segregated crystalline mineral matters—some of them in the form of hollow geodes—and is intersected besides with numerous strings or little veins. In these spheroidal nests occur beautiful linings of crystallized epidote and other minerals, and bunches of large crystals of the fine variety of garnet called Melenite. The list of the minerals occurring here is not extensive. The conditions under which they present themselves are such as strongly to impress the geological observer with the notion of their having been introduced chiefly in a vaporous state, or by sublimation, for

Fig 572. Ore ground at St Marys, Old Warwick.

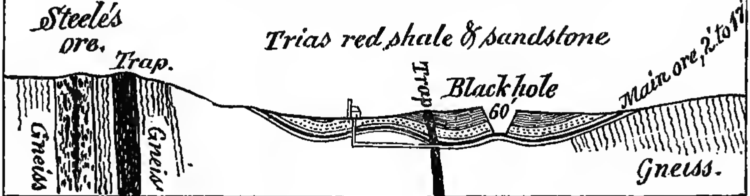


Fig: 571. Leighton's ore bank; Warwick township. (H.D.R.)

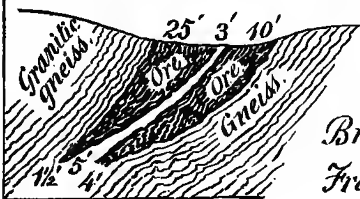
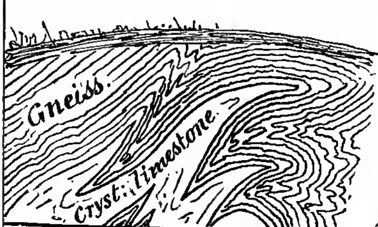


Fig: 30. Bailey's farm.
Broken saddle of gneiss (H.D.R.)
Franklin town: Chester Co.

Tongued anticlinal in limestone.
near Chads Ford. (J.P.L.)



Tongued anticlinal
in Coal
in South Virginia. (J.P.L.)

J.P.L.

in many of these hollow spheroids we can detect no connection whatever between the interior or even the exterior walls of the geodes, and any external veins or filaments of injected matter, such as any other theory would demand, for the introduction of the materials of the crystalline minerals here so curionsly insulated.

"The bed of iron ore for which this locality is chiefly noted is of very variable thickness, fluctuating from 1 or 2 to 9 or even 17 feet. As illustrating the general levelness of this undulating deposit, it may be stated that in no place has it been required to sink deeper than about 60 feet to reach the ore, while generally the covering is so thin that the ore is conveniently procured by merely stripping off a thickness of a few feet or yards of loose disintegrated rock. The average richness of this ore may be stated at about forty-five per cent. of metallic iron, though much of it exceeds fifty per cent. It is somewhat sulphurous, and when care is not employed in selecting it for smelting, and in the after-processes, it tends to produce a hot short or red short iron, but when carefully manufactured it yields an excellent metal. The annual product of the Warwick iron mines for fifteen years was not less than 4,000 tons, and the average yield for the past twenty years has been 6,000 tons. In the year 1853 the amount mined reached 12,000 tons. These ore pits have been wrought for the last 120 years, and there would seem to be at present really more ore within sight than there has ever been before at any one time. The present average cost of mining this ore is about one dollar and fifty cents per ton.

"Annexed is a little section—not the result of any critical measurements however—of this valuable and interesting mass of iron ore.

"This ore is intermediate in its physical characters and aspect between the true brown hæmatite and the magnetic oxide of iron. As, on the view of its having been originally a hæmatite, but subsequntly altered by igneous action, we might naturally anticipate, those portions of it which have undergone the highest degree of metamorphic influence are of a grey grey color, quite crystalline, and partially endowed with magnetic force, whereas the less altered parts are nearly in the condition of a compact, closely cemented hæmatite. Minutely interstratified with this ore, there occurs more or less earthy matter, apparently lamina of indurated slate or shale; and when the layers of this rock are thick, and they disperse the ore, they interfere materially with the economical prosecution of the mine. This slaty or earthy matter tends furthermore, by intimately mixing itself in with the finer granular ore, seriously to reduce the richness of the mingled mass in iron."

Mr. Rogers adds the following:

"*Steel's Iron Ore Pits.*—The next metalliferous vein of the tract of any note or present promise is one situated about half a mile N. of the village of St. Mary's. This has not been wrought for many years, and very little precise information is derivable respecting it beyond that furnished by observation of the old surface diggings and by vague tradition. There is obviously here a true lode or vein of magnetic iron ore, containing much of the octahedral variety. A wide surface pit and an adit suggest that the ore was in some abundance here, and such is the tradition of the neighborhood; but what the precise geological characters of the vein may be, or what promise it may have held out of some day proving profitable, there are no sufficient data for determining. It occurs in gneiss, a little N. of a heady dyke of trap rock, and seems to have an E. and W. direction."

"*Leighton Iron Ore Mine.*—A little south of the village of St. Mary's, just outside of the margin of the shallow deposit of the red sandstone, and its fringing lower layers of conglomerate, is situated the Leighton iron mine. A large surface excavation, embracing two veins of igneous magnetic iron ore; these range N. E. and S. W., and to the N. W., at an angle of about 33°. The overlying vein, when first opened at the surface, measured 15 feet transversely; but, pursued for 25 feet below the water level towards the S. W., it has dwindled to a thickness of only 15 inches.

"The other, or lower vein, distant from the first from 3 to 5 feet, was 10 feet thick at the surface, and declined in size to 4 feet. The mining and exploratory shafts together extend along the vein about 500 yards, but the actual excavations in the ore do not cover a length of more than 200 feet. The dip of the open cut of the ore is about 40 feet.

"From this mine the whole quantity of ore removed before its abandonment was about 20,000 tons. The accompanying little section (Fig. 571) illustrates the form and position of these veins.

"*Knauertown Iron Mine.*—A little N. of Knauertown, just on the S. margin of the tongue of red sandstone which there divides the N. belt of gneiss from the principal district of that rock, there occurs a small deposit of iron ore precisely identical in geological position with that of the Warwick mines, and very similar to it in aspect. A few shafts have been sunk in the quest of this ore, under the hope that it might prove abundant enough to be a source of profit, but no sufficiently large deposits has been reached to justify anticipations or encourage any further mining. The indications of igneous action, though not entirely wanting here, betray much less of the subterranean energy than was manifested in connection with the ore at the old Warwick mines.

"*Crossley's iron ore pits*, about one mile N. of Knauertown. These pits are no longer wrought, (1854,) and the true geological character of the vein or veins in which they are sunk it is now difficult to ascertain, inasmuch as they are abandoned, and, indeed, were never very extensively pursued. Sufficient indications prevail, however, and enough information is accessible in the neighborhood, and through persons at one time commercially interested in the success of the mines, to satisfy me that these several pits all pertain to an irregular lode, or a chain of closely-connected lodes of igneously-derived magnetic oxide of iron. This vein occurs between walls of gneiss rock in a low ridge just E. of the N. branch of French creek. Near the extreme western end of this little ridge, the ore, when uncovered to the day, presented a mass in the form of a large expansion of a vein of several feet thickness; but upon sinking the mine in it, this promising body of ore rapidly thinned down, and was even almost cut out by a contraction of its walls. Well-formed octahedral crystals of the magnetic iron ore are very abundant in this vein; and this variety is rather characteristic of the iron lodes of this northern belt of gneiss. The absence of regularity in the vein, and the necessity of providing steam-power for the deeper prosecution of the mine, caused its suspension some years ago; but it is not improbable that it will be resumed at a future day, since the work done was not without encouragement.

"*Elizabeth Copper Mine.*—Immediately adjoining the before mentioned vein of magnetic ore of iron there exists a very interesting mineral vein, known sometimes as the Knauertown copper lode, or that upon which is seated the Elizabeth copper mine. This injection, likewise, occurs in the gneiss; but a granitic vein, composed chiefly of feldspar and augite, forms its actual wall on the S.; the vein itself, observing a course nearly parallel with the strike of the strata into which it has been injected, consists largely of crystallized calcareous spar, dispersed through which occurs well-crystallized oxide of iron, and many brilliant octahedral crystals of the sulphuret of iron, and likewise some copper pyrites. The copper ore, diffused feebly throughout the calcareous spar, is most abundant next the N. wall of the vein. Measured transversely on a horizontal line, the dip being steeply N., the width of this whole vein or bed of spar is not less than 45 feet; an engine shaft descends upon the lode a depth of 140 feet, and there is an interior underlay shaft descending from the bottom of the main shaft 45 feet deeper. From the bottom of this latter pit a cross-cut runs S. 28 feet, and another to the N. 22 feet; while a drift has been carried along the lode E. a distance of 55 feet; and this is the present extent of this small experimental copper mine, the active prosecution of which was suspended in May, 1854, whether to be resumed or not I cannot say. It deserves to be here noted that these mineral veins are situated a short distance N. of a very thick dyke or wide belt of trap rock, which extends along the N. side of the narrow tongue of middle secondary red sandstone which insulates the metalliferous belt of gneiss from the main gneissic region south." (1854.)

The French creek magnetic orc mines, situated at the terminus of the St. Peter's branch of the Wilmington and Northern railroad, half a mile south of Harmonyville, are owned and worked by the E. & G. Brooke Iron Company, and the Phœnix Iron Company in equal shares.

There are two shafts, about 250 feet deep, with hoisting and pumping engines at both of them. The capacity of the mines is about 15,000 tons per annum. The ore contains sulphurets of copper and iron. (E. B. Harden, 1882.)]

Passing east from the Warwick mine the rock fragments visible on the surface (for there are no exposures) are principally of trap and of a crystalline rock, containing a green mineral. No rocks of certain Mesozoic age are met with.

Near Peter Gile's house near the middle point of the boundary between Warwick and Berks county the north line of the Mesozoic measures is drawn on the map. The rocks change character in crossing the stream. On the south side the fragments are mainly if not entirely of amethystine grains in a matrix of decomposed argillaceous matter—like the quartz conglomerate schist (or "Mountain creek rock") of the South Mountain so often mentioned in the York and Adams report and observed at Harper's Ferry.

North of the creek these are found and also earthy whitish gray sand rocks the latter predominating.

It becomes an exceedingly interesting question whether so exact a *fac simile* of the South Mountain can have been formed by the Mesozoic sea (?) on top of and out of the same measures. In other words whether these blocks have been re-made or not, and if so how much of the yellow color (indicating on the geological map the Welsh mountain Primal or Potsdam sandstone) may have to be changed to the reddish brown of the Mesozoic.

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13. West Nantmeal.

This lies S. W. of Warwick, and contains representatives of all the formations but the Mesozoic found in the latter.

From the south-eastern border to the broad belt of trap which crosses the township from the residence of Jacob Dampman, half a mile west of Perkins run railroad station, to that of Joseph Pawling, a mile north east of Loag P. O., the rocks are all Azoic and in general syenitic granite, or hornblendic gneiss.

The trap in question is partly dolerite and partly syenite, (i. e., with only accidental quartz.)

This belt enters the township at the cross-roads about a mile west by north of Isabella station, and follows the road very nearly, leading thence through John Benner's. It passes north of A. E. James' houses, and is found all along the road from Jos. Kurtz's to Wm. Hawk's, and passes out of the township into East Nantmeal on both sides of Jos. Pawling's. A thin tongue of Azoic rocks crosses the border above this, separating the Potsdam from the trap for a couple of miles westward; but they are in close proximity thence to the western line of the township.

The north-western part of the township is entirely covered by Potsdam quartzite and quartzose sandstones, except a narrow strip in the extreme northern apex, where the western extension of the lenticular trap outburst of Warwick township crosses into Berks county.

[*Iron ore* has been dug on Wm. Buchannan's property, nearly a mile south-west by west from the Springfield railway station. Also on the East Nantmeal line, one mile east south-east from Loag's Corners.

Green's iron mines (Eckert & Co.) are two large excavations lying two or three furlongs north of the East Brandywine and Waynesburg railroad, (which follows the right bank of the N. Branch Brandywine,) the one half a mile, the other three quarters of a mile north-west of Barneston station.]

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14. *Honey Brook.*

This lies next south-west of West Nantmeal, and adjoins Berks and Lancaster counties. As the Potsdam and trap are parted by a tongue of Azoic rocks on the eastern side of West Nantmeal township, while in contact for the rest of their extent to and beyond the Honey Brook border, so a similar tongue of Azoic separates the Potsdam and the trap (which terminates south of Talbotville) on the western side.

Owing to the discrepancy of the Honeybrook township map with the compiled county map on which the geology was laid down, and the lack of agreement between the border of this and the border of the Lancaster county map already published (which has obliged the western border of this county to be forced to meet the eastern border of Lancaster,) it is almost impossible to set down the boundaries of formations near this junction line with anything like an approximation to accuracy. Nevertheless the general limit of the different formations may be given roughly.

A short distance north of the town of Cambridge the lower edge of the Potsdam crosses the Lancaster county border, and, running north-east, past Mrs. Cath. Edwards' house, and Poplar Grove school-house, changes its direction to about E. by N. at Thomas Nebin's house, and so runs on, slightly increasing its distance from the county line, until it crosses into West Nantmeal, in close proximity to the dyke, near the house of Mr. Bernard Unangst.

The trap, which is a continuation of that in West Nantmeal, enters near Jacob Dampman's house, and following in general the line of the Wilmington and Northern R. R. terminates somewhere between Mrs. Harriet Graham's house and that of Peter Dampman's. Its southern border passes back into West Nantmeal, near St. Mark's Episcopal church.

About half a mile north of Cambridge the trap is a peculiar compact bluish rock of duller and bluer color than ordinary dolerite, and not less tough, but weathering like it. It was only found in fragments, but the place of its occurrence is significent, since it would be a prolongation of the West Nantmeal dyke. In fact fragments were found at various points between the place where this dyke is supposed to terminate, (the middle of Honey Brook township,) and this point and the fragments are almost the only guides to the formations which are here attainable. All things considered, however, it was deemed unsafe to carry the line of this dyke further than a point about 1½ miles N. E. of Waynesburg.

Another dyke disconnected from this one commences on the Lancaster line, near Mrs. Rachel Edward's, a mile south of Cambridge, and passes due east, with a breadth of about half a mile, ending near Samuel Chrisman's house. Between these two trap areas and for some distance south of the southern one the rocks are azoic and principally syenitic granite or hornblendic gneiss.

About half a mile south of this last mentioned trap, is the northern edge of a mass of Potsdam quartzite and quartzite sand rocks which come in from Lancaster county. It passes across the township nearly at a uniform distance of a half mile from its southern border line, but widening a little towards the Wilmington and Reading R. R. as it approaches the south-east corner of the township. The line commences on the west near Mast's clover mill, passing above Seth Buckwalter's house and Harmony Hall schoolhouse at the headwaters of a small branch flowing into the Brandywine west branch, which it follows to Beaver Dam station on the W. and N. R. R. Here it seems to leave the course of the stream and follows the county road to Joseph Mackelduff's house.

Limestone. Between the outcrop of the Potsdam and the Azoic ¾ mile east of Harmony hall and school-house is an outcrop of limestone.

This limestone is a drab crystalline rock much broken and cleft, and stained yellow on the edges. It dips S. 20° E.-68°. Its exact limits are not clearly defined, but there seems to be no hydra-mica schist associated with it, but it appears to lie in contact with the quartzite to the south and the syenitic granite to the north.

[Small veins of magnetic iron ore have been shafted on, but they have not proved to be of any value. Isaac King sunk shafts but found nothing encouraging.]

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14. *Wallace Township.*

This is without a semblace of other rocks in place except the hornblendic gneisses and the quartz conglomerate, and the series that has been mentioned as concomitant with these.

In the northern part, along a road of which the direction is clearly marked by a divide,* the decomposition to clay has been very complete, as for example in the neighborhood of Obediah Keen's house. Further south the fragments are more like granite but the exposures are rare or wanting down to the house of John Todd where a gneiss seems to dip N. 40° E.–30°.

On this road there is only an appearance of quartz in the form of porphyritic gneiss, in the form of loose fragments, except at one point in the extreme S. E. angle of the township where it dips S. 30° E.–36°. Another dip in the gneiss in place near the Seminary is S. 30° E.–40°, and again a kilometer (0.6 miles) east of this near L. Krauser's house a hornblendic gneiss dips S. 36°. From the road crossing near John Carnog's S. E. along the above-mentioned road there is no rock in place, and most of the fragments are of the character just mentioned until near W. A. Speakman's lane where quartz fragments are again numerous.

The N. W. and W. side of the township appears to consist almost solely of crystalline rocks, including the settlements of Wallace, Norwood, and Springton.

Near the boundary between Wallace and West Nantmeal, and near Hurtz's mill, a quartz porphyry occurs in place.

Near the S. W. end of this boundary there is much clay and feldspar porphyry.

The Potsdam Sandstone.—The quartzite enters Wallace

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*The road from Wallace P. O. northward to the W. and E. Nantmeal corner.

township a little west of the S. E. corner and after running N. W. a short distance curves and ends a little E. of the S. W. corner. Its shape is therefore that of a crescent, with the horns (both of which end near the southern township line) extended towards the south. The rocks between the two points of the horns just described appear to be crystalline. The quartzite and white sand rock representing thus an outlying part of the Potsdam possesses the following characters. Near the extremity of the left horn the quartz sand rock dips S. 10° E.-30°, which leaves its unconformability with the underlying rocks out of all question. The appearance which it gives to the soil is also peculiar from the extreme whiteness of its sand where the rocks have disintegrated, and the line of division between the formations is sharp and evident. On the R. R. a short distance below Mr. Guthrie's house there is a dip of E. 30° S. 75°. If this should prove to be more than a local variation it would explain the presence of this isolated mass of quartzite as due to a sharp inverted fold whose axis had no great length. Just below this and where the R. R. crosses south into crystalline rocks again near Jacob Rea's house the rock has a fine-grained bluish black massive character somewhat resembling dolerite, but probably a modification of the hornblende holding gneisses, and perhaps a syenite intrusion of which the traces are covered up by the soil.

Near Jacob Rea's house in the S. E. corner of Wallace the feldspathic conglomerate with quartz is in place striking E. 30° N. Dip difficult to ascertain but probably S. 30° E. 85°. This rock introduces itself after the crystalline rocks between here and the crossing of the Brandywine above Downingtown.

Just S. E. of the Presbyterian church and ⅛ mile N. W. of Wallace P. O. a decayed greenish granitoid rock dips apparently N. 30° W.-30°.

Upper Uwchlan.

Although the rocks seem to be exclusively crystalline or crystallized in this township and older than the Potsdam, there is a variety of them which is interesting and other occurrences make their study of more than usual interest.

Continuing on the road near J. L. Krauser's house, mentioned in the description of Wallace township, where the hornblendic gneiss dips S. 36°, a fine-grained feldspathic rock, near D. H. Krauser's, dips S. 10° E-50°; and near Jas. S. White's a gneiss dips S. 45°-60°. Near Isaac Lewis', on the Conestoga road, a gneiss dips S. 10° E. 55°; and 400 meters (about a quarter of a mile) still on the road to the S. E. a porphyritic feldspar rock dips S. 30° E.-85°.

Between here and Windsor, (also called Uwchlan P. O.,) there are few exposures and the surface is covered mostly with sand, which continues more or less to be the case, though the adjacent fields testify by the peculiar molding of their hills and by their exceptional fertility, to the crystalline character of the rocks of which their soil has been formed, to and beyond the line which separates Upper and Lower Uwchlan.

A curious occurrence among the few exposures mentioned which is found at the sharp angle of the road, about 800 meters (½ mile) N. W. of the town, consists of a compact dolerite-like syenite, which occupies one side of the road while opposite to it the coarse quartz porphyritic rock shows a dip of N. 20° W.-25°.

Following the road from Windsor a little west of north we first encounter the porphyritic feldspathic rock in fragments close to the town, and about 800 meters (half a mile) further on a greenish gneiss and distinct, layers dipping about S. 20° E.-85°. This is evidently a part of the same anticlinal axis noticed in Wallace township. Further on the blocks of porphyritic rock containing bluish or amethystine quartz and often closely resembling a conglomerate are met with, to the residence of John Brumback. Between here and Fairmount school-house the surface specimens lead one to suppose that there might be a quartzite outlying area here, and this is somewhat confirmed by an examination of the road due west and near L. E. and E. B. Krauser's houses, but as the evidence rests entirely upon loose débris and not an exposure of rock in place could be found to confirm it, it was not admitted in the geological map.

North of this the extreme point of the township is covered with coarse granitic blocks made porphyritic with quartz.

This is also true of the S. W. and S. portions of the township where the dips wherever found accord with those already mentioned as constituting the S. E. limit of the supposed synclinal axis.

Graphite.—Near the town of Windsor and some quarter of a mile south of the Phœnixville and Pickering Valley R. R. is a mine opened for *graphite* and now owned by the Pennsylvania Graphite Company of Reading. This company leased 500 to 600 acres of the estate of Jno. Todd, deceased, and one mine adjoining the mill has been wrought continuously ever since the graphite was discovered by Mr. Berritt and Dr. Thos. Brown lying in flakes on the ground. This belt of the conglomerate with bluish or amethystine quartz containing *graphite* has been traced all the way to Phœnixville and in the same course but opposite direction to the Brandywine, but its occurrence in quantity is confined to a width of a few hundred yards, though its existence can be proved on almost any farm in the district.

Another belt nearly parallel with this one runs through Pughtown but it is said not to be as rich as this belt by those interested in the latter.

The mine is opened about 60 ft. in depth by open slope along 500 ft. of the outcrop.

The portion of the rock sufficiently permeated by graphite to pay for excavation is 12 to 15 ft. from wall to wall. The dip of the underhand slope is S. 15° E. 30°.

At the western extremity of the gangway the rock is a decomposed gneissoid rock containing several large horses of a whitish rock similar in character to the foot. From 50 to 80 car loads were sent up per day (Aug. 12, 1880,) each car containing about half a ton. The ore contains perhaps 4 p. c. graphite. The engine is 30 h. p. working pumps by flat rods making ten 3 ft. strokes a minute and throwing 3 or 4 gallons to the stroke. Seven hours pumping keeps the mine dry for 24 hours. Twenty-eight men are employed in mill and twelve in the mine. Five miners at $1 25 and seven laborers at $1 10 per day. The engine runs the pumps during the night and the machinery during the day. The car drivers work on contract for 6 cents a car.

The rock from the mines is passed into an agitator where it is jigged, the lumps having been broken. Two men manage the washer on night and day shifts at $1 10. Two men and two boys are employed at the drier.

From the jig or agitator the graphite is carried to the furnace where it is heated and separated into four parts.

No. 2 is gravel of the size of a pea and quite free from graphite.

No. 3 is the cleanest part of this first separation, but still contains 33 p. c. to 50 p. c. impurity.

No. 4 is the fine dust consisting of at least one half graphite which is thrown away.

Altogether in mill and separator about four tons of anthracite (Schuylkill coal) at $5 is used per day.

No. 1 grade from the separator is brought to the mill, where it is ground in Cornish rolls, falls into a vat, and is carried by an elevating belt up to the loft, where it is bolted through bolting cloth, and is conducted thence to the kiln. The bolting cloth here used is a wire screen 60 meshes to the inch. The operations are somewhat in order as follows:

a. The product of the separator is crushed in iron rolls, and carried to the top of the building, where it is bolted.

b. It is then dried in kilns. (The fine is buddled, and is then treated along with the rest by process *c.*)

c. The material is bolted through two bolting cloths, No. 12, like grist-mill cloths, and separated into 1, 2 and 3 grades. No. 3 is the finest. The latter grade, ground in a burr and bolted again, produces the finished product.

The quality of this article appears to be excellent.

The chief interest, however, in this graphite deposite is found in the light thus shed on the probable age of the rocks in which it occurs. In the first place this occurrence of graphite in such large quantities leads us to ascribe the rocks which contain it to either the Laurentian or the Huronian period. It is true that graphitic shales are met with in the Lower Silurian, (see T. S. Hunt, Chemical and Geological Essays) and even have been thought to be recognized in the Carboniferous, but not in the form in which we here view it. From other analyses Dr. Hunt, in the essay on the "Geography of the Appalachians and the Origin of Crystalline Rocks," is induced to ascribe to this region the age of the Green Mountain series, while the occurrence in them of graphite would add another if not a decisive confirmatory resemblance. It is to be ascribed either to the Laurentian or to the White Mountain group.

It will naturally occur to one that if the original graphitic Laurentian or Huronian rocks were torn up and made over that their constituents would also exist in the newly formed rocks. The manner in which the graphite is distributed forbids this supposition. For being of much lower specific gravity than the matrix in which it is imbedded a disintegration of the rock would lead to the aggregation of the graphite into one horizon or bed, whereas it is disseminated throughout the rocks in which it occurs.

It would seem, therefore, to tend to show that the age of these rocks is Laurentian or Huronian, or, to be more exact, Laurentian, Green Mountain, or White Mountain.

A number of *iron ore mines* or their remains are found in the township most of them grouped near the town of Windsor. The largest of them is north of the town. There is a belief among some of the inhabitants of this region that the occurrence of the iron ore and graphite have relation to each other. and they point to the fact there is a similar concurrence of graphite and iron ore further to the N. E. and close to the border of the Mesozoic sandstone. It is indeed extremely probable and perfectly harmonious with what is known of the genesis of these iron ores, that they depend upon the presence of organic matter as a reducing agent and that cæteris paribus they would be more likely to be encountered near the graphite beds than elsewhere. But the popular notion alluded to is that the graphite is the result of the ore, an hypothesis which is not so easily maintained. Lumps of magnetic ore have been ploughed up on the farm of Isaac Trego.

The rock called sometimes "*conglomerate*" offers more difficulties in determining its true nature. In appearance it is very like a conglomerate, and yet the fresh character of its feldspar, the unrounded angles of its quartz, and the even distribution of the graphite through it, make it appear likely that it is a porphyritic crystalline rock in a state of decomposition.

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16. Lower Uwchlan.

Passing up the east branch of the north fork of the Brandywine from Downingtown one traverses the quartzite of the Potsdam period, which however does not seem to show on the right bank of the stream to any great extent. This is part of the great body of quartzite which bounds, on the north, the Silurian limestone valley and dips normally under it.

The rocks seem to pass at about this point from Potsdam sandstone into the crystalline older series; but owing to the gravel no very sharp line of demarcation can be drawn.

The largest of a set of curves in the boundary between the two formations (which curves are generally obliquely inclined to the axis of the valley and seem to indicate divergent anticlinals,) passes up into the western part of Lower Uwchlan.

The line of division follows the course of the stream just mentioned nearly to its source, where it trends abruptly to the south, passing about one mile west of Lionville until about the same distance south of the latitude of that place, when it changes abruptly and runs due east, rising to the north near the S. E. corner of the township and passing into Charlestown township in about the same direction before making the next southerly deflection.

Proceeding along the Conestoga road from the northwestern township line where its description was left when speaking of the last township, we find large numbers of fragments of the feldspathic rock so often referred to but no exposures down to the house of W. P. Phipps where the coarse conglomerate-like rock with large quartz grain is found in place with a strike of E. 20° N. A great deal of quartz débris is found down to this point making the impression that there is Potsdam in the neighborhood, but it is probably the remains of the weathered rock just mentioned of which this constituent would be the last to disappear. Both in and on all sides of Lionville the soil is principally composed of the weathered feldspathic rock as far south on the two roads leading in that direction as the houses of Wm. Miller and H. Litzenburg where a sudden deflection of both roads to the west marks where the formation changes to the Potsdam sandstone or quartzite.

Passing up the Brandywine, north, the dips are as follows: Beginning at the extreme S. W. edge of the township quartz slate and S. S., with some flakes of black mica, S. 30° E.–85° (S. W. corner.)

500 yards higher up is whitish sandstone, with some included minerals, S. 10° E.–89°.

The same distance north is white sandstone with dark spots S. 10° E.–80°.

A few hundred yards higher on the left bank is chloritic mica-schist with much quartz with a strike E. 20° S.–vertical.

From this up, the creek leaves the quartzite, and dips of 70° to vertical are obtained in the chloritic mica-schist, the high angles continuing into Upper Uwchlan, and evidently belonging to the more vertical limb of the synclinal previously spoken of there.

Near Norris Dowlin's, at the south-east corner of Upper Uwchlan, a rock consisting of coarse grains of quartz disseminated through a schistose matrix, together with quartzite proper, dips from S. 10° W. to S. 20° E. from 81° to 89°.

This character continues to the next northern crossing of the road and railroad.

There is, however, another hypothesis of the cause of these high dips and the apparent conformity between the quartzite and the gneisses and conglomerate or feldspathic rock, which though it is opposed to the hypothesis on which the map was colored, has some points in its favor.

This is, that the real demarcation between the old and the Potsdam rocks is to be sought along the line heretofore spoken of as a synclinal axis. If this be the case the structure is not an overturned synclinal, but the S. E. beds would be unconformable to the N. W. beds, and, for a certain breadth of present contours, made out of them. This would seem to account for the puzzling conglomerate (or feldspathic porphyry) as in reality a conglomerate coeval with the first deposition of the Potsdam period in this region. If there were not objections to this, elsewhere noticed, it would also explain the gradual transition of the apparently crystalline rocks into pure quartzite or sandstone. It is evident that if this hypothesis might be believed the boundary line of the formation would only have to be removed to a greater or less distance north of where it is, parallel with the line already traced, which would then represent the line along which the crystalline habit of the rocks merged into the sedimentary sandstones.

The rest of the township is filled with feldspathic and hornblendic rocks, the latter forming an important fraction.

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17. West Caln.

This appears to be the largest as it is from a geological point of view the most important township in the county. It is here better than anywhere else that we can assemble a number of evident facts bearing on the difficult problems which have in part been discussed and in part are reserved for the future.

This township abuts on Lancaster county, having Honey Brook and Sadsbury respectively north and south of it and West Brandywine on its eastern side. The Potsdam sandstone attains its widest development in West Caln, broadening enormously in a north and south direction, at the same time that on its southern edge it gradually leaves the contact of the limestone below the borders of this township, permitting an uneven wedge of the older crystalline rocks to intervene between it and the latter in Sadsbury and Valley.

With the exception of a small tongue of limestone extending eastward from the great Lancaster limestone, (which is of great importance in understanding the structure) the entire western boundary of this township is composed of Potsdam, which reaches a little above its N. W. corner and covers about half of it midway between the northern and southern boundaries. From this median line it broadens both to the N. E. and the S. E., projecting an upper arm through the S. E. corner of Honey Brook and into West Brandywine (as has been described), and a southern arm almost to the lower border of the last-named township where it breaks off suddenly, and descends in one of the scallops, already mentioned as characterizing the northern edge of the Potsdam north of the Chester valley, almost to the limestone.

This expansion of the quartzite and quartzose sandstone seems to indicate then the western end of a local anticlinal axis of which the ridge has been subsequently planed off, leaving the lower rocks exposed within a frame of Potsdam.

The small tongue of limestone, which at Compassville juts across the county border to the east, is of great importance stratigraphically, and seems to lend support to the hypothesis just enunciated. For there can be no doubt of the direct connection of this small *bay* of limestone with the Lancaster limestone. Since this latter has been traced into direct connection with the Chester Valley limestone, near Quarryville, and since the Chester Valley limestone lies unconformably against the Potsdam sandstone for nearly its entire length inChester county, undoubtedly there must be an anticlinal axis of which the western end, running nearly parallel with the Chester Valley itself, dies down at or near "Welsh mountain."

The sudden alteration of the lines of outcrop at this chain of hills, of which the nucleus is gneiss and mica-schist, is not easily explicable at first sight, but will be referred to directly.

If this view, mentioned as an hypothesis, in regard to the genesis of these feldspathic rocks which sometimes assume the form of a conglomerate and sometimes of a porphyry, be correct, viz: that they constitute the lower portion of the Potsdam formation and resemble the underlying true feldspar porphyries and hornblendic gniesses, because the waters which produced them were in direct contact with these latter, and at first merely tore them to pieces and recomposed them, we should look for the rocks in the eastern portion of West Caln township to belong to this horizon, because they are next to the eastward of the quartz or sand rock along the axis of a denuded anticlinal. In point of fact, not only is it the case that the rocks embraced by the two arms of the Potsdam *skeleton anticlinal* actually do possess in a high degree that intermediate character so often alluded to (and especially remarked along the northern contact of the Chester Valley sandstone,) but here another characteristic, briefly alluded to in the preliminary remarks, allies them to this belt (and its congener near the Delaware State) line by the extent of their weathering and the *kaolin* deposits to which it gives rise.

Kaolin surface deposits.—One of these, south of Wagontown, is exploited by a pit showing weathered and unweathered varieties of the feldspathic rock containing quartz. Large blocks of the micaceous rock with fragments of quartz are found throughout the pit, and much of it is so quartzose as to resemble quartzite. Quartz fragments are found through the mass of the kaolin, where they have evidently been left unchanged, while the feldspar was completely decomposed.

From the northern border of the Chester county Valley and a short distance west of the Brandywine, to and beyond the Cedar Hill school-house, kaolin deposits of greater or less extent have been found and partly opened.

There the most extensive works north of the Chester Valley have been opened by Mr. Williams, of West Chester, in 1878. Some of the kaolin was sent to Trenton and some of it to Phœnixville. Here again there is a great deal of quartz found among the decayed rock. Mr. G. W. McFarland began the opening in October, 1878, after considerable experience with similar works in Delaware. In the Okerson valley, 12 miles N. W. of Wilmington and 4 miles south of Kennett Square, the yield of one of the works was three tons of "sand" to one ton of marketable clay.

The clay is shipped to East Liverpool (Ohio), to Trenton, and to New York. There are four grades recognized. The first grade forms less than one per cent. of the mass, and is worth $18 50. It is run through a silk lawn screen. No. 2 is surface clay. No. 3 is still coarser, and No. 4 is entirely refuse and rejected. The quartz which is separated from this clay is also sold to the glass-makers. The day before my visit to the mine 125 tons of a bluish milk quartz had been thus disposed of.

The pitch of the decomposed rock which furnishes the kaolin is towards the east and gentle.

A well 12 feet deep at the bottom of the pit, and 50 feet from the surface, is still wholly in kaolin. The excavation covers perhaps half an acre.

The boundary of this feldspar rock sweeps south-westward in a curve, from near Mr. Maitland's residence where it crosses the northern border, just including Martin's Corner, to Jas. Entrekin's house nearly in the center of the township, and thence in several curves south to Rock run, which divides it from the Potsdam to the south.

The *kaolin* deposits which are worked in Chester county, and near it, are mainly if not exclusively in that belt of rocks which skirts the Potsdam where its lower layers are exposed to view. This is the case also here where there is a rough parallelism between the line along which the kaolin has been extracted, (nearly north and south), and the direction of the inner edge of the previously described anticlinal, dying towards the west. If it were established that a certain thickness of rock composed of mica, quartz, large crystals of pegmatite, and some hornblende below the Potsdam were really pseudo-Laurentian (as the undoubtedly genuine metamorphic series below them are taken to be) it would be easily understood why the feldspar which they contained became more easily the prey of decomposition than that of the latter, since the percolation of water through a re-made rock is necessarily greater than through the original rocks out of which it has been made.

Two other circumstances, neither of which would be decisive in itself, lend corroboration to this view. One is the frequent presence of *iron ores* in this belt resembling those which are well known to accompany the lower Potsdam, and of which a more particular account has been given in the volume devoted to Lancaster county.

The other is the frequent instances of agreement between the dips found in this belt and in the overlying sandstone, and the frequent disagreement of both with the dips found in the lower and true crystalline measures, both in direction and intensity.

A large surface *iron ore* mine (for example) is found in West Caln about 1½ miles north of Sadsburyville belonging to S. B. Worth & Co.

In general these mines resemble those so often mentioned and described in Rept. C, (York county.) The iron ore in them seems to have been derived from two sources, a primary and a secondary. *The first* is the alteration in place of strings, pockets, and beds of pyrites, and other iron compounds, producing a corresponding mass of iron more or less hydrated. *The second* is intimately connected with the disintegration of the rocks themselves, and depends upon it, and is in fact a deposit of oxides of iron among the impermeable clays, caused by the disintegration of the feldspars from its solution. Thus, while it is probable that any rocks of any age containing sufficient silicate of aluminum to form clay on decomposition would give rise to the formation of secondary iron ores of greater or less extent, depending upon the amount of iron solutions which had access to them, it is sufficiently well known as a feature of the formation we are considering to lend additional weight to other suggestions of the hypothesis under consideration.

The surface of West Caln is very much covered by loose débris, and the exposures of rock in place are not numerous, especially in the zone where for the test of the agreement of the stratification it would be most convenient to find them, viz: near the border of the sandstone; because as usual this rock is widely distributed in fragments over the surface of the ground; but a couple of dips are found about two miles (3.2 kilometers) apart, one in each of the two belts which we desire to compare; one about a mile S. E. of Compassville in quartz slate; the other near the Worth iron ore mine in what appears to be hornblendic gneiss. The first of these is S.–80°, and the last S. 20°E.–85°.

While the difference in strike between these two is considerable enough to warrant the assumption of non-conformability if they were close together, this assumption cannot be maintained on account of their distance apart, and the universal undulation of the beds. The rocks giving this last mentioned dip occur near the Bonsal school-house. They are massive and partly chloritic, but partly resembling normal finely laminated gneiss, in which a layer of quartz conglomerate feldspar rock dips S. 20° E.–85°.

On the other hand, the high dip is a factor of greater constancy, and does not at all agree with that of the lower crystalline rocks where they are best observed, and where their inclination to the horizontal plane averages about 30°. The quartz slate is of itself an interesting occurrence, resembling as it does the *Edge Hill rock* of Bucks county, which has been so well determined by, and forms such an important horizon in the theory of Mr. Charles E. Hall.

Before leaving this interesting township it is worth while to remark, that, between the limestone and the quartzite of the small bight which enters the township from Lancaster county at Compassville there is a good representation of the *hydro-mica series* (which, though generally, is not universally present in this position) as if to remove any difficulty which might remain in identifying the various members of the two formations. It is due to the candor which should be the leading characteristics of every sincere work, the object of which is to attain the truth, to say that this occasional absence of the hydro-mica schists between the quartzite or sandstone of Potsdam and the limestone of Auroral age, is at first sight more easily reconcileable with the view of Prof. Henry D. Rogers that these schists are the *upper member of the Primal*, than with that which I have felt bound to assume, viz., that they are the *lower member of the Auroral;* but it is not incompatible with the latter view, as I have pointed out before, and there are good reasons for the assumption that the schists and the limestone above them are part of the same formation.

For further illustration of this subject, see Rept. C, pp. 130–131, where the sections 1, 3, 3*a*, and 5*a*, are mentioned as supporting the opposite view, which they do not seem to do. The view here presented is defended in Rept. CCC, pp. 6, 7, and 8.

An instance of the non-conformity of the quartz slate and the hornblendic gneiss is found on the road from Compassville to Wagonville and about a mile north-west of the latter place, but it has not been presented among the important facts bearing on the stratigraphy of the township, because, from the circumstances of its occurrence, it seems likely that the first mentioned rock is not really in place. Slabs of quartzite or quartz slate here seem to lie nearly horizontal on the upturned edges of the hornblendic gneiss. The high angle of the latter would place it in the belt which, as has just been suggested, may be in reality the lower part of the same formation to which the quartzite belongs; but if this observation could be taken as decisive that would end the hypothesis, unless we supposed some violent crumbling and disturbance of the members of the same formation among themselves. But it may be safely assumed that a deception as to the rock being in place is more likely than such a position of the quartz slate, which is discordant both with its lithological analogues in the same region and with the rocks which are supposed to be their stratigraphical equivalents.

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18. West Brandywine.

This township though of irregular shape contains but a single area of Potsdam sandstone which appears to be isolated within its borders. A blunt broad protrusion of this formation belonging to the large area mentioned in West Caln extends a short distance into its N. W. corner. The curved mass of this formation spoken of in Wallace scarcely crosses its border in the N. E. corner. Its south boundary from Caln township seems to be as nearly as possible the dividing line between the crystalline schists and Potsdam at that place; and another promentory of Potsdam fails only by about a mile to touch its S. W. corner. The position of the isolated patch of Potsdam in the vicinity of Brandywine Manor P. O., between the first two masses described, leaves little doubt of its being really continuous with them, and that it makes with the southern belt of quartzite and quartzose sandstone a short denuded anticlinal axis of which only the borders remain.

Along the Harrisburg and Downingtown pike, from the corner where Honeybrook, W. Nantmeal and W. Brandywine come together, the ground is covered with débris of feldspar porphyry with no observed rocks in place, to the Brandywine Manor house.

Hence to the blacksmith shop and hotel of Aaron Smith that formation appears to be replaced by white sandstone and quartzite fragments.

This is due east of and not more than half a mile from the N. W. area of this formation previously spoken of, from which it is separated by the West Branch of the Brandywine creek.

From Aaron Smith's hotel to the Wild Briar P. O. in default of exposures and owing to the difficulty of distinguishing between the true débris and that due to the making of the turnpike, true character of the rocks along this line is not easy to determine; but on lines north and south and east and west, both above and below this portion of the turnpike, and so run as to have it as the hypothenuse of two nearly right angled triangles, the appearances testify strongly in favor of their crystalline character. From here to Ligget's corner and 1½ miles below, the rocks observed were feldspathic, containing large grains of quartz; were in fine the rock so often referred to as *conglomerate* in appearance.

From Ligget's corner west and south-west to the extreme corner of the township the same character is preserved, while the exposures in place are more numerous.

Near Amos Snyder's house this rock dips S. 20° E.–30°

while a little over quarter of a mile mica-schist with probably a similar strike is vertical.

The western corner of the township is made up of hornblendic gneiss or syenite rock, of which however no important dips were observed.

The Potsdam area of the N. W. corner of which the right bank of West Branch of the Brandywine is composed is confined to the fork between this stream and a small subbranch or feeder which passes close to the house of Jas. G. Templeton. The rock is principally a sandstone, and in the neighborhood of Mrs. Sarah Miller's dips about N. 20°, a dip which is probably pretty constant for the prong of Potsdam under consideration.

On the left bank of the West Branch of the Brandywine and therefore very near to it the hornblendic gneiss dips S. 10° E.–30°.

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19. East Brandywine.

This township, lying between West Brandywine and Uwchlan, and Wallace and Caln, is composed entirely of the hornblendic gneisses, feldspathic rocks, and pseudo-conglomerates; except on the extreme northern boundary line, where the eastern horn of the Wallace crescent crosses its border for a very short distance; in the extreme S. E. corner (which the boundary of the Potsdam, passing from Caln to Lower Uwchlan cuts off); and an isolated patch in the middle, which was determined mainly by surface débris, having so far as ascertained but one exhibition of rock in place, viz: on the Harrisburg and Downingtown turnpike near the Guthrieville school-house, dipping about N.–30°.

The rock here is a sandstone with some mica. As nearly as the shape of this isolated patch of Potsdam could be determined it is triangular, the long side or hypothenuse being closely confined to the turnpike, and horizontal and vertical lines from Corner Ketch to this turnpike determining the other two sides.

The south-east corner of the township cut off by the Potsdam area of the south, connecting with that of Uwchlan township, extends from a point on the southern township border east of its intersection by the Harrisburg turnpike, to a point on the eastern border south of Dowlin's station.

Various portions of the surface of the township are largely covered by *white sand*, the presence of which is easily explained by the proximity of the Potsdam formation ; for example the middle part of the northern border which is embraced between the crescent shaped quartzites of Wallace and a part of the township east of Corner Ketch. In the main, however, the township is composed of the older feldspathic and mica schistose rocks which give it the rich *deep red soil* so valuable in judging of the nature of the underlying rock in the absence of exposures.

Near R. Powell's the rocks are of the quartz conglomerate character with pink pebbles. A large exposure dips S. 15° E.–89°. For about a mile back of this the quartzose sandstone and quartzite assume more and more of this character, and this gradual passage between two rocks so different in character lends confirmation to the hypothesis of the true position of this rock which is elsewhere stated.

This completes the list of townships north of the Chester valley. The description of the townships of Chester county was divided into those north of the valley, those which touch or are cut by the valley, and those south of it. Nor is the prominence thus accorded to the valley by this method without sound foundation from a geological point of view, while it is strictly in conformity with the habits of the citizens of county.

In my preliminary remarks some reference was made to several questions of interest in connection with the Valley ; but no attempt was then made to answer them. The first of these was why is the southern edge of the Chester valley so straight ? and the second question was, why is there such a lithological difference between the rocks to the south and the rocks to the north of the Chester valley ? As a working hypothesis we may answer both these questions by saying that a fault along the axis of the valley or parallel to it and the subsequent raising of the rocks to the south would account for both phenomena, providing that there were no interfering facts; and it will be one object of the next portion of this report of the geology of the townships through which the Chester valley passes to consider whether there be sufficient reason in every case to permit this hypothesis to be maintained. The consideration of these questions will involve a third: What is the structure of the rocks of the Chester valley.

The Chester county valley is a long, narrow trough of not more than two miles and sometimes as little as ¼ mile (400 meters) in width, which seems to be divided from the lower edge of the great Lancaster limestone (except in a single point dwelt upon in Vol. CCC) by the end of the anticlinal axis of which the phenomena in West Caln township has just been described. On the map as put together at present the true significance of this structure does not appear, owing to the non-registering of roads and places on the maps of the two counties embracing the valley, which were made the basis of this report, and by the fading of the color of the Lancaster county map, and the non-agreement of color of the York, Lancaster, and Chester maps where the same formation is intended.

There is little doubt that in spite of these irregularities enough is shown to indicate a long scalped anticlinal, of irregular outline, represented by the fringe which can be followed from Christiana through the corners of Lancaster, Chester, and Berks till it is covered by the Mesozoic band in the latter two counties, and along the north border of the Chester valley to Valley Forge, where the same formation hides it. Where this anticlinal narrows to the south-west, and the planed off portion is replaced by the continuous quartzite, the Welsh mountain appears; but shortly after the Lancaster county border has been passed, the axis which has been descending must rise again, carrying with it the outlying rocks, and leaving no representatives of this formation visible except in fragments between the limestone and the crystalline rocks.

20. Sadsbury.

This lies on the Lancaster county border adjacent to the township of the same name in that county. It is another part of Chester county where the study of the geology has a most important bearing on the proper understanding of the relations of the formations in the county.

The Pennsylvania railroad makes almost a perfectly straight line through the township and lies almost exactly upon the northern boundary of the limestone from Octorara Creek Branch to and beyond Pomeroy. At no place within the distance does the limestone touch the quartzite or sandstone though removed from it by a belt of varying width nowhere very broad except at the two points mentioned.

The quartzose sandstone approaches the limestone valley more closely at Parkesburg than elsewhere, but then the nearest point is on the road (running north) a little to the east of the town, where at about ¼ mile north of the railroad, a quartz slate dips S. 15° E.–45°. The Strasburg road marks very nearly the dividing line between the formation to the north-west although apparently lying itself wholly in gray and black gneiss.

On the Valley road which is plentifully covered with sand there are a few exposures of *black gneiss*. One of these near Mr. John N. Chalfant's house seems to be a dip of N. 45° W.–10°, but may be due to the *sagging* of the soft exposed strata. Another just south-east of the Greenwood Forge dips N. 10° W.–30°.

These gentle dips are further confirmation of the dying out of the anticlinal spoken of in the description of West Caln, though so marked a transition from the steep dips just to the north, in the quartzite, would seem to intimate a *non-conformability* between them, and suggest that this gneiss belongs to the original metamorphic series. This part of the country presents to the mind the possibility that the anticlinal was divided by a *fault* previous to the deposition of the limestone, and that only the northern half of it remains. This, with a not unusual eroding activity would account for the remarkably narrow and straight belt of limestone which remains, and for the divergence of the boundary lines of the limestone and quartzite from Valley township westward.

Some of these dips may serve to mark the differences in structure upon which the above hypotheses have been formed.

A small stream which flows westward into the branch of Octorara creek which divides Lancaster from Chester counties, seems to be throughout its entire length (about one half that of the township) the boundary between the limestone on the north and the mica-schists on the south.

About ¾ mile west of Parkesburg there is a water shed in the valley, and due south of that town another small stream runs in the opposite direction (east by north), but almost in the same straight line with the first. The line which passes through both and joins them is almost if not quite accurately the southern margin of the limestone south, of which are the mica-schists of the "South Valley Hills," forming a border to West Fallowfield and Highland townships.

At Stottsville this line breaks off abruptly northward as far as the turnpike, which it then follows eastward, thus contracting the belt of limestone to a few hundred yards.

With the exception of this part the limestones dip very generally S. (or S. a little east) from 60° to 80°.

The Rolling-mill of H. A. Beale & Co., at Parkesburg, stands in part on decomposed gneiss and in part on limestone, the latter striking about E. 25° N. with a vertical dip; while the clay formed by the decaying gneiss in contact with it dips gently ± N. W. and the gneiss in the hills about 660 feet to the north dips N. 20° W. 84°.

On the opposite side of the valley from Parkesburg, and on a road leading across an exposure of limestone mixed with gneiss layers, a dip of S. 10° to 20° E.–60° is observed. The limestone is white and partially crystallized, and the soil is full of spangles of mica. It seems most probable that this *gneiss*, however derived, is the same as that lying between the limestone and the quartzite on the opposite side of the valley. The original crystalline beds to the north are evidently those which have furnished the mica found mixed both with the sandstone and limestone.

Making a hasty resumé of the principal dips in the gneiss and mica-schist along the south border of the Sadsbury township limestone belt, they are as follows, commencing at the west end: S. 10° E.–70°, gneiss S. 10° E.–40°; mica-schist, S.–53°, S. 15° E.–85°.

The limestone is entirely covered at the west end of the township, except in one place long since closed up. The reasons for continuing it through are chiefly topographical; the land presenting the low, level surface common in our limestone, and there being occasional sink holes indicating the likelihood of its existence in the dips.

The dips in the eastern part of the township are S. 10° E.–80°, S. 10° E.–60; S. 30° E.–60; S.–60° to 80°, &c.

An exception to the S. E. dip of the limestone is found at the Pomeroy station, where the limestone dips N. 10° W.–57°., which seems to be in some way connected with the sudden narrowing of the limestone belt at that point; or it may be a deception, as immediately in its neighborhood and almost in the line of its strike, a dip of micaceous limestone is found to the eastward of S. 10° E.–80.

The mica schists in a steep hill north of this dip S. 10° E.–85°; and again immediately north, S. 10° E.–50°.

All the way to Sadsburyville the fragments along the road are gneissoid, mica schists, or clay, all containing much quartz, and representing either the original crystalline rocks or the lower Potsdam compound of them.

Other dips in this series (again from west to east) are N. 10° W.–30°; N. 45° W.–10°; N. 10° W.–5° (?); N. 10° W.–84°, &c. The non-conformability, therefore, seeme here plain.

To these might be added the mica-schists on the west of the Octorara branch forming the county border, which are N. 30° W.–58°; N. 20° W.–50°.

The reason for connecting this series therefore with the underlying beds of mica-schist seem adequate, and this would lead, as was the intention of the author of the

Chester county colored map, to a uniformity of color along the border of the two counties.

The sandstones and quartzites have dips as follows: S. 20° E.–78° (north of Parkesburg); S. 25° E.–70°; N.–55° (about a mile south-west of Sadsburyville); N. 10° W.–50°, (on the Lancaster turnpike, near the county line.)

There would seem to have been a flexture here corresponding pretty well with the position of the supposed anticlinal, which would thus pass nearly through the Presbyterian church, about a mile north of Parkesburg, and of which a line from here to a point a little north of Penningtonville would nearly mark the direction.

A white quartzose sandstone but half the distance from this axis to Parkesburg, near the crossing of the road by a small stream, dips nearly vertical. The previous dip just mentioned as S. W. of Sadsburyville, and which evidently belongs to the other limb of the anticlinal, is not isolated, but is confirmed by another south of the turnpike and near the county border which is also N. 10° W.–50°.

A few hundred yards north of the Swan tavern the fragments of rocks lining the road are broad crystallized micaceous gneiss, and a quartz porphyry made of fragments of limpid quartz with a net-work of intervening decayed feldspar—*i. e.*, the rock which has all along been referred to. Another illustration of the different phases it assumes, is found about half a mile west of Sadsburyville. It is here a decomposed quartzose rock, containing some feldspar, large fragments of quartz, and small clumps of mica. It strikes E. 10° N. across the road and appears to dip N. 10° W., and is to all appearance a crystallized rock.*

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21. *Valley.*

This lies next east of Sadsbury, south of West Caln; west of Caln, and north of East Fallowfield.

*Mr. G. H. Chandler, of Kennett Square, reports having found "titanium" near Pomeroy. But what form of the metal, from sphene to rutile, and whether belonging north and south, he did not say.

Shortly after passing eastward into this township the contact of quartzite and quartzose sandstone with the limestone is renewed.

Numerous exposures of limestone continue the structure mentioned in the last pages. Some of these here follow again, proceeding from the west to the east. S.–85° ; S. 30° E.–60°; S.–70° ; S. 10° E.–70° ; S.–87° ; S. 20° E.–80° (this latter within the borough of Coatesville.)

The exposures of the mica-schists to the south of the limestone valley and in this township are few ; but enough is known from the observations made along the hills bounding the southerly adjacent townships of East Fallowfield, to render this part of the structure clear. Near the western border, and above the Penn. railroad, a massive cliff of quartzite, about half a mile north of the limestone border, dips S. 20° E.–58°. The border line between the quartzite and the mica-schists waves several times across the road to the N. W., making the intrusions of the latter across the Sadsbury border like those along the north boundary of the same quartzite.

Just about Coatesville, and north of the valley, there is an area where the quartzites are wanting, and are replaced by the mica-schists and gneisses, or their semblants.

Near the station one of these dips is S. 30° E.–65°. Above this a gneiss dips S. 30° E.–80° ; S. 20° E.–88°. In the vicinity of the mill-dam a quartz slate dips vertically ; and there seems to be here a narrow isthmus of quartzite connecting together over the gneisses and mica-schists the large mass in the western part of valley with that in Caln. This quartz slate is noticed also in the western part of the township.

On following the Lancaster turnpike westwardly from Coatesville a thinly laminated micaceous rock is encountered at the crossing of the Penna. R. R. It answers the description of "Edge Hill" rock, but contains much mica, (a psephite.) Its first dip is apparently N. 30° E.20° ; but a short distance west this is changed to N. 45° W.–55°, repeated to the abrupt angle of the road, where it dips S. 45° E. very steeply, (say 85°.)

Observations along the Brandywine north of Downingtown, but especially here north of Coatesville, reveal a quartzite of white quartz at varying distances from the limestone valley; and between it and the latter arenaceous gneiss containing mica occurring in flat plates. North of this quartzite (and sometimes south of it in fragments) a coarse grained, heavy bedded rock occurs, called variously in my field-notes feldspar porphyry, conglomerate, granite, and heavy bedded gneiss.

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22. *Caln.*

This lies east of Valley, south of East Brandywine, and north of East Fallowfield and West Bradford.

The edge of the limestone is very obscure along the south side of the valley, owing to a lack of outcrops.

At the western township line, south of the R. R. and near Coatesville, a micaceous limestone dips S. 20° E.–60°.

The limestone proper is very much intercalated with beds of hydro-mica-schist to the decomposition of which many clay banks owe their origin. One of these banks of hydromicaschist, which really belong to the Auroral, lying just north of Caln P. O. and the R. R., shows a dip of N.–85°; but the quarry in limestone still further east and somewhat north, discloses a dip of S. 15° E.–67°.

At the west end of Gallagherville the railroad cuts through the nose of a hill crossing the limestone. The bed of a small stream, generally dry, shows limestone for 100 yards south of the railroad, the southernmost exposure being very much mixed with mica. The covering of the hill just back of this is sward with no exposures. A road to the east across the track gives indications that the limestone extends as far south as to an exposed outcrop in a field, some distance off.

Some dips in the limestone from Gallagherville eastward are as follows: S. 10° E–74°; S.–68°; S.–65°; S.–70°; S.–55°; S.-55°; S.–65°.

The limestone expands greatly N. E. of Gallagherville; but attains its greatest width in East Caln.

Besides *clay* deposits noticeable here and in the easterly townships wherever, as is usual, the hydro-mica-schists appear among the limestone, there are numerous *sand* pits on the borders of the Potsdam which have been for a long time worked for a superior quality of sand. These generally are found at or near the line which divides the quartzite from the limestone. A row of these is met with just to the east of Coatesville conforming nearly to the boundary just mentioned.

The remaining part of the township is divided between a narrow band of mica-schists in the south, of which the average dip is S. 30° E.–65°, and an uneven belt of quartzites at the north, broken above the space between Thorndale and Gallagherville by a blunt protuberance of feldspathic rock, extending south with a strike of about E. 20° N., and a dip very nearly vertical; a position which does not closely agree with the micaceous sandstone in its immediate vicinity, which shows an average dip of S. 20° E.–85°.

The schists to the south are no where visible in contact with the limestone between Coatesville and Downingtown, the fragments on the road sides and hills being the only guides to the establishment of an approximate line of contact.

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23. East Caln.

This lies between Caln and West Whiteland in a line east and west, and between Uwchlan and East Bradford, in a line north and south. It contains Downingtown, and the very interesting expansion of the limestone belt in which this borough lies. The East branch of the Brandywine forms its western boundary, and the direction of this stream is nearly north and south. The dips in the belt of mica-schists which passes south of the limestone varies in strike from E. 10° N. to E. 30° N., and from 80° to vertical. Some of the dips in the limestone are as follows: S. 10° E.–85°;

S. 10° E.-60°; strike E. 10° N.-vertical (this latter at the upper marble quarry of Caleb Baldwin.)

In an excavation made by the Pennsylvania R. R. to straighten its line near Baldwin's station, variegated or *paint clays* occur in profusion at the east end, while a micaceous limestone at the west end dips S. 10° E.-85°.

On the road from Downingtown north, close to the Uwchlan border, the sand rock assumes the character of a weathered porphyry, though arenaceous to the touch. A small band of hydro-mica-schist in extremely fine layers occurs here. The prevailing dip is S. 10° E. to S. 10° W. very sharp (say 80° to 85°.)

Nearer to Downingtown close to the limestone east of the road, there is a short ridge of rock which exhibits the character of a dark syenitic granite.

At several points on the road leading south from the Downingtown R. R. station surface fragments of *trap* somewhat resembling dolerite, but of higher luster and greener color, are observed.

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24. West Whiteland.

This lies next east of East Caln, between Uwchlan on the north and West Goshen on the south.

The Pennsylvania R. R. at about the E. Caln and W. Whiteland boundary line (after a curve, now straightened) leaves the limestone valley and commences the ascent of the South Valley hill. Its track lies in the township wholly within the schists which fill up the entire southern half of the township. In the S. W. corner, near the house of Mr. Baldwin Kerch, these schists dip S.-75°, but a short distance north of this, the dip is changed for a short distance to N. ± 20° W.-50°. That this deviation from the normal structure is local is however evident, from a dip near the store near John Berry's, where the inclination ± S. 10° E.-80° is observed. The rocks here and to the eastward are various modifications of mica-schist containing milk quartz.

The limestone, in which are a number of quarries, shows very constantly throughout its entire extent dips of S. 10° E.–70° to 85°, and offers no data for the construction of *plications*.

There are a number of *iron ore* mines of greater or less extent on the northern edge of the limestone, analagous to those found in York county in the same position. One of these near the house of Sol. J. Roberts is of considerable extent, and its actual proximity to the limestone is attested, even were there no other evidence, by the sinking of a little run out of sight close by it—a phenomenon which is almost invariably connected with cavities in an underlying limestone.

Near this same margin, close to the house of John Bell, an excavation has been made for iron ore and kaolin. Some lean ore is visible, and some white clay, the latter being the representation of the variegated and paint clays so often mentioned, and almost always found in this horizon in York and Lancaster counties.

[The ores and this clay are representatives in the Chester Valley of the brown hematite and white clay deposits which range along the south edge of the Kittatinny, Lebanon or Cumberland Valley across the State from the Delaware river at Easton to the Potomac river at Harper's Ferry, and so on south into Tennessee. They are all produced by the decomposition of ferruginous lime slates at the base of the great limestone formation, overlying the Potsdam formation.]

The northern part of the township is covered with the quartzose sandstone in which, however, no dips of importance were noticed.

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25. East Whiteland.

This lies east of West Whiteland, west of Tredyffrin, south of Charlestown, and north of E. Goshen and Willistown.

Following the Indian King road from near the south-west township corner eastward, the dips at first all lie between or near S. 10° E. and S. 30° E–± 80°.

An apparent exception to this is found near Abraham Coursey's house, between the old, now abandoned, part of the West Chester Branch R. R. and the Penna. R. R., where it appears to be N. 10° W.–70° to 80°. This is probably not true for any great extent of the measures, for immediately to the north and along the main track of the Penna. R. R., numerous dips in the same strata agree at about S. 10° E.–75°.

Near Malvern Station, on the road north of the railroad, a strike of E. 25° N. with vertical dip is found, and still nearer to the track another anomalous dip of N. 30° W.–62°. Such tight folds as these dips would indicate are not by any means uncommon in the underlying floor of the limestone and especially in the eastern part of the State.

The hydro-mica-schists which forms the hill north of Malvern Station appears to dip, but not steeply, about S. 15° E. ±60° to 65°, for a short distance down towards the first crossing of the road by a small stream. Here they show both S. E. and N. W. dips very steep, and the average being very nearly vertical.

The limestone between the Penna. R. R. and the Lancaster turnpike is generally reasonably constant in its position. Some of the dips here follow: Near M. W. Lockwood's house S. 15° E.–85°; ¼ mile (400 meters) east, S. 15° E.–80°; about the same distance east near blacksmith's shop, S. 15° E.–75°; just west of the Friends' meeting-house S. 15° E.–85°; near Warren school-house, S. 20° E.–78°. North of Frazer station a hill of hydro-mica-schist rises in the middle of the limestone, and the dip here agrees with the latter, viz: S. 15° E.–80°. Just west of this at the school-house the dip is S. 10° E.–70°; but at Levi Griffith's, N. of the Warren school-house and the turnpike, the dip is N. 45° W.–73°; and a little further eastward near the Swede's Ford road, a succession of exposures show the limestone to be vertical. This occurs too at that point of the limestone valley which is stratigraphically opposite to the northerly dips in the schists near Malvern station.

The broadest part of the Chester limestone valley is here;

but as it extends to the north few other deviations from the generally southerly dip were observed.

Of these one was in the northernmost of two quite large *quarries*, located near a right angle in the road north of Warren Tavern P. O. The dip here was N. 20°, while in an adjacent quarry a few hundred yards S. W. the dip was S. 10° E.–80°. An exposure near to the first-mentioned quarry gave in limestone ± N.–±60°. Other exceptions were found about a mile (1.6 kilometers) north of here and near St. Peter's Episcopal church, where the dip was in two places respectively N. 10° W.–26° and N. 10° W.–55°.

No other N. or N. W. dips were noticed in the extension of the strike of these rocks to the west unless a doubtful one near Norris Hibberd's (a mile north of Warren Tavern P. O.) of ± N. ± 60° be regarded.

A curious rock, though not in place, was observed near Mr. Lockwood's tenant-house unlike any observed elsewhere. It is a curiously compacted ferruginous sand rock with grains of quartz, the whole being washed out by the action of water, and weathered like the rotten serpentine which compose the "Indian rocks" in Fulton township, Lancaster county.

Two railroads have availed themselves of the limestone valley for building their tracks westward. The Penna. R. R. having traversed the valley from the north side in Caln to the south side in East Caln, skirts its southern edge, and finally leaves it finally in East Whiteland. The Chester Valley R. R., which runs from Downingtown to Bridgeport diverges somewhat to the north of the former, and lies wholly in the limestone.

Just north-west of White Horse station on this railroad there is a knoll in a road leading to the north-west, which shows kaolinized slates (white clay) and white sand, together with thin plates of sandstone. A very questionable exposure gives N. 20° W.–40°.

A sink hole near Pearce's house in the N. W. corner of the township is the best means of locating the border of the limestone, and close to this appears one of a line of iron ore pits. The iron ore pits in various parts of the township, all belong to the same horizon, and are located similarly in a geological point of view.

The Potsdam sandstone crosses only the extreme N. W. corner of the township, and is principally represented by a sand of white color and by few exposures. The extreme N. E. corner of the township is also truncated by this formation, though its breadth here is exceedingly small, and it is replaced immediately to the north by the crystalline rocks. Between these two corners the township line is also the line of division between the formations.

The large Cedar Hollow Lime Company's quarries are on the east township line near the northern border; they work with patent continuous kilns.

To the west are a number of pits sunk for iron ore. Squire McCurdy, of this neighborhood, represents iron ore as on all the properties on this line; but heretofore not in quantities sufficient to pay expenses. He discovered iron ore on his own farm, and a lease to the Phœnix Iron Co. was soon effected. An engine was erected, and about 150 tons of ore were taken out, after which the latter seemed to be wanting.

[The *Trimble brown hematite iron mine*, situated in the north-west corner of the township, half a mile from each township line, and owned by the estate of Thos. R. Trimble, was abandoned for a number of years. Recently it was re-opened by sinking a shaft, about 50 feet deep, into the old workings.* Several car loads of ore were taken from near the surface for trial, but its percentage of phosphorus was too great.

Mr. J. Creagh Smith's analyses of two samples (July 16, 1880) were as follows:

	1.	2.
Peroxide of iron,	42.28	——
Alumina,	4.77	——
Silica,	38.60	34.27
Phosphoric acid,	2.83	——
Metallic iron,	29.59	27.33

Iron ore has been dug just west of William Whiteman's

* Fine specimens of *Wavellite*, and *ceruleo-lactite* have been found here; see Report B, page 143.

house, three quarters of a mile from White Horse railroad station.

The *Samuel Coffman brown hematite* mine lies half a mile west of the dam of Hibbert's grist mill, and a mile and a quarter west of Warren Tavern P. O., in the eastern side of the township.]

An *iron ore* mine near the house of Thomas R. Trimble, ½ m. from the northwest corner of the township, was opened, but abandoned 15 years ago.

An adjoining smaller pit was opened for *kaolin* and ore on the Trimble property.

Along and south of the Conestoga turnpike there are several outcrops of kaolin. A large pit near Mr. Weightman's is not at present being wrought.

One of the largest ore banks is that of Samuel Coffman's, near the Valley Creek school-house, near Warren tavern P. O. Nothing is showing here in the bank but clay (more or less like kaolin,) and a few ore fragments.

Between this mine and the North Valley hill intervenes a smaller hill of which the steep southern face is composed of limestone, and here to a great extent the ore is located.

Willistown, (north end.)

This is so peculiarly situated that it will be more convenient to refer to it twice.

Its N. E. corner interposes partly between East Whiteland and Tredyffrin. The region just north of the old intersection of the West Chester Branch and the Penna. R. R. main line has been already referred to as of importance, as indicating exceptional structure. The corner of Willistown just spoken of, almost reaches but does not inclose any examples of these abnormal dips. South of the Valley limestone, which only touches the extreme angle of the township, are hydro-micas and mica-schists, dipping about S. 35° E.–62°.

The southern contact of limestone and slate occurs in this corner near the blacksmith-shop just east of Phineas Lewis' house. The hydro-mica-schists and mica-schists to the south which inclose this are principally vertical, but with some rolling, as shown by a dip of N. 30° W.–48°. Vertical dips seem to be uniform for nearly a mile south, on the road parallel to the Easttown boundary. Just over that boundary, and a short distance S E. of Paoli, another dip is seen, also northerly and moderate.

For the rest of the township see page 287 below.

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26. Tredyffrin.

This is the easternmost township of the Valley tier. The outcrop line of the Mesozoic descends to it from the north. The belt of serpentine and crystalline rocks crosses its south-eastern part.

The junction of the limestone and the Potsdam sandstone at the N. W. corner of Tredyffrin has already been alluded to, (see § 7, Charlestown, p. 224) as well as the small band of the latter which separates the limestone from the crystalline gneisses to the north. The valley attains a width here almost as great as that spoken of in East Whiteland, and at the N. W. corner just mentioned is located one of the largest limestone quarries in the county. The dip is here steep, increasing from about ±60° (at about $\frac{1}{4}$ mile from the southern margin of the Potsdam) to 80°, and more close to the junction.

At the Cedar Hollow station of the Chester Valley R. R. an argillaceous limestone dips S. 20° E.–74°.

The inclination of all the limestone in the township is very steep to vertical.

A few dips along its northern margin, from west to east, give respectively ±S.–80°; ±S.–85°; ±S.–50°; strike E.–vertical; S.–80°.

Along the Chester Valley R. R. also the dips are very steep as a general rule. A few give S. 20° E.–74°; S. 10° E.–80°; S.–70°; S.–(?); S. 10° E.–80°; S.–80°; S. 10° E.–60°; strike E.—vertical.

It is the same with the schists which occupy the belt to the south. A series, as nearly as possible, at about equal distances apart, gives S. 10° E.–82° ; strike E. 30° N.–vertical (to N. 30° W.–±85°); strike E. 20° N.–vertical; ±N.±70°.

The structure here seems to be in its large features monoclinal from the southern edge of the mica-schist to that of the limestone, and although there are discordances and exceptions to this as a rule it may be safely considered so.

There arises here a question of structure of the first importance, viz: the relation of these schists to the limestone. 1. Are they of the same age, whether above or below? 2. Are they in time older or newer?

Mr. Hall's reasons for adhering to the latter of these two views have been clearly set forth by himself in his communication to the Philosophical Society. The result of his conclusions is to place this series of schists above the limestone, which thus becomes the oldest of the formations represented in Chester county, with the exception of his "black rocks" (syenitic granites, gneisses, and concomitant sometimes very dissimilar rocks,) and the Potsdam sandstone or quartzite. This view would explain the absence of the quartzite on the south side of the valley, a problem of the utmost difficulty; and also the reappearance of the Potsdam to be presently described in the townships to the south. It is also supported by the observation often referred to that in many places where small bodies of limestone appear they are covered with mica-schists of very much the same character as those considered by the author as generally underlying the limestone.

On the other hand there are grave objections to this view, such as the clearly synclinal shape of the eastern end of this valley, established by Mr. Hall himself, and the absence of the Potsdam in the vicinity of some outlying southern calcareous beds.

These theories can best be discussed after a more thorough description of the facts. On the southern edge of the schists, and close to the Delaware county border, is a dyke of trap which seems to owe its position to that line. Crossing the Penna. R. R. between Wayne and Eagle, about $\frac{1}{8}$ of a mile east of the old Spread Eagle tavern, this trap dyke follows the road which marks one of the numerous projections of Tredyffrin and enters Easttown, where it will be taken up and followed later.

Just north of this trap are two outcrops of a belt of serpentine which requires the closest attention and may aid in explaining some difficult points of structure.

An old quarry close by the Spread Eagle hotel, which is now filled with fragments of trap and rubbish, shows serpentine *along with the schistose matter*, with a dip about S. 35° E. and seemingly about 35°; though this latter observation is exceedingly doubtful, owing to the great amount of decomposition which the rock has undergone, a phenomenon which very frequently accompanies the occurrence of serpentine. This quarry is over the line in Delaware county; but there are two occurrences in Tredyffrin; one an old quarry on the property of Mr. Warren, (formerly estate of Annie Pugh,) and the other a smaller one made by Dr. Palmer.

The first of these was opened for building stone about 1812 to 1820, and has been in operation from time to time ever since. The dip seems to be S. 30° E.–75°.

The strike through this and the Palmer quarry would carry the serpentine to a point on the Pa. R. R. not far north of the Delaware county line; and in point of fact a strong outcrop is found on the north side of the R. R. between Eagle and Radnor; and the eastern end of this belt continues much further into Montgomery county.

As soon as one passes the creek north of Radnor station and turns into the Wayne station road, the measures assume an unctuous, schistose, and partly chloritic character. These characteristics are observed on all the fragments of the crystalline rocks which, together with a large number of pieces of milk quartz, are found all along the road. The convolutions of the schist are more numerous and their surface is more lustrous than in the true argillites, and generally they resemble those of the Georgetown belt. Where weathered they produce clays with slaty structure, but otherwise the well-known features of the paint clays.

Near Wayne station a curious pseudomorph of quartz after pegmatite was found loose among the fragments on the road.

A curious instance of weathering of a granite is seen a few hundred yards west of Radnor, where a mass of this rock seems to cross the R. R. track. Though coarse there is a distinct layer or shell of decomposition around this knob which projects towards the track.

A decomposed friable white gneissoid rock, together with a hard serpentine-like rock, cross the railroad about Wayne station.

[*Iron ore* from the excavation just south of Wm. Roberts' house, half a mile north-west of Centreville, was analyzed (March 12, 1880) by Mr. J. Creagh Smith, for the Phœnix Iron Company, as follows:

Peroxide of iron,	27.45	Iron, 19.22
Silica,	37.04	
Phosphorus,	1.93	

Potsdam sandstone is quarried on the north line of the township by the Phœnix Iron Company, from their own lands, for sand used in the rolling-mill and furnaces at Phœnixville. The stone is crushed by machinery and screened. Mr. Bean has large works for this purpose on the Philadelphia and Reading railroad at Valley Forge.]

Notes on a rough section to conneet Radnor with the Gulf Mills.

For the purpose of joining the author's work in Chester to Mr. Hall's work in Montgomery a section was made from Radnor to Gulf's mills, where Mr. Hall has made some very interesting studies.

The following are some notes of this rough line (which by means of the line from Radnor to Paoli elsewhere found) unites the two areas of work.

The fragments of rock just north of Radnor station show a finely laminated gneiss with thin layers of black and white (the latter of course including the feldspar and quartz and the former the mica-hornblende and other amphoterolites.)

At the crossing of the first stream north a gneiss of the same character occurs in fragments which enclose garnets. Here are also numerous bowlders of dolerite.

Just beyond the stream fragments of chloritic mica-schist, similar to those forming hills half a mile south of the southern junction of limestone and gneiss south of Parkesburg, and also forming the large mass of the Georgetown hills in Lancaster county.

At Ker's marble quarry on the King of Prussia road, the excavation is on the dip and 200 ft. (61 meters) deep, of which 80 ft. (24 meters) are covered by water. This marble is light blue and the dip is S. 10° E.–67°.

In passing to Conshohocken from the limestone valley, in which is the King of Prussia, one comes on a wide hill of gneissoid mica-schist; after which, close to the gulf creek, follows a very gneissoid looking limestone which fills this valley and dips S. 10° E.–80° to 85°.

The hyphothesis that the limestone is beneath the schist is incompatible with the following facts:

1. If the mixed limestone and gneiss were the result of the deposition of the latter upon the former this must have been in the form of mud which subsequent metamorphism changed to gneiss. But in the heat and pressure required for this process the limestone itself would have suffered complete change if not decomposition into a marble; or perhaps combined with the former to produce some basic water-holding, secondary-igneous rock ending in *yte*.

2. The gneiss and schists of this region agree with those found in Lancaster and Chester counties, and especially along the well-exposed Susquehanna river section.

3. The shape of this hill which points out at or a little beyond the Schuylkill is easily explained on this hypothesis of structure, but not so easily on another.

4. The strike of the limestone if produced would carry it through the Buck ridge; so that clearly its extent here is limited.

The nacreous schists which come to view along the road by Bullock's mills have a very high luster like those south of Parkesburg, &c.

Townships south of the Chester valley.

On some accounts the order heretofore pursued of proceeding from the west eastward would have advantages, for it would enable one to settle at the outset the continuity or non-continuity of the rocks eastward, from the points to which they were followed in my last report (CCC, on Lancaster county.)

But, on the other hand, it would break the connection in the description of this county. On account of the fact alluded to above, that the boundary lines of formations converge eastward into Tredyffrin, the method of following the upper half of those lines to the east and following the lower half back again, has this advantage, that it not only makes no disjointed narrative, but that one can judge by comparison how far the apparent juxtaposition of the measures, where they are confined within a small space, is real where the spreading out of the lines permits very small breaks in coincidence to be observed.

Therefore, in the following pages, the progression will be as evenly westward as the broadening boundaries of the townships south of the valley will permit.

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27. Easttown.

Between the houses of William P. Serrill and J. H. Askin the fragments are partly syenitic granite, which occurs usually in large bowlders; partly milk quartz; and partly dolerite. This is nearly a mile west of the Spread Eagle tavern.

Between Askin's and Hipple's the surface specimens are almost exclusively large bowlders of syenitic granite, with occasional fragments of porphyritic granite, in which the mica is present in very small quantities, and the quartz is in great abundance giving a light color to the rock.

Near James Smith's a quarry in syenitic granite or heavy bedded hornblendic gneiss, with garnet, strikes E. and W. and dips about vertically, (1¾ m. west of Spread Eagle.)

The trap dyke, traceable only by its broken fragments on the surface, which has been alluded to as occupying the southern edge of Tredyffrin township, enters Easttown near the house of Annie Pugh, and follows very nearly the Paoli road westward, lying however a little north of it until near the residences of Joseph Sharp and Peter Supplee, whence it continues to the border of the small stream east of William Wayne's house. It crosses the Leopard and Paoli road a short distance north of another house of William Wayne, where its traces cease to be apparent, though a few scattering bowlders and fragments of trap are met with.

The whole of the southern part of the township is composed of syenitic granite (or heavy bedded hornblendic gneiss) with garnets, and a granite with various proportions of quartz from a little to none at all, the rock then assuming the character of a true feldspar porphyry.

Just south of Askin's house is a ridge of syenite which sinks away to the west and south ; but the syenite continues entirely across the township to Sunny Side, where it enters Willistown.

The large quantity of hornblende and mica which these rocks contain, together with their quantity in the State and in the county of Delaware has induced Mr. Hall to give them the name—little distinctive it is true—of the *Delaware Black Rocks.*

Taking a general view of the geology of this township it is noticeable that it consists mainly of two formations, viz: mica-schists partially chloritic on the north, and dark green or black syenites and hornblendic rocks interspersed with feldspar porphyry on the south. Between these two, as if to form a natural barrier between them, is a wall of dolerite, on the north side of which a belt of serpentine is visible, and but a short distance from it. The decomposition of the rocks is too profound to permit a satisfactory section to be made, especially in the south.

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28. Willistown.

This township, which lies west of Easttown, spans the distance between Delaware county and the Chester valley.

Its northern part in the valley has already been referred to. *See page* 279.

Four kinds of rocks represented within its borders will have to be considered, and their mode of occurrence is very instructive.

Between the limestone and the serpentine the northern part of the township is filled with broad conchoidal mica-schist containing much chlorite and milk quartz. When dips are obtained they are either vertical or nearly so. On the Sugartown road opposite to the Paoli monument these rocks dip N. 20° W.–80°. Near to Malvern station they dip ±S. 15° E.–85°. On the State road near George Hoskins S. 35° E. 62°. Near to the margin of the limestone they correspond very nearly with the latter.

At an average distance of 1½ miles (2.4 kilometers) S. E. of the limestone valley these slates are bordered by a *great belt of serpentine* of irregular breadth, but of which the northern boundary line is *nearly parallel with the southern margin of the limestone itself*, as if the mass of schists intervening had about an uniform thickness and the serpentine were a true contact formation occurring between these schists and the lower rocks.

This belt of serpentine does not actually join that which exists in detached exposures in Easttown township; but its strike is the same, as also is its horizon. Near the house of Wm. Shank* and a little east of the road the serpentine appears and broadens rapidly to the westward. A dip near this termination agrees pretty well with the dips observed in the schists to the north of it, and is S. 15° E.–85° on its southern side. About a quarter of a mile north-west of here near the house of Jas. McCaslin it dips S.–60°. This northern edge passes nearly parallel to the State road which

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* 1 mile south of Paoli.

it crosses and recrosses a little east of the Sugartown road and the township boundary on the Willistown P. O. road a little west of Samuel Yarnall's.

Its average breadth is greater in Willistown than any townships eastward of Nottingham. Between this belt of serpentine and another isolated patch in the extreme south of the township is a region of syenitic granite and garnetiferous hornblendic gneiss.

In the midst of this on a feeder of the west branch of Crum creek and just south of H. Lúken's*, a dyke of trap, (dolerite or what Dana calls metadoleryte) crosses the road. It is here about 150 feet wide. To the north it is a weathered dolerite on the outside every fragment containing a nucleus of unaltered purplish rock with now and then a duck-feather luster and color.

Just north of the William Penn tavern† is an abrupt hill of syenite which has an abrupt face to the west. It seems to be singularly free from admixture of quartz. Just above George Pharaoh's house‡ a gneiss occurs in place, but it is very difficult to determine its dip owing to its shattered condition and the number of conflicting planes which it exhibits. It is either S. 10° E.–20°; or with the same strike (E. 10° N.) vertical. Along with this gneiss occurs a peculiar purplish hyaline quartz reminding one of opal or hyalite. This generally occurs in thin seams, perhaps parallel with the bed planes, and also in tolerably large fragments.

On the east fork of the road leading near George Matlack's a hornblendic gneiss strikes N. 45° E.–vertical. This is near the county line and Ridley creek.

Just west of this and on the West Chester road an isolated patch of serpentine of irregular shape appears and is traced west, but not beyond the township border. It is apparent to every passer by, the barrenness with which this rock invests the soil; but no reliable dip was obtained.

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* $\frac{3}{4}$ mile N. W. of the point where the two townships corner on Delaware county.

† Near the county line, just east of Ridley creek.

‡ $1\frac{3}{8}$ miles N. of Willistown Inn P. O.

This *serpentine* seems disconnected with the large mass in the upper part of the township, but the space between them is the only space on which this rock is found in Chester county, and taking a general view of its appearance westward and southward, if we take all the small patches together, there seems to be a certain regularity in the belt.

To sum up again:—at the extreme northern angle runs the limestone belt;—below (south of) this are the micaschists;—bounded in their turn by a belt of serpentine;—south of the serpentine is a band of irregular width of quartz and feldspar porphyry;—and southernmost of all a broad band of syenitic granite and hornblendic gneiss, in which latter are dykes of dolerite (as near Lukens') and another band of serpentine, (on the West Chester road.) How would these facts agree with the hypothesis hinted at above, that the lower Primal was represented by this pseudo quartz porphyry and feldspar porphyry; that this was overlain by the quartzite proper; this by the schists, and these by the limestone; that there had been first a synclinal valley of all these, and finally a break in or on the side of the Valley by means of which the lower measures had been thrown up on the south and planed off evenly? There is nothing in the observations just alluded to in discord with this hypothesis.

The southern part of Willistown and the northern part of Charlestown are formed of the "black rocks" which is by all conceded to be the floor. On this comes the porphyry; and on the north of the valley the quartzite. South of the valley (and of the supposed east and west fault) this fails, having been planed off by erosion after the elevation; but the series is below this just as would be expected in a broad synclinal contracted in its present surface extension by the upthrow.

The serpentine under no circumstances has any direct connection with the series of hypozoic and palæozoic strata, or strata of primary origin. It is clearly secondary whether metamorphic or (as the idea is still prevalent with some of the best European geologists) igneous.

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29. *East Goshen.*

This lies next west of Willistown, and though not so long, actually spans all the geological formations represented in Willistown, except the limestone, although its upper border is close to the latter.

There is nothing of special interest to be observed as to the northern portion of this township which lies wholly in mica-schist. This extends for about one third the length of the township to the south, where the serpentine band, just described in Willistown, cuts it off again, forming a boundary between the fine crystalline mica-schists and the older crystallized rocks or the imitations composed of their débris.

The serpentine has reduced its width very much in the short distance from where it was last described in Willistown, and crosses the East Goshen line near Job Gorman's with a breadth of but a few hundred feet. It passes the State road at and below the house of Joseph E. Hoopes, and the Goshenville P. O. road at the fork north of Goshenville; and the road passing through Rocky Hill and Kirkland station, on the West Chester Branch R. R., just above the house of Mr. Edward B. Garrett. That it is continuous through this distance there is very little doubt, but it is difficult to establish fixed rules for when a formation of this kind is and when it is not continuous *geographically*. That it is so geologically the straightness of the line which it forms is abundant proof, but it is very seldom that a rock so susceptible of decay as the greater part of this impure serpentine should preserve its outcrop in the midst of plowed fields and arable land. It is true, that the proverbial barrenness of the serpentine soil will oftentimes assist the geologist in tracing it; but when the belt is small and the adjoining lands are rich, this oftentimes fails. The apparent dip of bedding near Garrett's house, is N. 10° W.–20°.

There are some fragments of quartzose sandstone on parts of the southern edge of this belt, but most of the fragments on the surface south of the serpentine to and beyond Goshenville are various forms of hornblendic gneiss, syenite fragments, and clay.

Not far above the General Green hotel west of Goshenville there is some appearance of *iron ore*, but not sufficient to be of value.

Near Ph. Conner's residence, east of Rocky hill, there are streaks of magnetic and titaniferous sand in the roads, together with large bowlders of syenitic granite at or near where they were originally in place.

Near William Cloud's a hornblendic gneiss dips N. 35° W.–20°.

Near Milltown P. O. a compact hornblendic gneiss dips S. 30° E.–30°. The fragments on the south border of the township are of this same character.

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30. West Goshen.

This is enclosed with East Goshen in boundaries which form a parallellogram and encloses the same measures.

On the north the mica-schists of West Whiteland extend down a little below the Ridge school-house, with very little variation from the characters there noticed except that perhaps the luster increases a little on passing to the south, and the fracture shows larger conchoidal masses than in the north; here and there the measures become more chloritic; but every effort made to define these changes into visible areas failed. A dip in chloritic mica-schists near the N. W. corner S. W. of Elwood Morgan's house gave ± S.–75°. North of Grubb's school-house a broad-faced brilliant mica-schist containing quartz is visible, which changes at the school-house to rotten gneiss. Near the house of John P. Green the mica-schist dips about S.–probably about 70°. Just below the Ridge school-house and west of the road a mica-schist dips S. 20° E.–62°. This is almost on the border of the serpentine belt. The N. E. part of the township is taken up with fragments of mica-schist, clay, and quartz.

The *serpentine* belt passes across in very nearly the same line as that of East Goshen, making a deflection to the south just north of the town of West Chester, but the evidence of its joining the latter was not deemed conclusive.

A serpentine exposure which appears near the Chester water-works strikes E. 20° N., and dips apparently (?) N. 20° W.–20°. The rock adjacent to it is a quartzose honeycombed nondescript rock containing some serpentine.

The northern part of West Chester is composed of syenites, and indeed this rock underlies the whole borough.

A dip of doubtful accuracy occurring near Mrs. Annie Matlack's house east of the middle of the town in mica-schist with quartz is W. 20° N.–75°. The degradation of the surface and absence of reliable exposures is noticeable here as it is generally to the west and south of the county. Some loose fragments of dolerite are found in the neighborhood of Marshall Walters', but no dyke was apparent.

In the S. W. corner of West Chester fragments of a ferruginous sandy slate together with fragments of dolerite are frequent. The former is due to the weathering of a gneiss rich in salt of iron.

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31. East Bradford.

This forms the left bank of the east branch of the Brandywine west of the borough of Downingtown.

The northern part of the township is entirely occupied by mica-schists, which near the western border are all unusually chloritic in character and contain milk quartz in abundance.

Below Mrs. J. Mercer's house the strike of these schists is N. 30° E. and the dip vertical. At the mouth of Valley creek the same rocks dip S. 20° E.–40°. Near the house of C. H. Kinnard they dip S. 20° E.–60°.

In all cases above mentioned the rocks are *chloritic* in character, but in the short space of half a mile between the last two recorded dips a quantity of *silvery mica* obtrudes itself and seems to change the lithological character of the rock, while its stratigraphical position is maintained, and its position is similar, as a dip of S. 20° E.–50° taken just above the fork of the road west of Sarah Durnall's house will show. A number of exposures north of Mifflin Thornbury's give with about the same direction a less inclination of about 20°.

On the eastern side of the township the character of the rocks is not chloritic, though there can be no doubt of the stratigraphical continuity of the beds. This character becomes therefore by itself of little or no value in determining geological position.

The road from Copeland school-house to Sugar's bridge marks very nearly the southern limit of these schists, and the fragments denote the neighborhood of syenitic rocks.

Here commences the small belt of *limestone* mentioned in West Bradford. The first well-marked exhibition of it is in Caleb Cope's quarry half a mile N. W. of West Chester where it shows a number of waves. The northernmost of these exposures in a field west of Cope's upper house dips about S. 30° E. A very short distance south of this and close to the road a dip of ± N. 20° W.–75° is seen. In the main quarry the cut has been opened nearly along an *anticlinal*, the northern half of the quarry dipping N. 20° W. and the southern half S. 20° E.

The rock is a white crystalline limestone and appears to be and is said to be excellent quality. To the eastward of this quarry a valley with no exposures extends across the West Goshen boundary to judge by topographical appearances; but the limit of the limestone in this direction is certainly soon attained, and in the absence of positive evidence it has been left where last actually seen.

Just north of Caleb Cope's house there is a limestone quarry opened W. 30° S. into the hill. The place is a well-marked *anticlinal*.

A coarse garnetiferous schist underlying the limestone dips gently S. 30° E. This rock contains much quartz. On the other side it dips N. 30° W.—50° at entrance of quarry to 70° at breast.

At another quarry about 100 yards N. E. a white saccharine limestone badly crushed dips ± S. 30° E. ± 15° (?).

The gneiss which bounds this limestone on the south conforms in structure to that all along the southern line of this formation, except that in place of the absolute and sharply defined uncomformability between the limestone and gneiss, there is a narrow band of gneissoid rock agreeing with the bedding of the limestone after which the true gneiss measures appear dipping to the north.

It is quite probable that this first southerly dip belongs to the limestone series itself, and that the gneiss in which it is observed is a pseudo-gneiss, made up of the fragments of the true metamorphic rocks on which it lies. The first set of these dips, as for example, S. E. of D. Caslins' and north of Joshua R. Howell's houses are south ±45°. North of John Hannum's, S. 25° E.–26°.

The dips are very irreconcileable here. One in Grant's quarry gives S. 20° W.–22°. One on the border of West Chester borough gives E. 20° S.–75°. On the western edge of Copesville a gneiss dips S. 10° E.–38°.

Below this zone is another in hornblendic gneiss, giving northerly dips, as for example, west of Hoopes & Thomas' nursery a gneiss dips N. 28° W.–89°. Another, with the same direction, 70° to vertical. Near the Black-Horse tavern dips both north and north-west, the former about 56°, occur. Still further south, near J. N. Hildeburn's, a gneiss dips S. 30° E.–60°.

Below this, north of Edwin James' house; a hornblendic gneiss dips ±N. 10° W.–58°, and a short distance south of the same house about S.–58°. There is here, therefore, a gentle plication of the limestone, narrow as the belt is, producing a northern synclinal and a southern anticlinal; and south of this, at least two anticlinals steeper than the former, but still not steep enough to throw any doubt on their true structure in hornblendic gneiss.

Here intervenes another part of the *serpentine* belt. A narrow belt in which the dip is not always ascertainable though the rock is undoubtedly in place, owing to the shattered and broken condition of the rock, occurs at the crossroads north of Alban P. Ingram's, where the dip is S. 10° E.–10°. This belt can be followed westward across the place of Alfred Sharpless, a little south of west where its traces run out before crossing the Brandywine. Another serpentine exposure is seen near Strode's mill, where the apparent dip is S. 30° E.–60°. Neither of them has been followed further to the eastward, where on the south they appear to be surrounded by hornblendic gneisses and gneisses containing little hornblende and some milk quartz.

At Strode's mill the serpentine seems to have the above dip of S. 30° E.–60° on top of a quartzose crystallized slaty rock, apparently dipping W.–80°, to all appearance unconformable.

In front of Philip Paxon's house, just north of here, parallel plates of fine grained gneiss are seen in the road. This rock is very siliceous and brittle, even emitting a clear porcelain like ring when struck.

Just west of West Chester, in John Grant's quarry, in gneiss the rocks are heavy bedded mostly rich in quartz and hornblende, with layers partly streaked with white efflorescent salts. The dip seems to be S. 20° W.–22°.

An exposure on a top of a hill S. W. of Richard Taylor's dam and south of the serpentine band, strikes E. 30° to 40° N.—dip not certain.

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32. West Bradford.

This lies south of the Penna. R. R. and immediately west of the east branch of Brandywine creek. The greater part of the township from the northern border south is covered with mica-schists which are either broad and conchoidal in fracture with highly lustrous planes of light blue to silvery color, or more or less chloritic. An exposure in the first mentioned rock on the road from Downingtown to Woodward's corner and near Wm. Hamilton's house dips S. 20° E.–85°. A characteristic specimen of the second variety at the first turn in the road south of Thorndale dips S. 10° E.–70°. At Woodward's corner a chloritic variety dips about N. 30° W.–80°, and from this point to the dip above spoken of at Downingtown the road is filled with clays of variegated appearance with occasional schists of which the dip is vertical or nearly so. On the road following the east branch of Brandywine a coarse grained mica-schist dips S. 20° E.–72°, (near John Pollock's house.) In the quarter of a mile (400 meters) between Geo. Kerr's and Jas. Gibson's on the same road, two dips in mica-schist give respectively strike E. 30° N. and strike N. 20° E.–both vertical, a difference in direction which will explain without further words how convoluted these schists are, and how rapidly they change their direction.

A little further south, near Jeremiah Keeler's house, they dip S. 20° E.–40°, and just above Sugar's bridge, S–40°. This is continued near Amos Scott's house by a dip of S. 20° E.–35°, which brings the measures to the borders of a small *limestone belt* which skirts the southern edge of these schists.

There can be little doubt that in these dips we have an *anticlinal* between the limestone valley of Chester (and the vertical dips immediately south of it) and the limestone belt here, with the moderate S. E. dips in the same schists just north of it. This again would be in strict accordance with the hypothesis elsewhere referred to, that these mica-schists, brought up by a fault and upthrow to replace we do not know how much of the southern side of the original limestone formation, really belong next below the latter ; and when they turn and descend to the south it is to be anticipated that they will bring to view the same limestone. This would not be the case if the limestone were the lowest of the series, for the gentle southern dips would then imply that in passing south we were passing over an increasing thickness of measures separating the surface from the Chester valley limestone. To harmonize with this theory, these would have to be considered a separate and independent limestone deposit. Some quarries and exposures indicate the outcrop line of this limestone to be nearly along the southern edge of a small branch which empties into the east branch of the Brandywine, north of Copesville. The dips of the limestone are generally to the south, and about 30°, though in places their dip is variable and occasionally almost flat. Thus in a quarry near the Poor-house the dip is E. 15° N.–±15°.

Just south of the limestone belt and in contact with it are compact gneisses partly weathered into clay which dip N. 20° W.-45°; N. 10° W.–20°; N. 40° W.–36°. These dips are important and reduce the problem of the structure apparently to one of two explanations. If the lithological evidence be accurate that these southern rocks are different from those to the north, and older, a non-conformable contact is here evident. If they could be supposed to be the same or modifications of the same it would form a very narrow synclinal valley here. In either case the limestone would appear to be of next later age than the mica-schists to the north of it, and these same rocks to occupy a similar relation to the limestone of the Chester valley. There are good reasons for rejecting the second of these hypotheses, as will appear hereafter, as well as the idea of a fault along the southern edge of this belt also. As to whether it is simpler to explain the two limestone belts on the theory of one or two horizons when each is proved to rest upon the same rocks the reader may judge.

Just south of Romansville, on the west fork of the road, the mica-schist is less chloritic and shows in small broken fragments, by which the position is not easy to determine; but a horizon of large masses of milk quartz dips S. E.–gentle.

A chloritic schist near Mrs. A. Baldwin's house a short distance from Mortonville dips about S. 30° E.–30°.

The zone of limestone which crosses this township into Newlin has its south-westernmost exposure near the Chester county poor-house. Here a breast of 80 feet is opened. The limestone dips E. 10° N.–15° to E. 20° N.–20° in the S. E. end of the quarry.

To the N. W. of the quarry a rotten gneiss dips S. E.–45°.

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33. *Westtown.*

This is a narrow rectangular strip lying south of West and East Goshen. It is covered by the hornblendic gneisses and syenites except at its eastern and western extremities, where deposits of *serpentine* appear; that in the S. W. corner furnishing commercially the most important set of quarries of this stone in the State. Near the N. W. corner and due south of West Chester the predominating rocks are gray gneisses. Eastward, along the northern border, the fragments are micaceous schist or gneiss débris with the quartz separated, besides some milk quartz not belonging to the rock. Near Hemphill's station a mass of *trap* appears which is in all probability syenite, though parts of the large bowlders are fine-grained, and resemble dolerite. On the West Chester and Media road a short distance S. E. of Hemphill's, at a cut in the R. R. near Yearsley's hill and R. W. William's house and on the south side of the stream, gneiss dips respectively W. 20° N.–20° and N. 20° W.–80° to vertical. At the northeast corner of the township the *serpentine* belt previously described in Willistown enters from the S. E. and traverses this corner in a direction similar in the main to that of the West Chester road ending below Dr. John R. Hoskins' house, where it is replaced by garnetiferous hornblendic gneiss and the débris from this and fragments of milk quartz.

Efforts to trace this *serpentine* westward to a connection with its exhibition in the west were not successful, but a small exposure was found in a ridge in a field a short distance south of the house of Caleb H. Cox.

Another exhibition is observable in an old quarry south of Shady Grove school-house; and an indication of its existence a very short distance north of the residence of Stephen Taylor. But the principal outcrop of serpentine and the most important one is in Brinton's quarries in the extreme S. W. corner and near the junction of the townships of Westtown, Thornbury, and Birmingham.

Brinton's quarry covers about an acre of ground. and

McClure's, just above it, perhaps as much. The faces exposed are about 40 feet high, and the rock much broken up between intersecting planes of cleavage and fracture—two of which have the same strike but opposite dips.

The most probable seems to be N. 40° W.–45°, and this would make the deposit a small remaining part of a synclinal (?) The other dip is S. 40° W.–45°, which would make it the southern limit of an anticlinal, (in the southernmost of the two openings.) The workmen all agree as to the uniformity of the dip, N. 45° W.

Brinton's quarry was opened in about 1867, on the property of William Jones. Mr. Brinton, in partnership with Mr. Joseph W. Savery, leased and opened it for building stone. At the time of the notes here taken, (Sept. 23, 1879,) Samuel Henry, the boss, reported the number of men employed as from 6 to 23. The drilling was done without the aid of machines. The steam sawing and driving was stopped three years before, (1876,) and the stones are roughly hand dressed. At the time of the inspection McClure's quarry had not been working for two months. Six men got out about 12 to 15 perch of stone a day.

A small end of a ridge of light colored quartzose crystallized rock containing some small specks of mica and hornblende cuts into the serpentine from the east, and partly divides McClure's from Brinton's quarries. Jefferisite is found in the S. W. corner of the quarry upon the serpentine.

This serpentine cannot be followed either east or west for any considerable distance.

[Two views of this important quarry are among the illustrations of this volume. They were lithographed from photographs kindly sent to me by Mr. Joseph H. Brinton, with the following letter dated May 6, 1882:

"DEAR SIR: Your favor of the 2d duly received. I enclose you by to-day's mail a couple of photographs of the quarry. I have often thought of writing a monograph of the serpentine of this locality, but have been deterred from want of leisure, also from the belief that my views would not be accepted as correct by others who have had a wider field for observation than myself. I am convinced however that the serpentine formation extending through Pennsylvania and Maryland, showing at uncertain and irregular intervals, has been caused by a *fissure of contraction,*) or perhaps I can better express myself by saying there was a settling down of the earth's crust causing a break in the gneiss and hornblende and other *very old rocks,*) which fissure did not always appear at the surface; but where it did occur it was filled in with a fused mass that now appears as a white granite, as seen near Media, Delaware county, at my place and more extensively at Port Deposit, Md. The size and extent of this fissure and the amount of injected material has determined the extent and character of the serpentine *which occurs on both sides of it* and is nothing but the surrounding schistose and hornblende rocks altered by the heat and pressure of the granite intrusion; and as we leave the granite it gradually passes from steatite to serpentine, from serpentine to gneiss or hornblende. This accounts for the great variety of the serpentine, as it never is alike in any two localities, either in color or composition. At my quarry the fissure passed through a vein of very dark green hornblende containing olivine, bronzite, garnet, &c.; and the serpentine here is more compact and uniform than any other that I know of. The granite vein (see photograph) did not show on the surface here, but is now found to cut directly through the centre of the hill, dividing it into two parts; and the *same changes have taken place on either side of it. . . . . .*"*

The diagram cut given on page 214 is a copy of Mr. Brinton's sketch, to show his theory of the structure. J. P. L.]

A mile south of Hemphills station, two fields to the west of Yearsley's house, serpentine outcrops are numerous, and steatite of excellent quality is found.

The rock on the N. W. side of the stream, near where the dip was previously mentioned on the West Chester, Media and Philadelphia R. R., seems to be for 100 feet or more a compact granite or very compact and heavy bedded gneiss. The lines of lamination, when traceable, are those

* For Col. Joseph Wilcox's description of the minerals, see *Serpentine,* in Index to Delaware county.

heretofore noticed and are nearly if not quite vertical. The rock is bluish and the feldspar in blotches, the main characteristic of the whole mass being its compactness. Over it and at the N. W. end of the cut a disintegrated laminated gneiss of variable thickness seems to dip unconformably W. 20° N.±20°.

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34. Birmingham.

This is the continuation of E. Bradford southward, along the left bank of the Brandywine. The rocks which have been described as underlying West Chester strike through the northern part of it.

A serpentine, too, about ¼ mile S. E. from that of Marshall Stroud's in East Bradford, and which has been noticed before, shows itself about opposite to the buildings of the Fern Bank stock farm, dipping S. 30° E.–35°. Could all these three outcrops be connected together they would imply a double synclinal; one narrow one in East Bradford, and another, wider, including the deposits in Westtown and Birmingham. Just south of this serpentine the gneiss dips about S. 30° E.–gentle.

The portion of the township where the battle of Brandywine was fought is covered deeply with sand and clay. The rocks below are gray or yellowish gneiss.

Above Sellers Hoffman's house a sandy gneiss dips S. 30° E.–45°. Just above the lower of Sellers Hoffman's two mills the same rock dips about N.–45°, and at the extreme south-western corner of the township S. 30° E.–89°. There is evidently here a series of waves in this gneiss, to the first and gentlest of which a dip of gneiss in Dilworthtown belongs of S. 30° E.–15°.

A small outcrop of *limestone* occurs on a stream between Thomas Brinton's and Abraham Huey's.

Just north of Dilworthtown is a bank of very much decomposed gneiss, existing simply as a sand with different colored layers, and dipping ±E. 30° N.±15°. The layers are very perfectly preserved.

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35. Thornbury.

This lies south of Westtown and east of Birmingham, and and is the smallest township in Chester county. The rocks are exclusively the hornblendic gneisses and their concomitants, which form the mass of the portion of Delaware county, adjacent to which it lies. North of Dilworthtown a gneiss of this character dips ±S. E.±15°, and forms part of the northern limit of the second synclinal roll mentioned as occurring in Birmingham ; as does also the dip of gneiss in its upper border, just south of Brinton's serpentine quarry mentioned before, which is ±S. E.±30°.

Another dip of very decomposed gneiss, a short distance east of Dilworthtown, has a strike of E. 30° N. and a probable dip of S. 30° E.–15°.

Across the boundary in Delaware county, near the house of James Dutton, hornblendic gneiss dips N. 30° W.–20°.

There is much loose débris of quartzite fragments over the western part of the township, but this rock is nowhere found in place.

The eastern part is covered with fragments of syenitic granite and hornblendic gneiss.

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36. East Fallowfield.

This lies south of the Chester valley near Coatesville, which is north of its central upper boundary a few hundred yards.

The rocks are all mica-schists similar to those described in a similar position already ; and the dip of those within a short distance of the northern border is singularly uniform at S. 20° to 30° E.–70°. A few of these enumerated from west to east along a belt of about a mile parallel to this border will illustrate this. Just south of Stottsville and Humphreyville will illustrate this. S. 30° E.–70° ; S. 30° E.–70 ; S. 30° E.–70° ; S. 10° E.–70 ; S. 30° E.–70° ; S. 30° E.–70 ; due south of Coatesville S. 10° E.–70° ; S.

30° E.–80° ; S. 20° E.–70° ; S. 25° E.–55° ; 4 exposures of S. 10° E.–80° east of Mollsville ; and S. 10° E.–65° near the house of Wm. Stamp. There appears to be less variation in the dip here. From this circumstance it would follow (if the hypothesis of structure of the Chester valley heretofore described be true) that the limestone which was once continuous with that valley would appear at a less distance to the south than elsewhere ; since the high and uniform dip just mentioned should bring newer and newer rocks to the surface as one advances south. This is precisely what is observed on the colored map, where the small and insignificant belt of limestone takes a wide extension to the north at Doe run in West Malborough township, thus diminishing the distance over the present surface between it and the Chester valley limestone by about two miles.

The hypothesis of a fault lifting the southern side of the Chester valley is not inconsistent with any facts thus far observed, and agrees well with many phenomena not otherwise easily explicable.

The central portion of these schists exhibit less chloritic characteristics than the eastern and western portions ; but it has been said before and is repeated here that differences of this kind which exist in the belt are entirely worthless for purposes of differentiation. The mica-schist along the Wilmington and Northern R. R. resembles what has been often described as the hydro-mica-schists of the Calciferous more than at most points in the county in similar position ; but the weathering is into variegated clays, like those which result from the decomposition of the older crystalline rocks. Variations are not uncommon. Thus near Ercildoun P. O. the results of rock disintegration are thick clays with very little mica.

What the exact value of the change apparent to the eye across Buck run may be, and whether the measures in the narrow strip to the N. W. of the limestone of Doe run be really of the older crystalline rocks, or only a local variation, is not certain ; nor is it of vital importance, though it must be inferred that in the former case the supposition of the limestone underlying the mica-schists and overlying the quartzite would also explain the phenomena in West Marlborough, but not in East Marlborough.

As far as the observations in East Fallowfield are concerned they conform well with the requirements of the hypothesis elsewhere elucidated.

About half a mile north of the Laurel iron works chloritic schists with steatite, in a quarry, show a dip of E. to S. E.-20° to 50°.

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37. *West Marlborough.*

This lies south of East Fallowfield.

We encounter geological phenomena in the extreme northern part of this township, on the small stream which separates it from East Fallowfield, which require explanation.

The evidence of the identity of the rocks north and south of Buck run and north-west of the limestone of Doe run is so overwhelming that the discussion of what would be the possible explanation if it were otherwise may be dispensed with. The map of the county contains this error only because as originally intended by the author when it was printed all the slate colored area was to have been pink, conforming to the area in Lancaster county, of which it is the continuation. The hornblendic or black rocks were to have been also pink of deeper shade.

The western and northern borders of the township are covered by mica-schists more or less chloritic, containing milk quartz. The dividing line between them and the limestone on the northern side is a curve which bends inward toward the center of the township, and the dips here are all gentle as has been before noticed, of similar rocks in a similar position. Some of them here follow. Near Webb's mill chloritic mica-schist S. 20° E.-20°; S. 15° E.-20°; S. 20° E.-30°. Near Pennock Marshall's S. 10° E.-30°.

No reliable dips were obtained on the western side.

The *limestone area* itself, of which it is exceedingly difficult to define the exact extent, seems, on those grounds to which recourse has been taken in other cases, to resemble remotely in shape the head and shank of a hammer, of which the axis of the head lies in a line a little east of north, and that of the bifurcated shank nearly east. A projecting nose of hornblendic and gray gneiss, flanked by the quartzose sandstone, bounds it on the south and reduces its southern portion to a narrow strip. The rest of the township is filled with the *quartzite* and quartzose sandstone, except another narrow neck of *limestone* which passes out to the east by the Apple Grove school-house and Mr. John McBentler's house, thus separating on the surface the mica-schists of the north and the *Potsdam* on the south. The rare dips obtainable in this latter formation conform well to the hypothesis of an *anticlinal* (overthrown) of Potsdam sandstone at this place, the northern dips being S. 35° E.–70° and upwards, while a short distance to the south, dips of S. 10° E.–45; S. 30° E.–50°; S. ? E.–30°, &c. These dips refer mainly to the portion of the township north of Woodville and south of the area of limestone before spoken of.

There is a southern projection of the township lying east of London Grove which does not properly belong to West Marlborough in a geographical point of view, and can be best considered with East Marlborough and London Grove, which it separates. In this narrow area the alterations in the strength of the dip are many and considerable, as if the Potsdam were plicated, as indeed it must be if the area which it covers in this region on the map be not exaggerated; for without plications even a very gentle dip would carry a formation as thin as this out of sight within a mile or less.

The limestone is not exposed in the hamlet of Doe run; but the water is hard in all the wells, the country is flat and full of sink holes, and there is no reasonable doubt about its underlying the surface. Passing south, down the Pomeroy and Delaware City R. R., limestone quarries or indications are carried down and around the horse-shoe curve in the interior of which some quarries have been opened.

South of this are many loose masses of *syenite* apparently belonging to a dyke, the exact position of which has not been determined. The appearance of the rock in place, or its fragments near to the parent rock, excepting the above, is of a broad-planed silvery mica, having nevertheless in some cases where large masses are exposed some characteristics of the chlorites. Here again is a locality which illustrates the imperceptible gradations of one of these rocks into another.

The dips of the limestone near its northern edge are very steep 70° to 85°, and immediately south gentle, i. e. ± 20°, which is the dip of all the middle portion of the limestone except one place near Jones' quarries where it is 45°.

The direction of the dip is peculiar. In one quarry towards the north three dips were obtained on as many faces W.–70°; S. 30° W.–20°; and S. 30° E.–85°. The direction of the limestone near Jones' quarries is S. 30° W.–45°; while on the easterly side of the formation at John Berstler's the dip is S. 20° E.–20°, and at Elisha Bailey's a short distance west of Upland S. 20° E.–70°. This latter appears however to be now a detached fragment.

The general lay of the limestone in the township indicates a gently dying anticlinal *underlying* the Potsdam sandstone, which shows similar dips to the south-west on the western side of the area, and to S. E. on the eastern side of the deposit; in both cases *above the limestone*, which dips under it. According to this structure, interpreted at this one of the most crucial regions, the limestone of the Chester valley and that of this narrow and isolated belt are of different ages altogether; the latter being a part of the great hypozoic measures, and the former of the Calciferous.

At first glance it would seem as if the hypothesis that the mica-schists south of the Chester valley limestone were *superposed* would answer the conditions of the problem very easily; and so it would if only the southern side of the valley and the northern side of this belt were taken into account. But whereas the Chester limestone lies *on* the Potsdam without the shadow of a doubt, this belt *dips* under it.

The appearance of the two limestones is also not entirely the same, (although this difference is not of itself sufficient to support so important a theory of structure) and resemble those measures described in York county as the "buff-colored limestone" of different strike and dip from the "blue limestone" with which it was there often found in contact.

As an example of the structure here given we find at Mrs. N. Stuart's limestone quarry near Doe run two kinds of limestone, one white and in part crystalline, with some heavy spar ? in layers. The dip is S. 20° E. and E. gentle. The limestone occurs in the hills and gives little evidence of its presence; the dip of the rotten mica-schists of Doe run (south of this) would place it below them.

There is an excavation for ore just west of this which has not produced in paying quantities.

At the "T" road crossing south-west of Doe run a mica-schist with milk quartz and containing much chloritic matter makes a bluff, around which two roads lead; the strata seem to have an average dip of W. 30° N.–85°.

The quartz slate which makes the hill south of Doe run shows in a good exposure the dip S. 30° W.

Passing east through Woodville, and neglecting some few floating specimens of *serpentine* as not sufficient to prove the presence of serpentine in place, the *quartzose sandstone* may be followed continuously to London Grove P. O.

Loose pieces of dolerite were deemed insufficient to warrant the placing of this formation on the colored map.

The rock taken as representative of the Potsdam is a psephitic quartz slate. It is of two kinds. One (called provisionally in the field notes *Toughkenamon rock*, because of its development near that station,) is composed of weathered particles of a gneiss or syenite loosely compacted and laminated. It dips south just north of the Avondale limestone. The other was called provisionally *Kennett rock.* It is a thin-bedded rock, lying in plates of fairly parallel sides, composed of fragments of white limpid quartzite, and is generally large grained.

It will at once appear that there are good lithological grounds for believing the first of these to be contemporaneous with the *pseudo gneiss* and porphyry, occurring so largely in the northern tier of townships; while the resemblance between the second and Mr. Hall's *Edge Hill rock* will strike any one who has seen his description of it.

According to the working hypothesis formulated early in this report, the former is the *lower* and the latter is the *upper* member of the Potsdam formation.

The *Kennett rock* just west of Woodville, near Mrs. Sarah Pennock's, dips S.–45° ; and east of Woodville, S. 40° E.–50°.

Near Sarah Leonard's the dip is S. 30° E.–50°. By Bennett S. Walton's the dip is about S. 30° E.–50°.

Opposite London Grove school-house there appears to be a local north dip of very limited extent, since a very short distance below the Episcopal church and Friends' meeting-house, opposite to it, a quartzose sandstone dips S. 30° to 40° E.–65. This rock is shown in the bank where it seems to be a quartz slate, loosely compacted of translucent quartz. There is an appearance of an overturn making a steep N. 30° W. dip, which becomes gentle within a short distance. This may be due to a local sagging or falling over of the upper portions of the exposed strata. In any case it is without importance in the general structure. Near Edward Marshall's the dip of quartzite seems to have been reduced to E. 20° S.–40°, but the material is the same. This gentle dip explains not only the extension of so thin a formation on so wide an area, but it seems to forbid any other structure to the limestone north of it, except that which would place the *quartzite beneath it.*

The south extremity of the prong of West Marlborough is probably in limestone, though no exposures were noticed exactly within its bounds. This limestone, which there is evidence to show belongs to the Chester Valley age, will be taken up more advantageously elsewhere.

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38. *East Marlborough.*

This adjoins West Marlborough on the east and contains principally the same rocks noticed in the southern part of latter township.

The northern part of East Marlborough is filled by the hornblendic gneisses and with rocks resembling the feldspathic granites and porphyries elsewhere observed. In the extreme N. W. corner and in contact with a part of the prong of limestone which enters Newlin township, a feldspathic gneiss dips ±N. W. (under it) ±40°.

Three quarters of a mile south of the upper point of the township is a limestone quarry owned by Eli Logan.

Just east of this quarry a cut through the hornblendic gneiss and mica-schist dipping S. 30° E.–45° reveals quantities of almost spherical garnets of about 2 mm. (.08 inch) in diameter.

In Logan's quarry the dip is S. 20° E.–40°. About 60 feet (18 meters) are exposed and the bottom is yet in limestone. On the east side of the quarry the dip is S. 20° E.–40°. On the western side N. 40° W.–45°, and on the southern side S. 30° W.–30°. The opening is about 100×150 feet (30×45 meters). Here is evidence of the same kind of structure described in the limestone quarries of Doe Run, where the dip is gentle and spreads out on three sides, looking as if the anticlinal were dying towards the S. W.

A little east by south of the North-West school-house the coarse-grained gneiss shows a dip of W. 20° N.–20°, which is satisfactory proof of a roll in the measures which overlie this limestone, but the dip of S. E. is resumed before reaching Unionville before bringing the limestone to the surface.

Whether there is an anticlinal between Logan & Hayes' quarries is not certain, but in any case the *limestone is inter-bedded with the gneiss*, which lies above and below it; and if the limestone of the two above-mentioned quarries was never continuous, that of one is separated from that of the other by a very thin bed of gneiss.

Numerous dips in the gneiss were obtained in the northern half of the township. After continuing the northeast dip for a mile or more and thus bringing newer portions to the surface, these are succeeded near Washington Alexander's by a decayed quartz conglomerate in a matrix of feldspar dipping also S. E. very gently.

Mr. Caleb Wickersham reports that in this decayed white conglomerate with fragments of quartzite he has found a great many garnets and that not only is the rock very garnetiferous but that it has furnished a number of specimens of precious garnet.

Of course this is conclusive evidence that its age is later than that of the garnetiferous gneiss which was despoiled in order to constitute it.

A short distance further south, near William Chalfant's, this is changed to N. 30° W.–20°, and there is abundant evidence that the lower Potsdam (to which this is supposed to belong) rolls gently, but always bringing newer portions to view up to near the Street road, which it crosses at a very acute angle and gives place to the limestone on its back.

There are few exposures of rock in place along the Street road, and these are in the quartzite; though, close to it on the south exists in all probability a continuous though exceedingly narrow belt of limestone. From the west township line east along the Street road to John Swayne's the soil is composed of clay sandstone with fragments of mica. Here there is a dip in a thin-bedded quartzose sand rock of E. 10°.–10° to 20°. Near Thomas Mullen's a very micaceous psephite dips in the same direction the intensity was not noted. On each side of E. L. Bailey's there are dips in the quartzite quite similar to the above. This strip of *quartzite* however is but the last vestige of the formation spared close to the equally narrow strip of *limestone under which it dips;* while probably three miles or more of the original area of the nearly flat Potsdam has been eroded leaving the underlying gneiss exposed.

This fact, if it be considered sufficiently established, serves as a practical illustration in answer to the objection suggested above to the structure which placed the mica-schists south of the Chester valley below the limestone, viz: that in that case one must suppose the erosion of a great extent of quartzite which was supposed to offer one of the stoutest resisistances to this kind of action. But here we find that it *has* been eroded; and the erosion has taken place at the eastern end, leaving a continuous breadth of of three miles in the western part.

The structure from here down to the border of Kennett is not established by any actual observations taken near the line of the limestone. This belt is all farm land covered deep under the finely-ground débris of the rocks or covered with grass. Towards the median line however, along with the clay and sand, decomposed gneiss are occasionally found dipping S. 30° E.–25°, and immediately thereafter appears the quartz rocks of Kennett followed by its limestone.

It is not difficult to reconstruct in imagination the folding here; and there is very presumptive evidence that this structure is correct. In other words there must be a *fold or roll* between the Street road and the Baltimore Central R. R. which (be it normal or be it overturned) has had the effect of bringing forth the limestone and the quartzite above the present surface level at the east of the line but not at the west. If these folds be traced in the continuous body of limestone north of the line from Avondale to West Grove the plication has not been sufficient to bring up the entire thickness of limestone to day, and it rests there connecting the two streamers of limestone that jut out of it to the east like the tail of a swallow. Here there is another *anticlinal* dying down to the west or a little south of it.

An obvious objection to the interpretation of this very difficult region will be that there is no indication—on the map at least—of the *Potsdam* south of the upper prong and east of the main body; nor is it represented north of more than a very small part of the eastern end of the south prong.

The only reply which can be made to this is, that the hard gritty (upper) part of the Potsdam is not only very thin but very friable, and the disintegration of the rocks very profound; so that it is not at all unlikely that such an edge should be covered out of sight; more especially as the lower Potsdam, which is composed of the materials of the crystallized rocks beneath it, resembles the latter in nothing more than in the ease with which it yields to weathering, even at considerable depths, substituting for itself clays with which the water and wind and their own weight have *puttied* over the outcrop lines. Nevertheless it is not to be disguised that the objection is a serious one, and the above explanation only the best that the author can offer.

But independent of extraneous grounds for believing that these two narrow bands are small *synclinals* (or parts of such) separated by a large *anticlinal*, is the evidence obtained from one of the quarries situated on the southern edge of the northern band. This is Pusey's quarry, and the dip in the south face is N. 30° W.–60°. In the north face the best average in 150 feet was N. 30° W.–20°. The limestone in this quarry, it is believed by some of the most intelligent inhabitants, has never been traced and does not continue further to the west than the road which leads to the north, passing a little east of Toughkenamon.

Just west of the Red Lion tavern, on the Street road, a gneiss decomposed to a loose sand dips S. 20° E.–30°. Another rock inter-bedded with this resembles a weathered felsite-porphyry.

Heretofore only the more widely distributed rocks have been considered, but there are also occurrences of *serpentine* in this township in the line of strike of this formation, described in a previous part of the report, in Willistown, West Goshen, East Bradford, &c. There are two townships which of right should have been mentioned before this one, since the serpentine crosses them to reach it, but for obvious reasons the more important questions of the limestone and quartzite rendered it necessary to pass from West Marlborough to East Marlborough.

Not only do these *serpentines* occur directly in the line of the belt as previously described, and follow the chloritic measures lying between the Potsdam sandstone and the true hypozoic gneisses (as was pointed out in considering their geology in Lancaster county,) but in East Marlborough the last serpentine exposure is found in the extension of the belt in this direction, until the large development in the south-western corner of the county is reached—an hiatus of fourteen or fifteen miles.

An exposure of the rock north of Mrs. Hannah G. Cloud's, lying unconformably upon sandy mica-schists, which just south of it dip S. 20° E.–30°, has a strike of E. 40° N.–vertical.

A quarry a short distance from the little settlement of Marlboroughville dips apparently E. 40° S.–50°, and these strikes if plotted on the map would intersect at a point not far from a quarry in a field near Moses Way's, about quarter of a mile from the African Methodist church, where a very rotten partly schistose rock, containing some milk quartz, mica and talc, resembling those nondescript rocks in which serpentine is usually found decomposed near the surface, dips ±E. 20° S.–10° (?).

This is the last point where the probabilities of the existence of serpentine are very strong, until one reaches Elk and Nottingham.

Another very small locality is marked on the map, but it is doubtful. This is at the fork of the road just west of the village of Unionville. A foliated rock to all appearance in place, and containing intercalated magnetite in places strikes E. 40° N.–vertical.

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39. Newlin.

This lies south of West Bradford and east of East Fallowfield and north of East Marlborough.

The northern and western parts of the township are covered by the mica-schists of the South Valley hill.

The approximate boundary line which has the *limestone belt* on its southern side passes in an irregular line from Jos. H. Pratt's* close to Embreeville and passes into West Bradford through the Chester county poor-house property and close to an observatory of Mason and Dixon situated 30 miles due west of Philadelphia, [i. e. of Third and Walnut streets ?]

In passing S. W. from Romansville in West Bradford township on the border of Newlin the dips in the chloritic mica-schist suddenly change from ± S. E.–steep to ± N.

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*1½ m. S. W. of Embreeville.

E. gentle. Intercalated are some black or gray beds of sandy character like *hornblendic gneiss* that had been torn to pieces and restrewn. Typical *chloritic schists* are found above and below these. All the dips in the chloritic measures in Newlin township (of which there is an abundance) are S. 10° to 30° E. close to the limestone and steeper (i. e. 50° 60° and 70°) in the N. W. corner in the neighborhood of Mortonville.

The appearance of the limestone near the poor-house, a small detached portion on the east of the township, has been described.

A somewhat unique occurrence is found west of this quarry and on the Newlin township line. It is called *Hayes' whetstone quarry*. The chloritic schists here are impregnated with fine sand, and a series of beds of black decomposed sandy slate are found in the excavation. As tothe chlorite in this character a similar class of rocks is found on the lower Susquehanna where the convolutions and the yellowish-green color of the chlorite series are perfectly preserved, but the rock is as hard as a quartzite. It is in fact a kind of *silicified chlorite* and in some cases actually *fossil* chlorite where the solution of silica has replaced the other minerals particle by particle without altering their forms. (The *limestone* which is found on the southern edge is part of the prong which extends from Doe run, where it has been fully described and its probable position pointed out.) The dip in the quarries of Jac. Hayes are S. 30° E.–40° and S. 30° E.–20°.

The gneissoid mica-schist which fills the other parts of the towhship S. E. of the limestone belt dips gradually in the S. E. quadrant from 35° to 52°.

A short ridge of *serpentine* extends N. E. and S. W. from a point south of Oak Hall school-house to A. P. H. Steward's.* Its average dip is S. E., but the inclination was not accurately obtained. It is probably similar to that of the gneissoid rocks among which it occurs.

On the south side of this serpentine an opening was under

* 1¼ m. N. W. of the S. E. corner of the township.

way (Sept. 24, 1879) for the exploitation of *corundum.** No corundum was observed at this time; but amongst the refuse thrown out of the mine was mica-schists with very decided chloritic character. This and other circumstances of similar bearing raises the question whether the line of division between the light pink and dark pink should not be drawn further south, or from the lower of the two prongs of the Doe run limestone.

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40. Pocopson.

This is bounded very nearly on the north and west by the west branch of the Brandywine creek, and lies east of Newlin.

The main mass of the rocks is composed of *gneisses of the lower series* among which several detached masses of serpentine are found, all however lying in the same general belt occupied by that rock.

The exposures of gneiss in the north and north-west are not numerous, deductions as to the nature of the underlying rocks being principally from fragments which are mostly gneiss and some milk quartz.

On the State road from Mary Hoopes to Stephen Baker's there are successive outcrops of *serpentine* striking a little N. of E.

In the vicinity of Locust Grove the rocks are mica-schists and milk quartz.

Near Joshua Cloud's (¼ m. S. S. W. of Locust Grove) a serpentine dips E. 30° S.–42°.

A short distance from Pocopson school-house† another serpentine dips S. 30° E.–40°. Near here is a very striking mound to the S. W. of Stephen Darlington's tenant houses. A mound of moderate height but symmetrical shape arises out of a level field, giving the impression of an anticlinal

*Mr. G. H. Chandler, of Kennett Square, reports the finding here of chromic iron ore.—[Since Prof. Frazer's visit, a considerable quantity of corundum has been mined See page 345 at the end of this report.]

† ¼ m. S. W. of Sagerville.

mound. Slabs of rock stand on end around it like head-stones in a grave-yard. The rock is serpentine and the dip about S. 30° E.–40°.

The remainder of the township is filled with gneiss.

Near the Pocopson hotel an opening has been made for *corundum*, but with what result was not ascertained.

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41. Pennsburg.

This lies at the corner between Chester and Delaware counties and the State of Delaware.

The rocks which it contains are only of two kinds so far as known, viz: the older hornblendic gneisses and some limestone.

Limestone is found in two places.

On the Wilmington and Northern R. R. close to the Brandywine and opposite to Brinton's bridge, limestone is in-interbedded with hornblendic gneiss.

The gneiss north of it dips S. 20° E.–45° to S. 30° E.–45° and is in character sometimes syenitic and sometimes quartzose. In a large quarry opened into the side of a hill, in the north end a green and white gneiss with much quartz dips S. 30° E.–45°; following this, and lying on it, a thin bed of limestone, with the same dip; and on top of this a hornblendic gneiss also S. 30° E.–45°. In spite of the moderate inclination to the horizon there are some indications of a complete overturn, not sufficient however to justify a theory of the structure.

Opposite Chad's Ford a decomposed gneiss, in very much convoluted strata, dips S. 15° E.–71°. This dip is maintained along the Baltimore Central R. R. opposite Caleb Ring's. A short distance west of Joseph Miller's (also on the R. R.) a decomposed gneiss dips S. 20° E.–45°, and close to it was a *limestone* pit in which nothing is showing. Patrick Kelly reports this to have been an old quarry on which a house has been since built, but an examination of the débris around it failed to reveal any fragments of limestone. A little further west near the crossing of the Baltimore Central R. R. by a lane from Aaron Mendenhall's a very friable quartz sand rock occurs on both sides of the track dipping S. 30° E.–50°.

Quite a number of excavations and lime kilms are found here, which, together with the appearance of the soil, indicate the presence of *limestone*; and the probability is strong that the quartz rock to the north represents a fragment of the Potsdam, and that the entire formation is a continuation of the southern arm of the Kennett limestone belt which will be described below. It was not found possible, however, to connect the two occurrences, and they were left separated on the map.

It is not unlikely that the bottom of the narrow synclinal filled by this limestone may rise above the present surface to the west, before descending in Kennett. It may be, too, that the rocks to the south, which are very much decomposed and consist largely of feldspar and loose quartz, may represent the series so often spoken of as the *lower Potsdam*, recomposed out of the débris of the true crystalline series beneath it.

In confirmation of this view we have the *feldspar quarry* near Joseph Seal's house, south-east of these limestone pits, where large masses of pure orthoclase have been found. Some of this feldspar is very little weathered and other parts of it has been kaolinized. In the neighborhood, too, are numerous fragments of friable quartz slate and sand representing probably the second and third states of disintegration of the rock which underlies the limestone in Kennett.

A *feldspar* pit further south, near Jacob Swayne's, half a mile from the S. W. township corner, shows loosely compacted flint feldspar and mica.

Without rock in place to indicate the structure, from these facts it would seem as if the Potsdam were repeated to the south of the limestone belt; but the existence of syenitic fragments (exclusively or with some surface sand) near Fairville, and between the two feldspar pits just mentioned, points to shallow remnants of waves of Potsdam separated by areas of the lower rocks.

On the line of the State of Delaware a gneiss dips S. 30° to 40° E.–40°.

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42. *Kennett.*

This lies north of the State of Delaware and south of East Marlborough township.

Starting from Kennett Square and the Baltimore Central R. R. across the belt of limestone, one crosses a syenite ridge which has apparently caused an anticlinal. Following this one finds laminated hornblendic gneissoid rocks, which under the glass appear to be principally composed of quartz grains with some hornblend and mica, as if weathered. These may represent one of the modifications of the lower Potsdam.

At the southern edge of the township S. W. of Dixon's mill* a syenite (?) with seams of quartz, dips at the snmmit of the ridge E. 30° S.–45°, and below (a few yards) E. 30° S.–80°. At first glance the rock seems to be genuine syenite, and on first fracture shows quite large pegmatite crystals; but loose fragments resemble a re-made rock.

Just east of Kaolin P. O.† it is very difficult to determine whether the hornblendic gneisses, decomposed to clays, are mere decayed and recomposed gneissoid rocks (*i. e.*, representatives of lower Potsdam) or original crystalline rocks. After careful consideration, the latter view was adopted.

Just east of this is an exposure of quartzite and quartzose sandstone (Potsdam.)

At the crossing of the second road south of Kennett Square, near the house of John Wilson, the mica becomes broad and silvery muscovite, and the fragments along the road are chiefly milk quartz, and the soil clay and sand.

Proceeding from Kennett Square west the *limestone valley* is indicated towards Toughkenamon only by the low lying ground and the *sink holes* a little south of the road. The débris are chiefly of quartz rock—very generally milk

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*1¼ m. N. E. of S. W. township corner.

† New Garden township, near the south end of the west line of Kennett.

quartz with a few flakes of mica. The "*Toughkenamon rock*" is the decomposed gneissoid rock already described.

At John Wright's Paper mill, half a mile east of Kennett Square, a massive dyke of syenite crosses the road, striking about E. 30° N.

From Kennett Square north to Taggart's cross-roads there are no outcrops of limestone, but "sinks" occur along and south of the Street road, from Reynold's through to Pusey's quarry.

In the northern part of the borough of Kennett Square a friable thin bedded rock, consisting in the main of quartz grains with some mica strikes about N. 30° E., and dips nearly vertically.

The *Sharpless limestone quarry* lies about a mile east of Kennett Square, S. of the R. R. Those interested in limestone here assert that there is no limestone between this and the openings in Pennsbury township, near Mendenhall's. In a westerly direction however the limestone is continuous through Jos. J. Walter and Robert Lamborn's.

Sharpless' limestone is a massive rock of excellent quality, generally of light color, but occasionally tinged with blue. It produces between 7,000 and 8,000 bushels of lime per month, which at 25 bushels to the ton would make a monthly production of from 280 to 320 tons. The excavation covers in all about half an acre.

An outcrop of limestone is found in a race on Robert Lamborn's place. The lime burned with coal for agricultural purposes brings 14 cents a bushel; wood-burnt lime between 30 and 40 cents a bushel.

To resume: the geology of Kennett township is understood to commence on the north by a belt of hypozoic gneisses,* which are little illustrated by exposures in place. After these a narrow band of weathered fine-grained quartz-*conglomerate* into which it seems to pass by gradual transition. The first dips in this appear to be very steep as

*Entering Kennett Square on the the north-west the rocks observed are partly friable and feldspathic, without mica, and partly gneissoid, micaceous, and dark colored; these two varieties being close together. This might represent either the Potsdam, or the underlying crystalline series.

though *rising;* but from the character of the rock itself and the decomposed state of the surface it may well be that this belt is preceded by the gentle south dipping southern limb of the same measures in East Marlborough. This steep dip is rapidly replaced by a gentle southerly dip of 15°, just north of the railroad, after which the limestone appears dipping near the New Garden border, S. 15° W.–20°, and in the Sharpless quarries S. 30° E.–20°, giving the appearance of an anticlinal directed west of north. This eastern exposure of limestone is separated from the western by a mass of syenitic granite striking E. 30° N.

South of this, *conglomerate rock* is resumed, dipping S. 30° E.–45°, after a short intervening space filled with hornblendic gneiss with a dip of S 30° E.–23° to 45°.

South of this uneven, and there seems to be a change of dip in the latter, for an interval at least, to N. 30° W. and S. 30° E.–80° to vertical, which is impressed upon the lower edge of the quartzite mass near Gregg's mill, which strikes E. 30° N., with a vertical dip.

As the writer understands the structure, there are here—

1st. A short synclinal and anticlinal of the Potsdam in the northern part of the township, bringing to view the limestone south of Kennett Square.

2d. A dyke (?) of syenite cutting off the eastern end of this limestone.

3d. A synclinal of hornblendic gneiss in the southern part bringing to view in its axis again the Potsdam series.

Mr. G. H. Chandler, of Kennett Square (formerly one of the surveyors of the Bridgers map, which was made the base of the observations already recorded) mentions as the result of his observations that Rock rose and *Asclepius viridis* grow by preference (or, perhaps, seem to by comparison with other plants which do not) on serpentine measures. Such connections between the mineral and vegetable kingdoms are important to the *field* geologist.

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43. *New Garden.*

This lies due west of Kennett and on the border line of the State of Delaware. In passing west from Kennett along the State road one finds abundant quartzose fragments of various kinds of quartzose rocks which are without difficulty ascribed to the Potsdam. On the left (to the south) of this road and a little beyond the line of the Baltimore Central R. R. is the limestone belt, indicated however by few exposures and mostly by the topography and the sink holes.

This *limestone* belt commences to trend south from near the meridian of Cedar Spring school-house; and although the ground is still covered by quartzose fragments the rock in place is decidedly gneissoid in character as far west and at Toughkenamon, where a somewhat sandy (?) mica-schist dips S. 20° E.–62°. The *Toughkenamon rock* is psephitic sandstone composed of the weathered particles of a gneiss or syenite loosely compacted and finely laminated. It dips south just north of the Avondale limestone as was said above. The gneissoid character of the rocks north of the limestone is still more marked the further one proceeds westward until just before reaching Avondale (where the R. R. turns a little to the north and the limestone broadens very much in that direction) a blue gneiss dips E. 40° S.–37°. Just above this a sandy hornblendic gneiss dips in the same quarry both S. W. and N. W.

On the road which forms the extreme north border of this township proceeding from the east one finds fragments of milk quartz lying on convoluted gneiss throughout the limits of East Marlborough; but on arriving at that narrow strip of West Marlborough which borders New Garden a very singular phenomenon is observable. This is an apparently clear instance of the *unconformable superposition* of very much decomposed micaceous gneiss on the upturned edges of a friable quartzose laminated rock. The latter is a yellow to white rock of small grains; but, in undecomposed portions, fragments of colorless transparent crystallized quartz are found. The dip of the gneiss is ± S. ± 10°, and that of the quartzose rock ± S. E. ± 42°. Nor can the *almost horizontal gneiss* be supposed to have occupied any other position. But if this be an unconformable contact of the formations it is difficult to account for it, because the hill a very short distance east and west has the dip and characteristics of the friable sand rock; and to suppose such a structure would require the hypothesis of a very narrow tongue of the gneiss a few feet wide which had escaped erosion.

Occasional quartzite and quartzose sand rock fragments are found in the hills, but seldom in place. A dip is obtained however in this rock a few hundred yards east of the locality just described, which shows ± S. 35° E.–15°.

Either this quartzite must be ascribed to an horizon inferior to much of the crystalline rocks—gneisses—in which case it would become a Huronian rock (or even still lower), or else it must be supposed to have once covered an area much broader than that where it now is found and to have been carried off by erosion.

The latter view, as will have been long ago gathered, is that upon which the hypothesis of structure in these pages has been founded.

In conformity with this view, it would be in accordance with the belief of the author if the area between the arms of the Avondale limestone were colored in the map to denote the *Potsdam sandstone;* for, although in lithological character the rocks here have little resemblance with those of this formation, as ordinarily exhibited, the preponderance of evidence in various totally different methods of considering them is in favor of this view. The reasons for holding more strictly to the petrographic characteristics were the following:

1. The whole region is one of the extremest difficulty and complication, so that it is quite possible that the author's view may not be correct.

2. Therefore the colors on the map are made as nearly as possible so as to require the least or at all events the easiest

changes, at the hands of the next and more competent student to make them conform to nature.

3. A lithological difference will and must always remain a difference desirable to retain, and the lines separating such differences in rocks will be all important as a basis from which to establish the true lines of demarcation of the formation when those lines are clearly established.

4. If there has been any mistake in assigning boundaries to the *Potsdam sandstone* by lithological distinction this mistake has been made in the counties of which the reports have already been published, and what changes may in the future be required can be more easily described if the maps of those counties are constructed on the same principle.

5. The formation of *lower Potsdam* into a rock *resembling* feldspar-porphyry or gneiss can only occur when these rocks were the bed of the Potsdam ocean, *i. e.* in the east; which same phenomenon (of compacting its lower members out of the underlying rocks to resemble these) may have and probably did occur also in the west, where those underlying rocks were of a different character, and the resulting re-made rocks therefore also of a different appearance.

To simply include those discovered only as the result of years of observation in the east and which are pseudo-gneisses, &c., without including those in the west (York, Adams and part of Lancaster) which are most likely pseudo-chlorites and other schists, would be to introduce an irremediable element of confusion into the series of maps.

6. The attempt to mark the limits of this margin of lower Potsdam would fail in many cases owing to the highly altered and decomposed condition of the rocks, and the deep soil with which they are covered.

It will be understood therefore, that bordering the yellow color in Chester county, which denotes the siliceous portion of the Potsdam, there is a band of feldspathic and gneissoid Potsdam of variable and undefined breadth, which, while it leaves the structure of the Palœozoic series the same, contracts the area of lower crystallized rocks.

The northern part of New Garden, (that lying north of the limestone,) is of sandy gneissoid character and probably of lower Potsdam age. The dips in mica-schist with quartz, micaceous quartzite and the like, are usually S. 20° E.–30° to 62°, or almost exactly perpendicular to the axis of the limestone belt.

This *limestone belt* after passing west on the Kennett border, through the quarries of McFarlan, contracts very rapidly to a thin belt.

On the east end of McFarlan's quarry the limestone dips S. 15° E.–20°. On the west side of the quarry the dip is S. to S. 15° W.–20°. The limestone is apparently of the best quality, light blue, and highly crystalline, the strata waving very much.

South of the limestone at Toughkenamon are hornblendic gneiss dips S. 20° E.–50°, near John Gray's and on the Lamborn farm, and the same dip was noticed still nearer to the limestone and further eastward, near Joseph P. Chambers'.

Mr. Ellis Hughes, who now occupies the Lamborn farm, (1879,) says in reference to an excavation there, in which limestone was said to have been obtained, that it is the opinion of some persons that limestone was *hauled there to be found*, and that he has never discovered any trace of limestone on the farm, which has been called "hornblend," on account of the rock supposed to predominate.

But among the most interesting occurrences are found in the west side of the township, opposite Avondale, and on the left bank of the creek forming the line of London Grove township, in *Watson's building stone quarry.* The rock looks like a sandy hornblendic gneiss, with layers of quartz rock. The dip is N. W. at the upper side and S. W. at the lower, indicating an anticlinal dying down to the west.

This occurrence, which has been mentioned before, is followed by another a short distance S. W. of it and in London Grove township, but which is of importance to consider in this connection. Near John Williamson's, in the road leading south, there is a large quarry, in the northern end of which is a crystalline limestone dipping W. 10° N.–40°, and at the south end a large quarry of quartzite with a similar dip. The quartzite seems to be so placed that its strike would very nearly border the limestone which broadens north of Avondale to the north, and is an additional and strong confirmation of the distribution of the measures by color on the map.

Of course this structure would imply that the *limestone belt* from Kennett square is cut off at this point, unless in the very improbable case that the culmination of the anticlinal just sees day, i. e. just reaches the present surface, and thins out the limessone on both sides of it. Whether the belt be cut in two or not it cannot be for more than a very short distance now invisible.

The breadth of this N. W. dip of the Potsdam, which brings up again the loose gneisses south of the limestone belt, is not certain, as no satisfactory exposures were found in New Garden to determine it; but, as has been said, at less than a mile on the Delaware side of the limestone the hornblendic gneiss begins to show itself occasionally with an average dip of S. 20° E.–50°. But that there are changes of the dip not at present visible on the surface may be inferred from the position of the quartzite where first found between New Garden P. O. and Kaolin P. O. where the dip is 80°. The rotten syenitic rock with clay containing quartz S. E. of this, as for example near the corner of Kennett, New Garden, and the State of Delaware dips S. 30° E.–80°.

It is more than probable that the whole of this area including all the *kaoline mines* in the southern part of this township is of the *lower Potsdam*, like that in the townships north of the Chester valley, which contains the same deposits, of which the very existence as decomposed feld spars or clays is probably due to the loose integration of the feldspathic fragments, which has permitted waters to percolate and leach them of all their silicates except that of alumina.

This part of the township near Kaolin P. O. is filled with this *white clay* which has been expoited and produced in large quantity by the American Kaoline Co. in their pits on Broad run.

Evidences of it are traced to the Wilmington and Western R. R. which skirts a second limestone band in the extreme south of the township, and joins the Pomeroy and Delaware City R. R. at Landenberg P. O. The surface is covered with clay and quartz fragments between Kaoline and Landenberg, and where the feldspathic gneiss occurs (as it always does in this region as the rock in place) containing hornblende the dip is very gentle, the average being S. to S. 20° E.-± 10°. This is sufficient reason for the wide expanse which this part of the measures here attains.

The *limestone* is well exposed in a quarry crossed by the Delaware and Western R. R., almost immediately after it enters the county. Its dip is ±S. ±30°, which is maintained wherever quarries or other exposures bring it to view between the railroad and Broad run into London Britain township, where it will next be described.

The abrupt hills to the south of it are covered with quartz and schist fragments; and on the Delaware line, near William Walker's, by a large quantity of gravel.

The American *Kaolin* Company's pits were first opened by Hamilton Graham, 40 years ago, (1879.) It afterwards became the property of the American Kaolin Company, and were sold, in the spring of 1879, to Mr. Spencer and a partner. The property comprises 200 acres of ground. There are two large kilns. The product is shipped to potteries in New York, to Trenton, and to Ohio. About an acre has been excavated to a depth of about 50 feet. The paying bed had been lost, and shafts had been sunk, while much that might have been won was left in the ground. The price for the first quality was $14 per ton and of the second quality $5 to $6.

At Brown's *limestone* quarry, already referred to, on the east and south of New Garden township the limestone dips ±S. ±30°, and no limestone of any importance has been found south of the railroad at this point.

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44. London Britain.

This is the southernmost township in Chester county bordering on the State of Delaware; and owing to the peculiar arc of a circle which forms the northern boundary of the State, a sharp prong of this township projects downward, across Mason and Dixon's line, terminating in an acute angle, which is the point at which Pennsylvania, Delaware, and Maryland meet. This prong belongs to London Britain township.

The feldspathic and gneissoid rocks of New Garden cross London Britain by Landenburg, as does also the belt of limestone bordering Broad run. A number of quarries and exposures confirming the evidences of the existence of limestone furnished by the topographical features along this creek, enable the measures to be carried without difficulty to White Clay creek proper, and across the east branch of the same. Here two large quarries along the road about 2 miles north by east of Strickerville, give a clear idea of the structure.

At Nivin's quarry the limestone dips W. 10° N.–10° to 20° in the middle portion of the quarry, and steep at the extremities, which, compared with the south-easterly dip of the quarries in New Garden and just within the north-east border of London Britain, (which latter is ±S. ±20°,) compel one to regard the structure here as an *anticlinal of limestone*, though one of very gentle dips.

At the southernmost of the two quarries the dip in limestone is W. 10° N.–40° in a fine exposure along the road and close to Nivin's house. Here is exhibited also a large mass of porphyritic gneiss (or gneiss with large crystals of Pegmatite and Biotite) dipping W. 10° S.–30°, showing evident *unconformity*. A very short distance north round the turn in the road this feldspathic gneiss dips S. 20° E. to the south and N. 20° W. to the north indicating an anticlinal and a narrow roll in the lower rocks.

From here to the southernmost pit of this limestone belt near the house of Lewis Passmore, which was opened but neglected on account of want of funds, no exposures of limestone were found. Its existence is inferred exclusively from secondary reasons.

A mass of quartz sand rock and quartzite fragments *underlies* this limestone to the S. E. coming in from the State of Delaware where it was noticed previously as emerging from beneath *gravel deposits*.

An evident *anticlinal* in this part of the Potsdam a short distance north of Strickerville is observed in two dips, the one to the north being W. 30° N.–20°, and that to the south S. 10° E.–50°.

Another evidence of this *anticlinal* is found close by the "Passmore" limestone pit, viewed in connection with an exposure further up, on one of the feeders of the East Branch of White Clay creek. The former of these near the junction of three roads, about ¼ mile (400 meters) south of the pit, is in gneissoid sand rock dipping S. 30° E.–45°. The other in the same rock ± N. W.–30°, so that the position of *this* limestone seems perfectly clear.

The rest of the territory of this township is covered by the feldspathic gneiss rocks which are believed to belong to the *lower Potsdam* age, though it is possible that here and there a small portion of the series underlying these may reach the surface.

The dips in this area, in fact in all the measures, are in unusual and very varying directions, and the angle with the horizontal plane usually low, which proves that there has not been excessive distortion of strata here, or at least of such as are now accessible to view.

Thus on the road fork which passes about a mile (1.6 kilometers) north of Strickerville a hornblendic gneiss dips N. ± 15°, while about the same distance north of this, near the house of Edgar Smith, a decomposed hornblendic gneiss shows its stratigraphical relationship to the rocks above the Nivin's limestone quarry (from which it is distant) but about half a mile (800 meters) by a dip of W. 20° S.–15°.

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45. Franklin.

This lies west of London Britain and on the northern edge of the State of Maryland. Its soil is dark rich red and fertile, and except on the borders of London Britain it gives little or no evidence of the existence of the doubtful series (taken to represent the *lower Potsdam*) further west than Kimbleville. Up to this rather indefinite boundary line, however, there are found quantities of low quartzose rock strewn over the clays and feldspathic gneisses just described.

The western half of the township or that portion west of a line drawn somewhere near from Chesterville P. O. to Kimbleville is believed to represent the genuine hypozoic gneisses of Rogers which are so frequent in Delaware county and State. It is interesting to remark that Prof. Rogers, while he covered the greater part of the area supposed to belong to this age in York, Lancaster, and Chester with his yellow of "altered Primal" or "Primal," excepts from this color precisely that portion along the curved boundary of the State of Delaware which it has been the object of the above pages to show the author's reasons for considering to be really Primal.

The *real* feldspathic and hornblendic gneisses which are exposed in this township have suffered also a very considerable erosion, which must be a sufficient reason for not representing the dividing lines between them and their secondary limitations more sharply.

Clays and fragments of crystalline rocks fill the road from Strickerville west, without exposures, until near the house of William Ritter the gneiss dips ± S. 45° E.–45°, a dip repeated near the house of R. K. Whitcraft.

On the road leading west from Kimbleville the strata are completely decomposed to clay, in which latter material near Mt. Olivet Church a dip of S. 20° E.–35° is found.

Kimbleville itself and the road east from it are covered with loose quartz fragments with no extensive exhibition of clay, the surface being covered by small fragments and sand.

N. W. of Kimbleville, near Mrs. Susan Furey's, a hornblendic gneiss dips ± S. E.–45°.

On the road to Chesterville the same materials—gneiss and clays—are followed across the west branch of White Clay creek where they dip ± S. E. ± 40°.

East of Chesterville P. O. on the middle branch of White Clay creek the same measures dip S. 35° E.–50°.

Beyond this stream they seem to dip about S. 45° W. but the observation is not important enough in itself in this region where the twisting is so general and the dips comparatively gentle to act as the basis of any change in the general hypothesis of a *northeast strike* to the rocks.

The same features are noticed to the junction of this township with London Grove and New Garden.

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46. London Grove.

This lies north of Franklin and west of New Garden.

The north-west part of the township (bounded very nearly by the Baltimore Central and Pomeroy and Delaware City R. Rs. which cross at Avondale) seems to be composed of mica-schists resembling in character those in and south of the South Valley Hill; but the surface is much covered with quartz fragments, as if it once had been the resting place of the silicious members of the Potsdam.

The northern border and the upper eastern border have been very fully considered on pages 304, 308, (West and East Marlborough) including the curious stratigraphical appearance in London Grove P. O. and its probable explanation.

The reasons which avail for considering the northern border east of Woodville and west of Woodville to lie in different formations, or at least separate and distinct parts of the same formation, have also been given; but it remains to give an account of the disposition of the measures between the Potsdam which appears south of Doe Run and the hypozoic gneiss which stretches north out of Franklin. As to the former the reasons for considering it in reality as *lower Potsdam* have already been given.

In the N. W. corner of the township the mica-schists dip N. 30° W.–80°. Milk quartz fragments are as usual frequently found among the surface débris, but none in the bedded rock. These mica-schists, with such a very different dip from the gneisses, quartzites and limestones, seem to occupy a space running approximately from the curve in the Pom. and Del. C. R. R. near Mifflin Baker's to the crossing of the township line by the head waters of White Clay creek.

The area above the stream as far south as Chatham, and as far east as Woodville, consists of gneisses which show no element of structure, but which are decayed representatives of the true gneisses and doubtless belong to the lower Potsdam.

The silicous or *upper Potsdam* is exceedingly well shown in the N. E. corner of the township where it enters with a dip of S. 25° E.–35°, the rock being very hard and white and composed of small but well-founded quartz grains.

Numerous dips of ± S. 30° E.–25° are found along the road leading east from Chatham, so that, with the dip in the quartzite a short distance N. E. of that town of S. 40° E.-45° (in actual contact with the underlying pseudo gneiss ?) there is little doubt that the structure suggested is the correct structure.

The *limestone* enters the N. E. boundary line across the strip of West Marlborough often before referred to, which extends as a rectangle southward from the main body of the township of which it forms a part. It is noticed in quarries near Harvey's, Lewis', and Benjamin W. Swayne's, at which latter place, close to the N. W. corner of New Garden, dips of S. 20° E.–15° and S. 6° E.–15° were obtained in the quartzose sand rock above it. The limestone in this quarry is full of quartz and powdery.* The dip changes so abruptly as to give the appearance of a non-conformity.

**Analysis of dolomitic limestone*, from Benjamin Swayne's quarry, London Grove township. The sample was sent to the laboratory in Harrisburg, by Prof. Frazer, and analysed by Mr. A. S. McCreath:

Carbonate of lime,	54.071
Carbonate of magnesia,	43.309
Oxide of iron and alumina,	.613
Sulphur,	.013
Phosphorus,	.003
Silicious matter,	1.950
	99.959

Coarse grained; crumbling; slightly brownish grey. See report MM, p. 79.

From here the south-trending township line is very nearly the eastern edge of the limestone, down to Avondale. A dip a few hundred yards S. E. of Hicks' mill in a sandy limestone give W. 20° S.–70°. Evidences of limestone are abundant westward, by Baker's quarry, to the large quarry near Levis Bernard's; beyond this no trace of it is found, the rocks replacing it being more or less chloritic mica-schists. The dip here in the quarry averages S. 20° E.–10° to 20°.

This is a very important locality which it must be confessed lends weight to the hypothesis of the relationships of these beds defended by Mr. Charles Hall.*

The large West Grove limestone quarry, near the house of Mr. Henry Storey, is situated about ¾ mile (1.2 kilometers) south of the Bernard quarry, the interval being occupied by a hill of one or two hundred feet in heigth, in which the chloritic mica-schists lie almost flat, or with very small angles of dip.

These schists seem to be similar to those in and below the South Valley hill.

The West Grove limestone which is white and crystalline, like that of the Bernard quarry, dips on the north exposed face W. 40° N.–65°, while the Bernard quarry dips S. 20° E.–10°.

Without some change of structure, which surface indications offer no right to suppose, there is here a *limestone synclinal* holding a hill of chloritic mica-schists.

On the south side of the West Grove quarry the dip is S. 30 E.–30°, showing that it has been opened on an *anticlinal* which however is of very insignicant breadth, as the sand rock (Potsdam) curves in a few hundred yards below it with a dip of W. 10° N. raising the calcareous beds beyond our present surface.

The chloritic mica-schists which extend for a short distance below the R. R. to Avondale are for the same reason *below* the quartzose rock, yet they are difficult to distinguish lithologically from the series that interposes between West Grove and Bernard's. If it were not for this circumstance

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* See chapter 2.

the attempt to show the possibility of another explanation than that of Mr. Hall would be an embarrassing one. But it seems to stand proven here that two series of very different age are nevertheless of nearly identical composition.

To represent these facts on the map would require the hydro-mica-schist color to be spread over a small area lying within the westward extending horns of the Avondale limestone; while the light pink, indicating the lower Cambrian or sub-Palæozoic, would be retained for that narrow belt south of the R. R. between West Grove and Avondale.

It may be as well here to complete the sequence of rocks to the south before taking up one other special point in connection with the geological structure at Avondale.

South of the State road and crossing the township from New London to New Garden the rocks belonging to the old metamorphic series are represented by original gneisses, and have dips generally in the N. W. quadrant and gentle; until a point near the S. E. corner of the township is reached, when the dip is about S. 20° E.–52°, showing this southern part of London Grove township to be composed of a low *anticlinal* of lower rocks.

Just west of the R. R. at the north end of Avondale a rotten quartzose gneiss dips S. 30° E.–40°, and appears to lie *unconformably* on a massive quartzite containing mica, which, if the main visible plane may be taken for one of bedding, dips N. 30° W.–70°. This occurrence reminds one of a similar one described on the boundary road between New Garden and West Marlborough.

A stone quarry has also been noticed a little west of south of Avondale showing *limestone* to the north and *quartzite* to the south.

This is the only place observed in this county where the stratigraphical evidence of the rock was confirmed by the occurrence of *fossils*. The white arenaceous rock on the southern end of the quarry dips W. 20° N., W. 10° N. to W. 10° S. with a dip of about 28°, which places it clearly below the limestone. In this quartzite were found evident traces of *Scolithus linearis*, which though perhaps not sufficient evidence to decide the age of the rock as Potsdam, is nevertheless strong confirmatory evidence.

The valley from Hughes' limestone quarry (Avondale) to West Grove, in which the R. R. is built, is said not to contain limestone, though it has the appearance of being underlain by that rock. According to the inhabitants the limestone leaves the R. R. at about the old switch and strikes west. About a quarter of a mile east of West Grove road and west of the R. R. the quartzite (in fragments and in masses looking as if in place) is pink and white without admixture of mica.

A large *iron ore* bank (not in operation) lies on the N. W. border between Penn and London Grove, on the middle branch of White Clay creek.

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47. *Londonderry.*

This lies west of West Marlborough and N. W. of London Grove. Exposures are extremely rare but the rocks, with the fragments of which its surface are covered, are the products of the decomposition of the chloritic mica-schists, among which a number of quartz débris are found. *Clays* abound but generally not of that peculiar variegated and plastic variety which results from the disintegration of the feldspathic older crystallized measures and their secondary derivatives. The land is very high in the middle of the township (near Daleville or Londonderry P. O.) and has been chosen for one of the U. S. Coast Survey triangulation signals.

This summit, from which small streams flow in all directions, is principally composed of the lighter and less chloritic mica-schists in which sand and clay are occasionally found. The mica of the strata dividing the township from N. E. to S. W. is generally more silvery than the rocks of the rest of the township. Some *manganiferous* layers of the more chloritic schists are found near the White Horse hotel. The dip of these measures where observed in the N. W. of the township was generally S. 20° to 30° E.–48°.

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48. Highland.

This lies south of Sadsbury and the Chester valley and west of East Fallowfield and West Marlborough. It is also like Londonderry entirely composed of the mica-schist series; but contains in its upper portions more exposures of rock in place.

A compact chloritic mica-schist in the N. W. corner of the township dips S. 15° E.–70°, but the dip is not maintained with this angle towards the middle, where the less chloritic measures dip ± S. 10° E.–40° and S.–53°.

Further east near a turn in the road by Daniel Ramsey's house there is a dip of ± N. 15° W.–20°; but this is purely local, as can be seen about quarter of a mile further east, just south of the Stottville hotel, where a number of fine exposures in a cut bordering Buck run dip S. to S. 20° E.–80°.

The soil in passing south is of much redder character than is usual from the decomposition of the lean slate-like schists, even when they contain iron-ore, an appearance due without doubt to the existence of more iron holding minerals (of the amphoterolite order.)

The high south dip is maintained by the chloritic measures on the western edge of the township down to the Fairview school-house, just above which place an exposure gives S. 20° E.–70°.

In this portion of the county the country for miles shows no exposure of rock in place, and but few fragments larger than those which compose sand and dust—(or mud according to the weather.) The principal fragments, as is easy to guess, are quartzes, which from their greater resisting power to decomposition have accumulated on the surface during its gradual degradation, so that they present now to the eye a quantity out of all proportion to their true relative importance compared to the other rocks. The same is true in West Marlborough from Doe run to the White Horse. Occasionally a few fragments of chlorite are seen, and there are sometimes small crystals of mica glinting on the road;

but nothing of sufficient importance to permit of more than a guess as to the underlying formation.

Two hundred yards S. W. of the Gum Tree tavern a heavy bed of very much convoluted chloritic mica-schist enclosing milk quartz dips S. 15° E.–40°.

The chlorite is not apparent in much of this rock, which is judged to belong in the same series with it on other grounds. The texture of the two classes of rocks making this body is alike as to convolution, and the quartz enclosures are also similar. On a simple difference of the micaceous constituent no general geological conclusions can be drawn.

A short distance S. W. of the Gum Tree a chloritic schist dips S. 20° E.–40°. The fragments here are much more gneissoid in character and their feldspar in greater abundance. As a consequence the clays are more frequent.

Very near Rosenvick in the S. E. corner of the township a bluish schist containing chlorite dips W. 30° N.–20°.

Quite a number of fragments of blue crystalline *limestone* were found by the roadside near Mr. J. G. Hartshorne's residence, but as there was nothing to show the existence of this rock in place they were not regarded as indigenous.

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49. West Fallowfield.

This lies south of Sadsbury and West of Highland, its western boundary being the Octoraro creek which separates Lancaster from Chester county.

The northern part of the township shows no difference between the rock on the right and left banks of the Octoraro. The rocks are mica-schists with more or less chlorite increasing in this mineral towards Highland township. The dips below the Valley Hill are S. 10° to 20° E.–60° to vertical. The surface has occasional patches of sand but little clay in this part. It ought to be mentioned that on the road which leads N. E. from the Ringwood Forge, and about quarter of a mile before reaching the first cross-road, an exceptionally fine view is obtained of the valley of the Octoraro from very high ground. The dip in the same mica-schists just above Steeleville is about S. 10° E.-85° close to the Octoraro. Further to the east there are no exposures, but only fragments of schists with broad faces, and clays. At a point where the road N. E. from Steeleville is intersected by the lane from Pennock Harvey's house rounded sandstone pebbles represent *a drift area* apparently similar to those indicated in Lancaster county.

The dips which are principally observable along the Octoraro continue to be S. and S. 10° E. ± 85° below Steeleville, where the lithological character of the rock changes and becomes more chloritic; one dip in this modified mica-schist appears to be ± S. 45° E. This more chloritic belt is noticed across half the breadth of the township.

The continuation of this belt in strike would probably join it to that isolated chloritic area of which the N. E. terminus was left undefined from a lack of sufficient data to fix it with preciseness; and it is very probable that the direction of the extension of this belt is the cause of the marked chloritic character already mentioned in the mica-schists bordering the Chester valley limestone (on the south) in the townships lying further east.

An opposite change takes place in the rocks on the eastern border, at this latitude, which clearly is the result of a more chloritic belt passing across the township from S. W. to N. E.

A dip in this less chloritic belt as high up as David Baird's house gives ± S. 25° E.-± 80°, and a similar posture is noticed, wherever observations could be made, as far south as Cochranville. Here the soil is composed of light sand and clay with much quartz.

About half a mile south of the village the chloritic series again dips S. 45° E.-65°, and from here to the S. E. corner, where Londonderry and Upper Oxford meet, the appearance is only changed by a greater or less amount of superficial quartz fragments.

From Cochranville due west the chloritic rocks are conspicuous by their *absence* up to a point a little west of the

Central school-house, where the belt to the north just mentioned about reaches.

A sandy mica-schist near Nancy Fleming's house on the S. W. township line, dips S. 30° E.–60°.

The chloritic zone *below* Cochranville stretches out as far as Glennville, where a dip of S. 30° E.–60° agrees so closely with that of the unchloritic rock further west just mentioned that no separation between them in structure seems possible, and the impression becomes more and more confirmed that these *are contemporaneous deposits with the mica-schists above and below them, and that their different texture is simply the result of local or temporary differences of the materials which were laid down by the water as sediments.*

There is a seeming vestige of an anticlinal in unchloritic schist on a road west of Poplar Grove school-house, where the dip changes from 20° to 80° at least in appearance. The value of this isolated observation, in a region where exposures are so rare may however be called in question.

The lower portions of the township exhibit débris of green and yellowish green mich-schists and clays bright with loose mica flakes.

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50. Upper Oxford.

This lies south of West Fallowfield and also on the Lancaster county border, which is formed by the Octoraro.

The rocks are entirely mica-schists and mostly chloritic. A short distance east of Andrew's bridge the chloritic schist dips E. 10° S.–40°. On the west edge of Homeville, S. 30° E.–50°. Near the store in the town there seems to be an anticlinal, the chloritic schist dipping ±N. 25° W.–80°, and just east of it ±S. 25° W.–85°. It may be, however, a simple wave in the southward descending strata.

The chloritic character of the rocks ceases to be so prominent, passing eastward beyond the Somerset school-house, the fragments being chiefly mixed with the other series, and some quartz. Just east of this, near Joseph P. Walton's, is very commanding ground. The soil consists of mica-schist fragments and clay on the straight road south of east beyond Russellville, the quartz fragments increasing from the first fork in the road to the Penn's Grove school-house.

North-east from Russellville, on the Street road, the rocks are chloritic to Fagg's manor, about 300 yards from which a very much weathered clay slate dips E. 20° S.–60°.

The chloritic character lasts along the eastern border from Fogg's manor about to Ferdinand Wood's house, where the mica-schist decayed to pink clays seems to have lost its chloritic character. A dip here gives S. 10° E. for direction and a moderate angle, probably. From here to the border near to Elk View station and Lincoln University the chloritic character is maintained, but no elements of structure were observed.

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51. Lower Oxford.

This is south of Upper Oxford and borders the Octoraro. Its rocks are all mica-schists generally chloritic.

From Worth's bridge on the Lancaster county line to the S. E. a succession of exposures show, in chloritic measures, S. 30° E.–50° to 60°. Near Wiley's mills there is little but clay visible and the dearth of exposures lasts all the way to the town of Oxford. On the Jennerville road (east) the same may be said to be true, with the insignificant difference that there are found occasionally quartz fragments (and cholerite fragments near Mr. Thomas McAllister's house.) Between Oxford and the borough of Hopewell the exposures are few, but the character is that given above, a *micaceous* mica-schist with the cleavage planes of this mineral everywhere predominating. The color is greenish and the "habit" of the rocks often chloritic.

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52. Penn.

This is east of Upper Oxford, south of Londonderry, and west of London Grove.

The northern portion lies in the mica-schists, which are of the character just described, though perhaps less chloritic.

An exposure of decayed material on its northern border shows a dip of S. 20° E.–76°.

The surface is very much covered with débris of quartzite and quartz sandstone fragments, with the usual clays now and then recurring. The *iron ore mine* on its N. E. border has been referred to in the description of London Grove township. A dip in sandy *red clay*, on the Cochranville road, north of Jennerville, dips E. 10° S.–35°. The soil is richer and redder east of Jennerville in consequence of the comminution of the chloritic rocks; but east of the town the chlorites show a dip of ±S. 15° E.–±50°.

South of Jennerville, between the east and west road on which it is built and the Baltimore Central R. R., the formation seems to change to that of the gneissoid and feldspathic rocks; but nowhere was it found practicable to test the underlying rocks or their structure by observations of strata in place. Here again *red clays* and quartz fragments covered the ground, and the change was inferred rather than established from the change of appearance of the soil.

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53. New London.

This is south of Penn and west of Franklin. The character of the whole surface of this township is similar to that just described as the southern part of Penn. Fragments of gneissoid rock mingled with fragments of quartz and deep red and brown clays cover the entire northern portion.

Decomposed quartzose gneiss about half a mile N. W. of New London P. O. dips S. 30° E.–45°, and above it is an apparent quartzite with the same dip. That this may be a very small remnant of the Potsdam lying with *apparent conformity* on the lower gneisses is rendered quite possible by the fact that in the town of New London a number of dips in these latter are visible showing N. 30° W.–45°; ± N. 45° W.–85°; and W. 20° N.–85°. If it be true therefore that the Potsdam comes down to the present surface here, it makes but a very small area. From here the soil is light and sandy from smaller quartz fragments which have probably been transported from the north to their present position.

The character of the gneiss becomes more micaceous and the faces of mica broaden in going south from Elkdale P. O. south along the east branch of Elk creek to the Papermill. Here the planes of *mica* are very large indeed.

A dip in convoluted gneiss near Robert A. Crowl's is S. ±30°.

This increase in the size and importance of the *mica*, which continues to the covered bridge near the Spring Law paper-mill, is probably connected with the development of this mineral to great size and purity in Delaware, where it has been and is yet produced for commerce with profit.

An *anticlinal* occurs just north of the covered bridge in these measures, the northern limb dipping N. 30° W. and the southern S. 30° E.–15°.

Near the junction of the east and west branches of Elk creek a broad lustrous mica-schist in a small flat anticlinal or roll of E. 20° S.– and W. 20° N. The edges of these schists are covered with a white efflorescence.

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54. East Nottingham.

This lies south of Lower Oxford, west of New London and Elk, and on the Maryland (Mason and Dixon's) line.

The borough of Oxford is partly in this township and partly in Lower Oxford. Proceeding from the town S. W. there is a rock resembling a quartzite, and composed of quartz fragments or pebbles, of which the apparent dip is ± S. E.–gentle; but close by this locality are the variegated clay slates, which dip nearly south.

These chloritic schists cover the lower end of the borough of Hopewell, and extend along the small feeder of the Octoraro creek which forms the township line (S. E.) and down the head waters of North-east creek to Stubb's blacksmith shop, where it passes into the serpentine mass shortly to be described.

From this point north-eastward along the straight road to Elkdale there is nothing but fragments (in which chloritic character prevails) to mark the formation, as far as R. J. Robison's a mile S. W. of Elkdale. The mica is light colored with dark streaks and seams, and in this respect differs from that observed on the true gneiss micas.

This character of the surface débris may be said to characterize all that part of the township lying within the boundaries of it described. At New Prospect the surface débris contains more gneiss fragments and more quartz, but this is all, and it is not enough to require a different interpretation of its sub-stratum.

Near McHenry's paper-mill* this character changes to that of feldspathic and quartzose gneiss which seems to dip very slightly S. 20° E.–15°. This rock resembles that described already both in the northern and in the southern parts of the county. Very much this character is observed N. E. to the township border line including Elkdale P. O. and due south to the junction of the township with Elk, west of Hickory hill. All to the east of the line thus roughly described (and indeed only approximately determined) appears to share the character of the primordial series ; and all west of it that of the mica-schists, with the exception of a narrow strip in the extreme south, which seems to separate the two great masses of serpentine.

The easternmost serpentine mass is bounded roughly by a line which crosses the East Nottingham-Elk border near Robert Cohan's, and nearly conforming to the direction of (though including) the road which leads to Margaret Sullivan's ; turns east and re-enters into Elk township just below the Methodist meeting-house.

From here westward there is a narrow space of a few hundred yards between two branches of a southwardly flowing stream. This space is filled by a tongue of gneiss reaching up from the south and extending about a mile north of here, but widening east and west on the Maryland line.

The eastern point of another and larger mass of serpentine is found at Chrome P. O.

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* On Big Elk creek a mile south of Elkdale.

Its northern edge crosses the stream which separates East and West Nottingham.

Its southern edge runs almost west from Fairview school-house, bending gradually south without meeting the Maryland border, until far inside of West Nottingham township.

Near Passmore's house (Fairview school-house) the rock fragments seem to have belonged to a dyke of syenite.

The rocks become more hornblendic from here on towards the south-east.

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55. *Elk.*

This lies south of East Nottingham and New London and west of Franklin townships, on the Maryland line. Entering Elk township from the west, south of Barren Branch run, the road runs nearly parallel to the Maryland line, though trending slightly to the south. The fields to the south of this road seem to be of the usual fertility, while the barreness of those north of the road is striking.

The *serpentine* southern boundary line crosses this road a short distance from the township line. Just west of the store at Rodgers' mill-dam* the rock fragments become more and more those of coarse mica-schist, the characteristic mineral being of a silvery white color. S. E. of the store by the mill the rocks are clay slates, with much mica. South of this point is one of the Isaac Tyson excavations. At the mill a broad crystallized mica-schist dips uniformly S. 10° to S. 30° E.-±45°.

On the south bank of the Big Elk, about half a mile from Bullock's Fording, large bowlders of granitic gneiss with pink feldspar abound. The dip of the strata from which these came, is probably south very gentle, but this is not certain.

This granitic character is observable in the northern part of the township as well. Thus on the road from Randolph & Arthur's paper-mill, through Peacedale, (Hickory Hill P. O.,) both the mica and feldspar are of brownish color,

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***A mile south of Hickory Hill P. O.**

and the rock is very compact. A dip in Peacedale gives ±S. E.±45°, and one at Buena Vista school-house, to the west, about the same.

The lower measures roll here as in the townships further east, as is shown by the dips in micaceous gneiss near Mrs. Sarah Nutt's, and east of Lewisville P. O., which are from W. 30° N. to N. W.–45°.

In the middle of the township, on Little Elk creek, the counterpart to this is found in dips ranging from S. 10° E. to S. 45° E., in direction, and from 30° to 60°.

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56. West Nottingham.

This lies in the extreme south-western corner of Chester county having part of the State of Maryland for its southern, and part of Lancaster county for its western boundary.

The entire northern part of this township is filled by the mica-schists which unite over the Lower Oxford and the East Nottingham border. South of Nottingham P. O. the road is filled with *reddish sand;* as it is also for a mile or more N. E. Here are also fragments of quartzite and also some of a dull earthy *serpentine* containing attached particles of *magnetite.* There are also weathered clay slates in place, but so destroyed that no reliable dip is obtainable. Milk quartz and quartz fragments are profusely scattered.

At the cross-roads about half a mile west of Nottingham P. O. an excavation for a cellar has thrown out large masses of chloritic schists which are properly considered by some of the most intelligent residents to form the main part of the whole region north. A dip in these mica-schists on the Christiana road gives S. 40° E.–40°.

Just across the run south of Ellwood Chambers* the slaty *serpentine* dips S. 30° E.–5°. An opening into the massive rock revealed *magnetite*, and the purple colors often seen in this formation. The dip here seems to be ± E. 20° S.–± 10°.

The mass of the *serpentine* south of Ellwood Chambers

*A mile S. E. of Fremont P. O.

dips in numerous exposures S. 20° E.–5° to 20°. Its shape is that of a belt, over a mile in breadth, of which the lower edge intersects the Maryland line obliquely, leaving the eastern extremity entirely in Pennsylvania. Its upper border is a curiously waving line, which joins the Lancaster serpentine across the Octoraro, trending slightly south of west. It is necessary to say perhaps that this serpentine is richer in magnetite and chromic iron, and poorer for building stone, than that further east has been found to be; and from this cause the name of the celebrated Baltimore firm which manufactures these minerals (I. Tyson, Sons) is found scattered along this belt as far as Wood's mine, which was described in the report on Lancaster county.

A chloritic schist near Freemont P. O. dips W. 20° N.–50° and from here S. W. the chloritic character becomes stronger. Near Mrs. Louisa Cooper's the dip is E. 30° S.–60°, and a strongly chloritic rock over the border in Lancaster county just above Wood's mine dips S. 20° W.–55°. The increase in chloritic character in the measures as we approach the zone of serpentine, and the bearing that this may have on a correct interpretation of the genesis of these rocks, has already been alluded to in the consideration of these questions in the Lancaster county report, and need not be dwelt upon here. It is sufficient to remind one that if the everywhere sedimentary appearance of this formation renders the explanation of it by igneous action difficult, the presence of hydrated silicates of magnesia in both serpentine and chlorite, and their juxtaposition, seem to be in some way connected, as results of the same cause.

It is not pretended, however, that the assignment of the proper structure to the serpentine is an easy task, or that the most or the best of it has yet been spoken in this problem. A series of twenty-five specimens representing the crystallized rocks of Chester county was carefully selected and their sections made. The study of them will be taken up at a future time.

Notes on the Serpentine beds of Chester and Delaware counties, with their associated minerals, Corundum, Chrome, &c. By Col. Joseph Willcox.

As the Serpentine rocks are very abundant in Chester and Delaware counties; and as some important minerals are associated with them, I have considered it desirable to publish some information about them, in addition to what Mr. Hall has written.

The origin of these rocks in Pennsylvania has not been satisfactorily determined. Though probably eroded to a considerable extent, they still exist in great thickness, having been penetrated to the depth of 700 feet, at the chrome mines in Lancaster county.

At some localities serpentine has resulted from the alteration of other rocks. Among the Laurentian rocks in northern New York and Canada, it is quite common to see pyroxene, tremolite and scapolite altered into steatite and serpentine; the two latter being nearly similar in composition. Wherever the granitic rocks, in that district, are found in conjunction with the white crystalline limestone, the surfaces of the former are frequently covered with crystals of various minerals, chiefly mica, feldspar, scapolite, pyroxene, hornblende, tremolite and apatite; more or less abundantly, as these minerals may happen to prevail in the rocks near the limestone. Several species of these crystals are sometimes found to be altered into serpentine and steatite; and the alteration occasionally extends into the rock masses. I have witnessed this in the cases of pyroxene, tremolite and scapolite; the forms of the crystals determining the character of the original species.

Serpentine is now used extensively for building purposes, and it is acquiring popularity on account of its color, and its softness, which permits it to be easily chiseled or sawed into blocks and other desirable forms.

On account of its light weight, it is easily handled and transported. Its softness has sometimes excited a suspicion in regard to its durability. The proofs of its endurance are abundant. The walls of houses in Chester county, built with this stone, during the last century, manifest no indication of erosion or decay ; and in that respect it is superior to marble. In northern New York and Canada serpentine is often mixed with the white limestone, the surfaces of which are abundantly exposed to view, above the level of the ground. The limestone is eroded so much more rapidly than the serpentine, that the latter always projects, in relief, beyond the surface of the former. This feature is very conspicuous along the Ottawa river, at Calumet Island, about 75 miles above Ottawa City, where masses of serpentine as large as a barrel may be seen, that have been eroded from the limestone. At that place the serpentine is often covered with small crystals of the same substance ; and their presence there proves the absence of any erosion or disintegration of the serpentine.

Among the products resulting from the decomposition of serpentine rocks in Chester and Delaware counties cellular quartz and limonite may be classed as the most abundant. These minerals may often be seen in the different stages of alteration, and in various degrees of combination, from limonite to pure quartz. The cellular quartz, locally called honey-comb rock, is nearly always ferruginous ; and it is a common, if not a constant, associate of the serpentine. It often occurs in inconvenient profusion ; and, in many cases, it is the only surface indication of the proximity of serpentine rocks ; the latter, near the surface, having been decomposed into soil.

Ferruginous, cellular quartz. similar in appearance to the Delaware county rocks, accompanies the crysolite beds among the mountains in western North Carolina. It so forcibly resembles in appearance the superficial gossan at the Ducktown copper mines in Polk county, Tennessee, that many prospecting pits and trenches have been dug in North Carolina for copper ore where the ferruginous quartz occurs ; the latter having been mistaken for gossan.

Limonite has been mined at several localities in Middletown township, in Delaware county, in the serpentine beds ; but not with profitable results.

The soil on the serpentine beds is naturally poor, except in cases where earth, resulting from the disintegration of better rocks, has been transported by water and wind upon them. From this cause much land of fair quality is found overlying the serpentine beds.

Though it is a well known fact, that, by the action of water, both in a liquid and congealed condition, Canada and portions of our northern States have been deprived of a large amount of their rich soil, which has been transported to other districts further south, the limits of which are well defined; little consideration has been given by the farmers to the fact that there has been, almost everywhere, and will be, in the future, much interchange of soil between farms, by the action of wind and water, especially on the slopes of hills. It is usually a slow process; but the operations of Nature generally proceed slowly, and much may thus be accomplished in a long period of time.

The amount of dust that settles upon one place during a windy day, in dry weather, is quite appreciable; and the owner of a poor farm is benefited, at least in a small degree, each year, if he has neighbors owning rich land.

Chromic iron is more or less abundantly distributed among the serpentine rocks. By the decomposition of these rocks a large amount of this ore has been liberated, chiefly in small crystals, which has been transported to the valleys below, and deposited in the gravel. A considerable amount of it has been washed out in Middletown, Delaware county, and sold. An analysis of it, made by Prof. F. A. Genth, may be seen in Report B, 1874.

Corundum is one of the most interesting, as well as valuable minerals, found in connection with serpentine.

Until 1870, when corundum was found in considerable quantity, and of great beauty, in North Carolina, the crystals of that mineral, from Chester and Delaware counties, were much prized by mineralogists in this country and in Europe.

In Delaware county fine crystals of this mineral have been found on several farms in Middletown township; and a few hundred pounds were mined on the farm of Castor Grey, one half mile south of the Black Horse hotel. It is associated in Delaware county chiefly with feldspar (probably albite) and sometimes sparingly with chlorite.

In Newlin, near Unionville, in Chester county, corundum has been found more abundantly.

The extent of the serpentine bed, at this place, exceeds 100 acres. Corundum has been obtained in many places there, and fine crystals were found during many years before its commercial value was known. Many large lumps were formerly lying on the surface of the ground, and vain efforts were made to drill holes in them for the purpose of blasting them. A final disposition was made of them by digging holes near them, in which they were buried deeply enough to cause no interference to the plow.

From my friend, Mr. William W. Jefferis of West Chester, I have obtained the following history concerning this interesting locality :

"John and Joel Bailey claim to have discovered corundum at that place sometime between the years 1822 and 1825. The former person still preserves the original specimens. About that time William Jackson also obtained specimens."

"Dr. Thomas Seal, of Unionville, also a collector of minerals, obtained specimens of corundum there about the year 1832."

Mr. Jefferis states that his first visit to the locality was made in 1837 or 1838, and at that time large lumps of corundum could be seen in the fields and fence corners. "In 1848 Mr. Lewis W. Williams sent to Liverpool a large lump of the mineral, which weighed more than 5,200 pounds."

"In the spring of 1866 John Leslie dug up about five tons of corundum, which he sold for $60 per ton."

Soon after that time the mineral was in great demand for certain purposes, being much harder than emery, and the price advanced to 50 cents per pound.

In 1872, John H. Smedley, while engaged in exploring for corundum, on the farm of Messrs. Pusey, Ball & Chandler, discovered a large mass of it, which weighed about 200 tons. It was found on the margin of the serpentine bed against a wall of gneiss-rock on the north side. On the other sides were serpentine and chlorite. Some portions of the corundum were largely mixed with margarite, damourite and lesleyite. In addition to these minerals, the corundum, found at other places in Newlin, is associated with albite, tourmaline, and spinel. At the various localities, where corundum is found in North Carolina, some of these minerals are always associated with it. This is the case, at least, at the 6 localities that I have visited there.

Corundum is still mined, to a small extent, in Newlin.

Feldspar is another mineral often associated with serpentine. It possesses some importance, as it is extensively consumed in the manufacture of chinaware and artifical teeth.

It has been mined in Delaware county, at Mineral Hill, in Middletown; on the farm of Joel Sharpless, in the same township; on the farm of Thomas Johnston, and the adjoining farm in Concord; and more extensively in New Castle county, in Delaware, near Chandler's Hollow, two and one half miles south-west of T. Johnston's mine. It has also been mined near the corundum locality in Newlin, in Chester county.

A large amount of feldspar has been mined at Dixon's and Way's quarries, in New Castle county, in Delaware. All of these mines are connected with the serpentine. They are either on the bed or on the margin of it or south-west of an outcrop of it, in the line of its prolongation, as at Johnston's, in Concord, and near Chandler's Hollow, in Delaware, a short distance from the State line.

In all these mines the feldspar is accompanied largely with quartz, but sparingly with mica, except in the cases of the quarries near Chandler's Hollow and on the farm of Joel Sharpless, where muscovite mica is found in large plates; but it is so much stained with black lines of magnetite as to be without value.

Asbestos is also an associate of serpentine. It has been mined on the farm of Jacob Sides, in Aston, Delaware county, and also in Upper Providence, where it exists in great abundance.

Steatite, or soapstone, also an associate of serpentine, is found in Marple and Aston, in Delaware county, but it has not been mined.

Among other minerals of less importance found with the serpentine in Pennsylvania, I will mention brucite, picrolite, bronzite, enstatite, anthophyllite, actinolite, talc, and chlorite in many varieties, the most beautiful of which are clinochlore and ripidolite.

In 1879, Messrs. Herman, Behr & Co. commenced to mine granular garnet rock on Green's creek, near Chelsea, in Delaware county. About 400 tons of this rock have been mined at this date. It is used in the manufacture of sand paper, being much superior to quartz in hardness.

This garnet rock was first discovered by John H. Smedley, to whom the credit is due of finding more localities of minerals in Delaware county than to any other man. A considerable amount of muscovite mica has been mined on the farm of Jacob Swayne, near Fairville, in Chester county. In that mine the largest crystals of mica, of that species, were found, which I have ever seen.

JOSEPH WILLCOX.

December 13, 1882.

It is evident that the *corundum* in Newlin township, Chester county, is a metamorphosed part of the gneiss composed more exclusively of alumina than the rest.

Pure corundum is simply pure alumina; but it is perhaps never found quite pure in nature, and it often contains notable percentages of silica and iron, with more than mere traces of lime and chrome, as the following analyses show:

	a.	*b.*	*c.*	*d.*
Alumina,	92.0	96.8	84.00	89.50
Silica,	4.8	0.5	6.50	5.50
Lime,	—	1.6	—	—
Iron oxide,	2.4	—	7.59	1.25
Chrome oxide,		1.1		

a. Lelièvre; Jour. d Mines. Fev., 1812.
b. Malaguti. C. R. t. IV.
c. The harmophane corundum of China. Klaproth.
d. The corundum of Bengal. Klaproth.

As *sapphire*, corundum reaches nearer to perfection; thus:

	e.	*f.*	*g.*
Alumina,	98.5	97.6	92.0
Silica,	—	1.2	4.8
Lime,	0.5		
Iron oxide,	1.0	0.8	2.4

e. Blue sapphire. Klaproth.
f. Red sapphire. Chenevix.
g. Blue sapphire. Vauguelin.

But both *sapphire* and *ruby* may be very impure corundum. Bergmann's "ruby" showed alum, 40; silica, 39; iron oxide, 10; lime, 9; and Bid's "sapphire:" alum, 58; sil. 35; lime, 5; iron oxide, 2.

Bricks of burnt clay, and all kinds of pottery, are the most indestructible relics of antiquity, offering a well-nigh perfect resistance to the attacks of air and water, even when charged with acids. The tower of Babel and the brick pyramids of Dashoor and Ilahoon in Egypt are among the oldest monuments of the work of man upon the surface of the earth. Much older pottery has been recovered in good condition from beneath the surface.

But the hardness of a brick of clay (composed of alumina and silica) is produced by heat. In the case of a lump of corundum, the original clay consisted solely of alumina, or nearly so; and it seems difficult to imagine its excessive compact hardness as produced in any other way than by heat.

But the tendency of recent geology is to lower the estimate of heat supposed to be needful for producing changes in the rocks; and to ascribe to the long-continued flow of hot waters effects which were formerly ascribed to furnace heats.

Serpentine is an exactly equal compound of *silica* (43.6) and *magnesia* (43.4) charged with about one seventh (13.0) of *water*.

Bunsen suggests (II, 316) that a bed of limestone may be changed into serpentine by percolating waters carrying the *silicate of lime*, (*or potash;*) the carbonic acid of the limestone going off with the *lime*, (or potash,) and leaving the silicic acid in combination with the magnesia.

Or, since *chloride of magnesium* is found in the water of many hot springs, it seems possible for beds of common clay slate (*silicate of alumina*, &c.) to be converted into beds of serpentine; the chlorine carrying off the alumina (with the &c. which is always in the clay; the &c. being other silicates) as chloride of aluminium. (It is remarkable that chloride of alumium in quantities has been found in the Dead Sea water by three chemists.)

Tschermak showed * that *serpentine* has been produced in grains, in larger masses, and in veins, in rocks, by a change of some *bisilicate* (like peridote, olivine, a bisilicate of magnesia and iron; or enstatite, Sil. 60, Mag. 40) into the simple silicate of magnesia, by the gradual removal of the more soluble ally; the form of the original olivine crystals being preserved by the serpentine in evidence of the change.

A. Geikie says † that there can be no doubt of the eruptive character of *some* serpentines, for there are real serpentine dykes cutting the Old Red sandstones and conglomerates of Scotland. The olivine crystals found in many serpentine masses is an evidence of volcanic origin. But it must be remembered that volcanic hair and ashes are in large part olivine; and that the bed of the Pacific ocean is in part made up of layers of *olivine mud* produced by the settling of this volcanic dust. Sedimentary serpentine strata would be the result of their uplift and subsequent alteration in air.

Sterry Hunt ascribes the serpentine beds in crystalline schists to an original deposit in sea water.‡ In fact the form of serpentine strata often proves this. In Banffshire, Scotland, thick lenticular beds of serpentine lie among the crystalline schists and limestone, and are crumpled and folded with them as an original element in the general stratification.§ The same thing occurs in Northampton county, Pennsylvania, and elsewhere.‖

* Trans. Vienna Academy, 1867.

† Text-Book of Geol. London, 1882. p. 152.

‡ Chem. Essays p. 153.

§ Geikie, p. 153.

‖ The Serpentine *organic* (glauconite) beds in Tertiary limestone (see Berthier), and the *eozoon* serpentines of Canada come under this head.

It is possible that none of the serpentines of southern Pennsylvania are in any respect eruptive or volcanic; but that all of them are original sedimentary magnesian rocks subsequently changed more or less into the simple silicate of magnesia, by percolating waters; assisted, in some places, it may be, by outbursts of volcanic traps, and perhaps eruptive granitoid rocks.

Bunsen says (II, 317) that the occurrence of *sapphires* in basalt and of *corundums* in gneiss and granite is to be explained probably by a process similar to that which has produced serpentine. Sapphires and corundums (anhydrous alumina) occur in rocks of silicate of alumina which contain no other combinations of silica and alumina, except such as have been produced by metamorphosis. The percolation of chlorine and sulphur waters seems to have worked most of the changes. If sulphate of alumina were first formed, and then the sulphur removed by lime or alkaline carbonated waters, there would remain hydrated alumina, which would in time change into pure alumina (corundum) just as beds of brown hematite iron ore have changed into red hematite by the voluntary departure of their water of combination.

This is the probable explanation of small crystals of alumina (sapphires, rubies, corundums, &c.) scattered through a gneissoid rock. The explanation, perhaps, suffices also for the existence in the rocks of layer masses. But the presence of large masses of corundum on the soil of the fields is explained by the long continued erosion of the country, the surface of which has been lowered slowly by the rains carrying away the softer parts of the rocks and leaving behind the masses, which therefore naturally, by mere force of gravity, occupy places vertically beneath the places which they occupied in the rocks. It is possible to find *corundum* in a persistent bed. Such a bed, 4 feet thick, runs for four miles, interbedded among the pholerite schists of the White Mountains, a formation of about the same age with the schists of Chester county.—J. P. L.]

INDEXES TO REPORT C[4].

1. Nominal.—2. Geological.

I. Nominal and Geographical.

2. Geological Index.

† Omitted by accident from the map.

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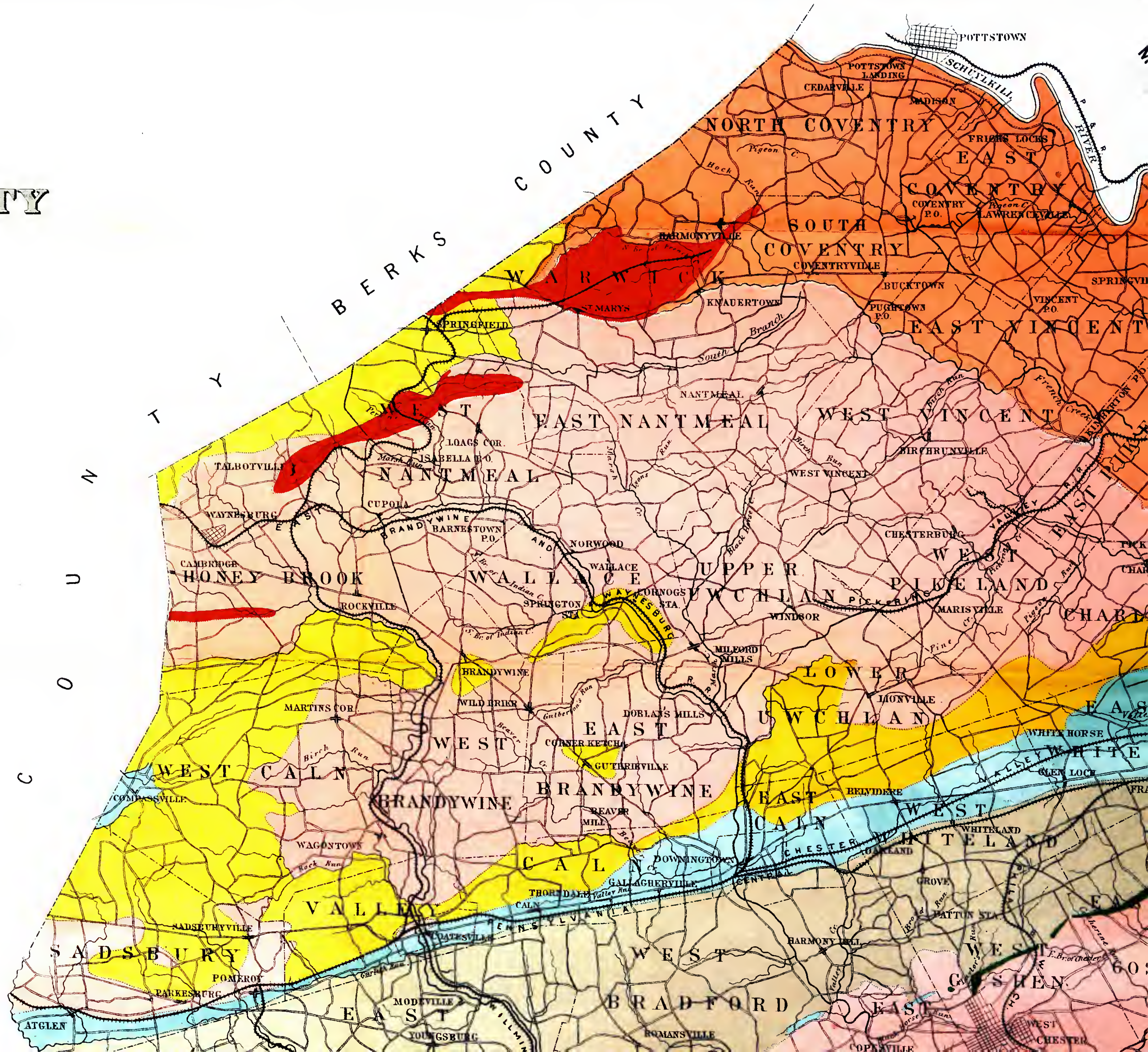
J. P. LESLEY, STATE GEOLOGIST

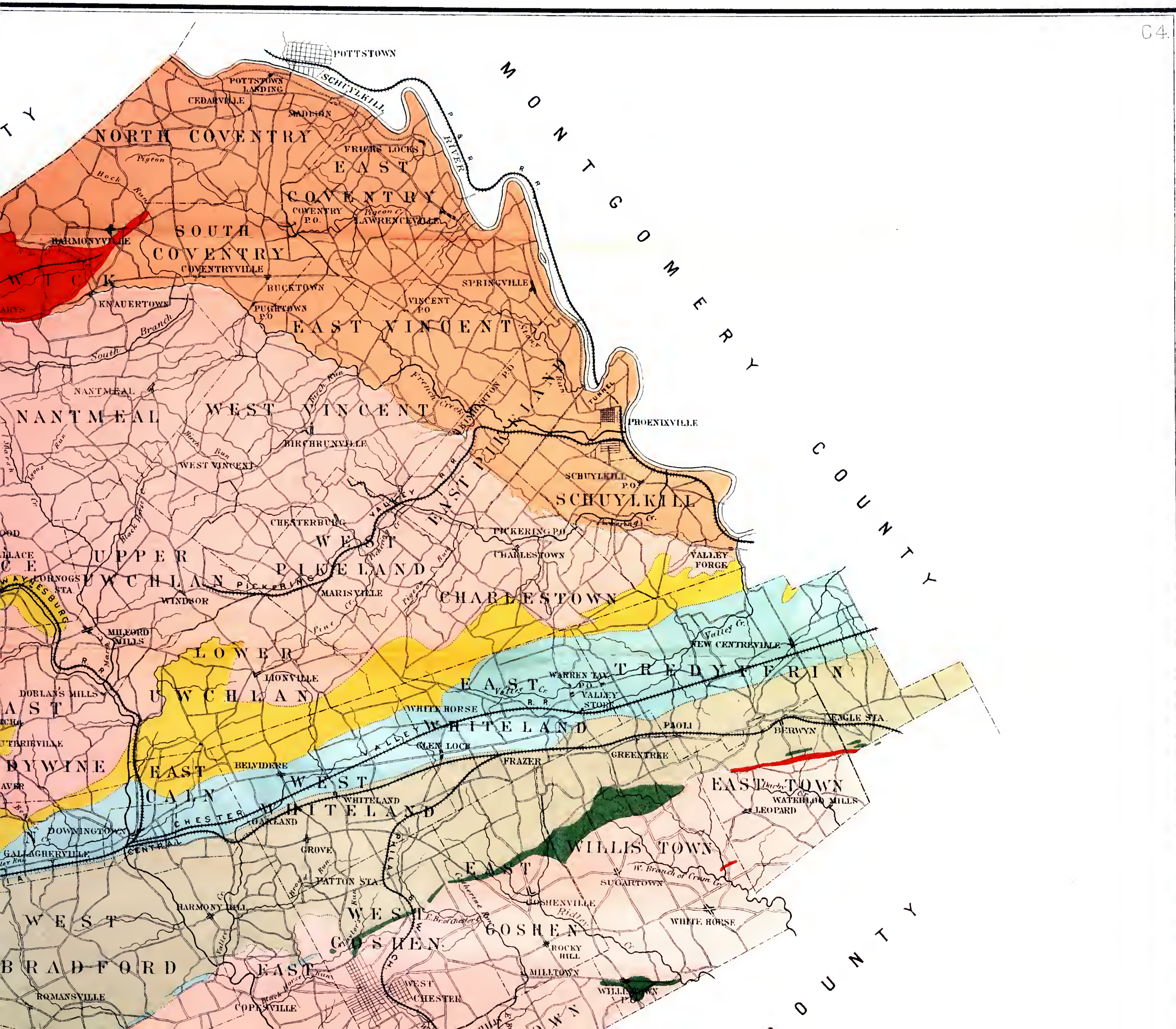
GEOLOGICAL MAP
OF
CHESTER COUNTY

PERSIFOR FRAZER, ASS'T. GEOLOGIST.

Scale: 2 Miles to 1 Inch

1880.

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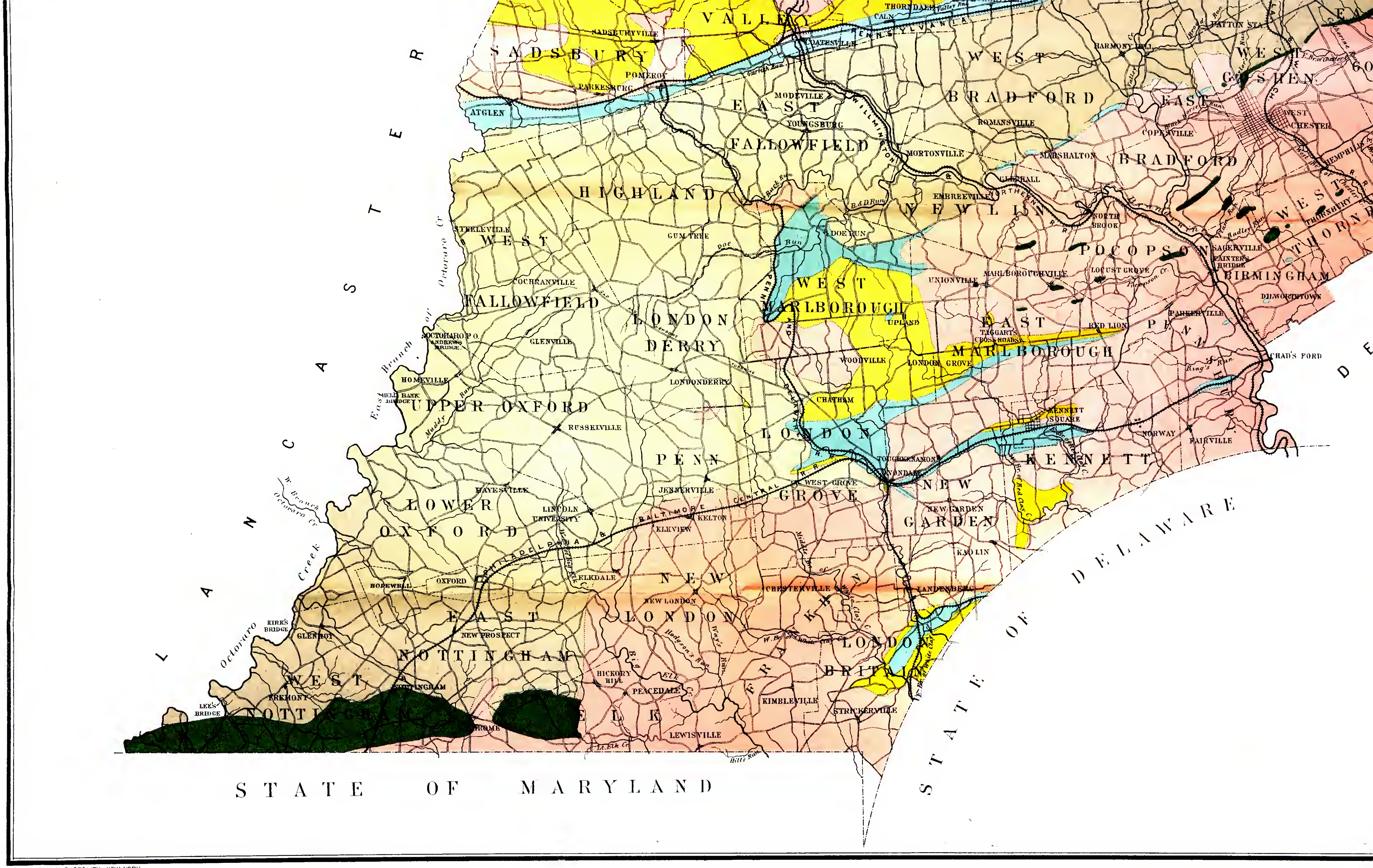

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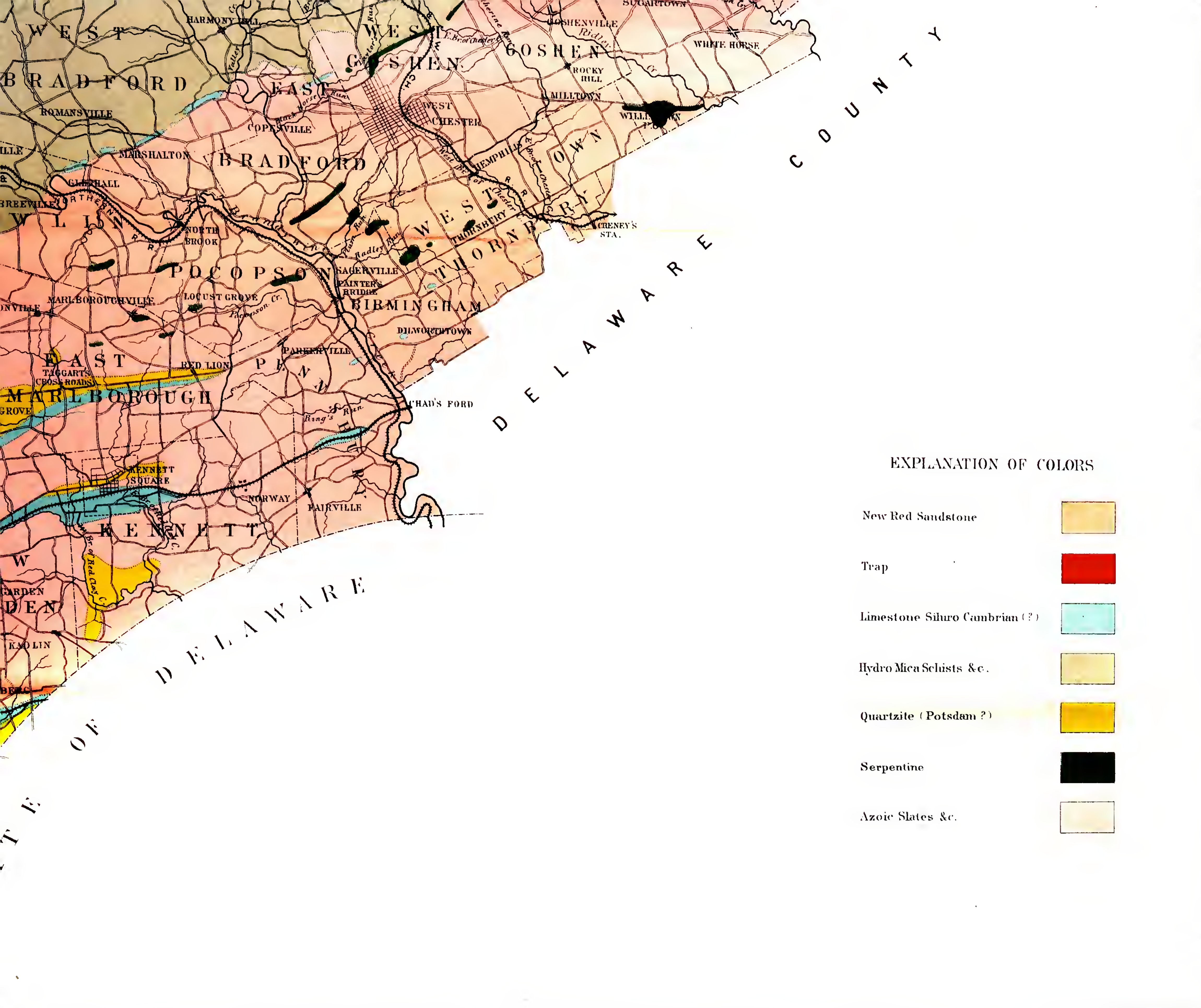

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