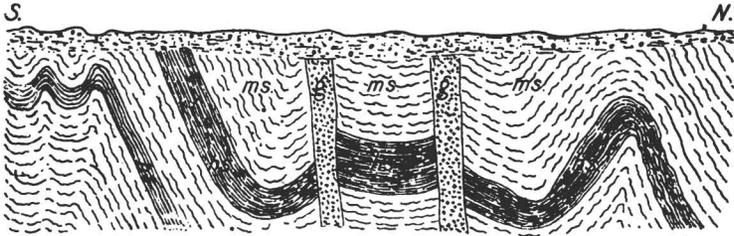
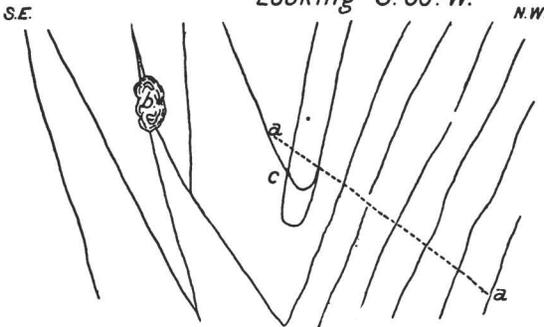


NOTES  
ON THE  
GEOLOGY OF RADNOR TOWNSHIP,  
IN  
DELAWARE COUNTY, PA.  
AND OF THE TOWNSHIPS ADJACENT.  
BY THEODORE D. RAND.

*Hornblende Schist and dykes of coarse Granite in Mica schist, S.W. side of Junction Railroad, S.E. of Connecting R. R. near 38th. & Penn Grove Streets, 24th. Ward Philadelphia. Looking West.*

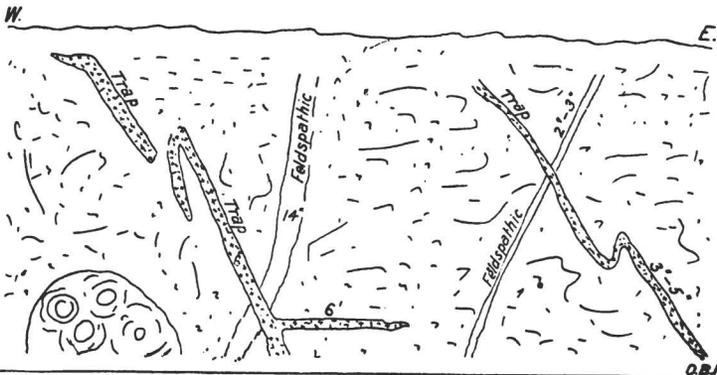


*Apparent synclinal of Serpentine in Quarry on property of John Stacker 1/2 mile N.W. of Radnor Station P.R.R., Radnor Township, Delaware Co., Pa. Looking S. 60° W.*



*a-a. Quartz parting.  
b. Knot of asbestos*

*Trap dykes cutting feldspathic dykes (or segregations) in Laurentian, 1/4 mile E. of Radnor Station, P.R.R., Radnor Township, Delaware Co., Pa. Looking North.*



*Notes on the Geology of Radnor township, Delaware county, Pa., and of the townships adjacent to it.*

By THEODORE D. RAND.

The area under study comprises parts of Radnor, Haverford, Newtown and Marple townships, Delaware county; part of the adjacent townships of Lower Merion, Lower and Upper Darby, Montgomery county; Easttown and Tredyffrin, Chester county, and of Philadelphia. In portions of these notes these townships will be designated by their initial letters. Where an outcrop is referred to and the nearest named place is in another township, it is the township of the *outcrop* that will be given.

The bearings given were taken by compass on the ground, but allowance was made for magnetic variation.

The indications on the map are placed with reference to roads and streams as drawn on map of Philadelphia and Delaware counties, published by G. M. Hopkins & Company, 1876; but the location of some of them does not strictly accord with my observations on the ground.

Where a rock seemed almost unquestionably to be continuous it has been so represented. In cases of doubt outcrops only are given.

The region mapped having been long under cultivation, and being a region in which decomposition of the rocks in place has gone in many parts to considerable depths, it is impossible to define the limits of the belts with accuracy, and those given on the map must be regarded as merely close approximations. It is very probable that the Serpentine, the Potsdam sandstone, and the white sandstone S. E. of the Laurentian (probably Potsdam) are continuous, but as this is not certain, actual outcrops only of these rocks are given. In some cases the outcrops appear to be very narrow, and it has been necessary to somewhat exaggerate their width in order to show them at all, but I have endeavored to represent them as nearly as possible, exactly as they are.

(1571)

There is great need of an accurate topographical map of this region. The maps used as the base are probably in error in many places, but nowhere seriously so. To avoid indistinctness it has been necessary to omit many minor roads and places.

The region is generally a rolling table land, ranging downward from about 480' A. T. The most prominent feature is the range of Laurentian granitic and syenitic gneiss, extending south-west from east of the Schuylkill river beyond the limits of the area under study. This hill forms a prominent feature of the landscape throughout almost its whole extent. The rock is exposed in many places, but probably best at the gap through which the Schuylkill flows. Its structure appears to be anticlinal. The rock, where undecomposed, is very massive, in thick beds, and contains quartz, feldspar, hornblende and mica in varying proportions. The quartz, feldspar and hornblende each in some places make a large proportion of the rock, at others they are more evenly intermixed. The mica (biotite?) is generally small in quantity. Garnets occur, but not abundantly.

The characteristic mineral of the formation is blue quartz, which occurs almost everywhere. Indeed, after a rain, in almost every road may be detected unrolled fragments of this quartz. The gneiss appears to be traversed by numerous dykes of dolerite, but I know of none which have been traced for any distance. Where visible they seem to have been eroded or decomposed equally with the syenite.

The concentric weathering of this rock, like that of the porphyritic belt hereafter referred to, gives rise to boulder-like masses, at times in place, at others strewn over the fields, as if waterworn and transported. This weathering was well shown when the cut of the Pennsylvania railroad east of Radnor Station (R.) was widened. Here as many as twenty concentric coats around an unaltered nucleus were visible, and the same structure can still be seen in a less degree. This weathering changes the hard massive gneiss into thin fragments, sometimes friable, but often quite hard and then resembling a schistose gneiss. Those portions which were hornblendic, appear to have decomposed

most completely and to have become a reddish-yellow sandy loam. Many of the quarries in this gneiss show this weathering, which often extends but a few feet; the rock being almost schistose near the surface, but massive and compact twenty feet below.

From the Schuylkill, south-westward, outcrops of this rock are almost continuous. Its boundaries are well defined by the steep slopes which mark them on both the south-east and north-west. The belt widens from a little over a mile at the Schuylkill, to two miles at the Delaware-Montgomery county line, and to nearly four miles at the south-west line of Radnor township. The slopes become more gentle as the floor of the valleys adjacent rise to the Delaware-Schuylkill watershed, which is nearly the line of the Pennsylvania railroad.

About 2000 feet N. E. from Villa Nova station, is a quarry (L. M.) on the property of Estate of E. H. Curwen. The western end shows a small anticlinal; the eastern, a folding, the dips being steep south-easterly on the north, almost horizontal in the middle, steep south-easterly on the south, bounded on the south-east by a bed of very massive hornblende-like rock, possibly a trap dyke. The lower portions are massive and heavy bedded; the upper, schistose from decomposition.

Along the line of the Pennsylvania railroad, going westward, the rock is first met in an old abandoned quarry, about 1,200 feet north-north-west from Rosemont station (L. M.) Immediately north-west large masses lie along the embankment of the old Columbia railroad, a loop of which remains on the east side of the present roadbed. North-westward of this to Villa Nova station (R.) about 0.9 miles the cuts are slight, and the rock greatly decomposed, but in the county line road, about 0.5 miles north-north-west of Rosemont, and close to the railroad, an outcrop may be seen. The same rock was found in the well on property of H. F. West, 0.4 miles north-north-west of Rosemont. West of Villa Nova, there is a cut some thirty-feet in depth, where the rock is much decomposed; at the westerly end near Upton station, (R.) the dips are  $45^{\circ}$  and upwards south-

easterly, becoming steeper eastwardly, until they become nearly or quite vertical.

About 1000 feet north-west of Upton station (R.), is a quarry on the property of Israel Morris, on the line of the old Columbia railroad and north of the Pennsylvania railroad. The rock is a massive, highly feldspathic syenite, unaltered. The dip is uncertain, but probably  $45^{\circ} \pm$  S. 30 E. Between this and Radnor station is a cut about twenty feet in depth, through decomposing Laurentian, which may be better seen in quarries on the line of the Columbia railroad, which here curved to the south. The rock is very massive below, schistose from decomposition above, dips steep S.  $30^{\circ}$  E.  $\pm 80^{\circ} \pm$ .

In this cut is a dyke of dolerite (analyzed and determined by F. A. Genth, Jr., C<sup>s</sup>, p. 115), and when the road-bed was widened, several small dykes, probably also dolerite, were apparent, dipping steeply to the southeast, and cutting granitic dykes dipping steeply north-west. In one case a tongue of the trap was intruded between the layers of the gneiss nearly at right angles to the dyke. See plate p. 1570

At Radnor station is the source of Harding's run, a branch of Ithan creek. It occupies a marked depression in the gneiss, characterized by numerous small springs of water. Comparatively shallow wells in the vicinity have long been noted for their abundant water supply. This location was taken advantage of by the Pennsylvania railroad, which many years ago established a pumping station and water tanks near by. For a long time the flow of the springs and the supply from a well, together with some storage in a dam, afforded an ample supply, but with the increased traffic, more water was needed. About 1878 an artesian well, 12 inches in diameter, was begun. At a depth of about 40 feet, undecomposed Laurentian gneiss was struck. Progress was slow and difficult. At one time, in a stratum containing inter-mixed pyrites, by 140 hours constant drilling only fourteen inches in depth were gained. At about 500 feet (probably about 100 feet below ocean level) the hole became crooked and the well was abandoned. It was almost perfectly dry. Subse-

quently a second well was begun, only about 50 feet in a northerly direction from the former, and was drilled of a diameter of about 12 inches, to the depth of 500 feet, and of 8 inches to the depth of 975 feet (about 575 feet below ocean level). From this well, 40 to 50 gallons of water per minute can be pumped, but it is questionable whether it is not surface water, and not from any deep stratum. This supply being insufficient, after other unsuccessful experiments, ten wells were sunk near by, in a space of about 150 × 200 feet, by driving an eight-inch steel shod pipe to rock; the pipe was kept clear by a sand pump. When rock was reached a perforated pipe of smaller diameter was inserted, and the outside tube was then withdrawn.

The strata passed through are reported.

Surface soil, . . . . .	4'
Clay, blue, sometimes yellow, . . . . .	7'
Gravel (?) and sand to rock, . . . . .	29' to 44'
Total to undecomposed rock, . . . . .	40' to 55'

The "gravel and sand" are without doubt the decomposed Laurentian.

These wells were tested by continuous pumping and the ten yielded 200 gallons per minute, or 288,000 gallons per day for a period of two weeks, and after the lapse of a year, in a dry time, were again pumped at the same rate for two weeks.

A remarkable fact in regard to them is that while pumping from the ten, if one be shut off from the pumps, the water will immediately rise in it to within 8 or 10 inches of the surface, although the remaining nine are being pumped to their full capacity.

The large well referred to is twelve feet in diameter and thirty feet deep. It (the second artesian well) and the ten driven wells are connected with pumps capable of forcing 700 gallons a minute into the tanks. The wells furnish this supply for from two to three hours, when the tanks being full, pumping ceases. The present consumption is about 120,000 gallons per day.

The stream, originally fed by the springs, was quite small. I am told that it would not have filled a two-inch pipe.

There are no large springs in the vicinity. The total area draining towards this pumping station, which is only about 500 feet south of the watershed (Darby creek and Schuylkill river), probably does not exceed 50 acres. The source of this large supply of water therefore seems obscure, as well as its outlet before the pumping was done.

About 1300 feet north-west of Radnor station, is a small cut. Here the rock is Laurentian, in part massive and unaltered, and in part wholly decomposed. Three thousand feet N. W. of Radnor station is a larger cut, in which most of the rock is unaltered. At this point its hardness is so great, that in the widening of the cut, it was found more economical to blast by dynamite laid upon the surface and exploded, than to drill it, and most of the blasting was done in that manner.

The Lancaster turnpike runs near and approximately parallel to the railroad. It has been so settled for many years, that outcrops that may have once existed are not now to be found. There is a quarry in highly hornblendic Laurentian on the property of Charles McKeone, south of the turnpike and about one-third of a mile south-west of Villa Nova station, and a rocky hill of Laurentian on the land of Miss Martha Brown, half a mile south of Radnor station, on the banks of Harding's run.

South of the turnpike flows Ithan creek, first eastwardly then southwardly into Darby creek. Along this, on the property of Mr. P. C. Erben, about a mile south-south-west of Radnor station, 400 feet north of the old Lancaster road and 800 feet north-west of the Spring Mill road, a considerable exposure of Laurentian may be seen, with an interesting dyke of trap about six feet wide, dipping  $\pm 30^\circ$  nearly due north. North-west of this, along the stream, are large masses of the rock and, after passing the road, (0.9 miles south-west of Radnor station) a bold bluff occurs. The exposures on Ithan creek to the south-east, will be referred to hereafter.

South of these localities is the old Lancaster road. This road, at Rosemont, is but about 800 feet S. of the turnpike, but it bears more westwardly until it is half a mile

distant ; it then approaches the turnpike again and unites with it 0.7 miles west of Wayne station, Pennsylvania railroad.

Along this road are many outcrops ; one of the most important is a quarry on the land of Jos. F. Tobias, 1800 feet W. S. W. of Rosemont, (L. on plate, page 1578), whence a reddish feldspathic granite was quarried, out of which the rectory of the church of the Good Shepherd, on the Lancaster turnpike half a mile north-west of Rosemont, was built.

In the north part of this quarry dips S. 80 E. 65° and S. 75 E. 72° were obtained, and in the south part 60° nearly due east. South-west of this there is a quarry on the property of Dr. Edward Williams, another on the property of Jesse Gyger, east of the Roberts road, 1¼ miles south-west of Rosemont. Dip 45° south-easterly. Also, an exposure on the Roberts road just beyond Valley run, about a mile south-west of Rosemont, and on the same road a quarter of a mile beyond. There is a quarry on the Cooperstown road east of the Roberts road on property of John K. Valentine, showing a dip 45° south-east. West of these exposures and south of the old Lancaster road the Laurentian is exposed along the banks of Ithan creek, particularly the west bank and in its bed. The rocks rise steeply, in some places precipitously ; along the summit (watershed between Ithan and Darby creeks) runs the Radnor and Chester road, along which the same rock may be seen in loose masses and occasionally in place (one large outcrop on farm of J. W. Worrall, north of the road), as far as the Roberts road, where it is succeeded by enstatite and serpentine.

Along the west bank of Ithan creek, on property of D. C. Abraham and David Paxson, the sequence of rocks going south-east is :

- 1. Laurentian, decomposed.
- 2. Laurentian, heavy bedded . . . . . 100'
- 3. Trap? dip S. 30°, E. 80°, . . . . . 5'
- 4. Concealed, . . . . . 50'
- 5. Trap, . . . . . 25
- 6. Concealed, . . . . . 40'
- 7. Laurentian with large garnets, rock quite garnetiferous, dip S. 30° E. ± from 5° at N. W. end to 0° at S. E. end, . . . 50'
- 8. Trap? in long angular fragments, . . . . . 30'
- 9. Laurentian, heavy bedded, dip S. 30° E. ± 40°, . . . . . 100'



In a quarry on the east side of the creek, south of the Roberts road, the dip is S.  $45^{\circ}$  E.  $60^{\circ}$ . On the east side of Ithan creek about 100 feet north of the Roberts road a dyke of trap is exposed in a quarry. South-west of this along Darby creek the exposures are almost continuous. The south-eastern border may be traced across Darby creek north-west of the bridge over which the road from Coopertown to Newtown Square passes (nearly a continuation of the Roberts road). There is a quarry in it within a hundred feet west of the road near the bridge. It crosses the road three or four hundred feet from the bridge. On Fawkes run, about  $1\frac{1}{4}$  miles from Darby creek towards Newtown Square (north), it is exposed in a cut for the Chester County railroad.

The north-west border of the Laurentian passes across Radnor township, crossing the county line road close to the Mattson's Ford road, a mile east of Radnor station, running thence nearly parallel to the latter road, and probably about  $5^{\circ}$  S. of W. crossing the Pennsylvania railroad and the Lancaster pike close to Wayne station. At the county line and eastward of it to the Schuylkill its slope north-westward is quite steep. It is well exposed in a quarry on the old Lancaster road,  $\frac{1}{2}$  mile south-west of Wayne, also along the back road to Eagle, south of the Lancaster turnpike.

About  $1\frac{1}{4}$  miles S. W. of Devon station (Easttown), it forms a conical hill of remarkable appearance, and here the belt appears to attain its greatest width, measuring nearly or quite four miles to the outcrops on the road from Coopertown to Newtown Square. Soon after passing this point the margin tends southwardly.

Along Darby creek are numerous exposures, but none of particular interest.

While we may not be absolutely sure that this belt is Laurentian there seems so little doubt of it, that I have so termed it. It seems certain that it is the oldest formation of the region, an anticlinal ridge against which rest the formations on the north-west and south-east. The dips on the south-east are quite uniform, on the north-west very obscure, but probably not far from vertical.

The rock of this belt has been much used in building. Many small quarries have been opened, and large amounts of surface stone have been used in foundations and rough walls. It has not been used largely for face stone, owing to portions of it becoming rusty on exposure, and because of its extreme hardness making it difficult to dress. Selected portions, however, make excellent face stone. Examples may be seen in the wall enclosing Dr. Williams' property on the Roberts road  $\frac{3}{4}$  mile south-west of Rosemont, also in two buildings on property of Thos. Williams, Jr.,  $\frac{1}{4}$  mile west of Radnor station, and in the residence of Mr. Morris, near Upton station.

The largest quarry is on the property of John M. Kennedy, Jr., on the old Lancaster road close to Wayne avenue  $\frac{1}{2}$  mile south-west of Wayne.

This was opened for bridge and culvert stone, for the widening and straightening of the Pennsylvania railroad, about 1880, and blocks with straight fracture and of many tons weight were abundantly obtained.

Forming a prominent ridge north-west of this Laurentian hill are the hydromica schists of the South (Chester) Valley hill, believed by Mr. Hall to be of Hudson River age. These have been frequently termed talcose schists and chlorite schists, but I have not met with either talc or chlorite in them. I think them exclusively hydromica schists. These have been so well described, and are so uniform over so large an extent of country that further description is unnecessary.

At Eagle station, south-east of and within 500 feet of outcrops of this rock an artesian well was drilled. No less than 300' of loose material was passed through before the solid rock was reached. This was quite unexpected, as nearly everywhere in this region the undecomposed rock lies near the surface. The well was continued in the same rock 1400 feet further, but did not yield much water and is now used for the supply of a private dwelling. This well is little if anything over 1000 feet from the line of serpentine outcrops, hence within 300 to 1000 feet of the edge of the hydromica, showing a steep dip, if the structure is synclinal.

From the well-defined Laurentian to the hydromica schists there is but a short geographical distance probably nowhere exceeding half a mile. This generally is a valley and to the northeast is a deep valley. In this narrow space we find a series of rocks, the relation of all of which to each other is not certain, the outcrops are few and poor. Nowhere are the rocks well exposed and no large quarries have been opened in them.

First upon the Laurentian is the rock described by Prof. Rogers and called by him "altered primal." His description of it is perfect, "metamorphosed with characteristic white streaks of imperfectly crystallized feldspar, and hard hornblende material with roundish specks of semi-crystallized feldspar."\* It is a gneiss much resembling some of the adjacent Laurentian, from which it was probably derived. It is characterized by thin layers of varying character, feldspar being abundant, mica, hornblende and quartz varying in the layers from almost nothing to great abundance, and many of these layers often appearing in an inch, giving at times a schistose character to the rock, but the mica and hornblende never so abundant that the rock can be properly termed a schist. Some of it is minutely, but excessively, contorted.

This rock forms part of the N. W. slope of the gneissic ridge, and is exposed in many places, while its fragments occur abundantly in the soil, from the Schuylkill to a point beyond the region under study. Its strike is parallel with the Laurentian ridge; its dip is nearly vertical, though good measurements are not to be had. East and north-west of Radnor station this rock is north-west of the Serpentine; near Paoli it is south-east of it. In terming this rock "altered primal" I am quoting Rogers and not asserting that it is really altered Potsdam. It seems quite distinct from the Laurentian.

North-west of this, at five localities, is a narrow outcrop of a rock identical with the eurite of Barren Hill. The rock is a friable feldspathic sandstone with rhomboidal partings, an easy cleavage in one direction, with micaceous

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\* Geol. of Pa., Vol. 2, p. 72.

coatings on the surfaces of cleavage, the rock full of minute tourmalines.

The most eastern outcrop in Radnor township is on the west bank of Morgan's run, on the land of Brooke, in the north-east part of the township, very near the north-west corner of Lower Merion township, 400 feet S. of the Gulf Creek road, and 300 feet W. of the Delaware and Montgomery county line road.

The most western is in the cut of the Pennsylvania railroad about 1200 feet west of Wayne station (R.) and about two miles a little south of west of the locality first mentioned. At the east end of this cut may be seen the altered primal of Rogers for about 200 feet, then trap (the Conshohocken dyke), then altered primal, then the eurite dipping apparently  $20^{\circ}$ - $25^{\circ}$  toward the north-west, then obscure, then quartz fragments, characteristic of the hydromica schists. Between these it outcrops in the bed of Gulf creek, about three-quarters of a mile east of the last locality, the exposure is poor, but in place; it is characteristic and accompanied by a mica schist exactly resembling that found close to the white sandstone in the Roberts road S. W. of the old Lancaster road (R) on the S. E. side of the syenite.

The eurite occurs abundantly in loose masses on the surface for a half mile west of the first locality. These masses were much more compact and hard than those exposed in place, but, making excellent building stone have nearly all been removed. These outcrops are in precisely the same relative position to the Laurentian and the hydromica schists as those of the Potsdam east of the Schuylkill, and in West Marlborough township, Chester county, of which they appear undoubtedly to be a continuation. There are also outcrops in the same line north-eastward on both Montgomery avenue and the Gulf road, east of the Mattson's Ford road (L M).

In the cut at Wayne a number of well-formed columns of trap were found.

North-west of the line of the eurite is a very narrow belt of limestone, apparently a continuation of the wider out-

crosses near the mouth of the same valley opposite Conshohocken, and of the still larger exposure N. E. of the Schuylkill. It contains crystals of pyrites and resembles the limestone of the south-eastern part of the Chester Valley on the N. W. of the South Valley hill, determined to be of Cambrian age.

In West Conshohocken there are two outcrops of this limestone, about two hundred feet apart, separated by mica schist, with mica schist S. E. of the S. E. one, the schist between them dipping S. 16 E. 74°. The limestone dips about 80° to the S. E., but at another exposure further S. E. 70° to 80° N. W. South-west of these the limestone is not visible for mile and a half. At the gulf, through which the Gulf creek passes through the hydromica schist ridge (U M), on the a south-east flank of the ridge, near and south-west of the Gulf flour mill, it appears with nearly vertical dip, on the south-east side of and almost in contact with the trap dyke. The outcrop is narrow and small, and not well exposed.

A mile west of this and 0.6 miles N. of Radnor station, on land of Brooke, formerly Stacker, is an outcrop in the bed of Gulf creek, where, previous to quarrying, a small waterfall existed over this limestone. It is about forty feet in width, the walls very compact slaty gneiss (?) on both sides. The strike of the limestone is about N. 65° E., the dip south-easterly but almost vertical. The westernmost outcrop is on the land of Peter Pechin, a few feet north of the Gulf creek, east of the Radnor and King of Prussia road and about 1,200 feet S. 76° W. of the last mentioned outcrop. It is very small. In the same general direction and at a very short distance north of a line joining the eurite outcrops are two sink-holes close together on a line S. 70° W., about a half mile due north of Wayne Presbyterian church. At the Brooke-Stacker quarry this limestone was many years ago burned for lime, recently it has been used for building purposes, the house of Mr. Geisse, one-half mile north-north-west of Radnor station, being built of it, but the deposit is so narrow and so near water-level, that the quarry cannot be wrought economically. This deposit is in line with the outcrops north-west of West

Chester, referred to hereafter. Adjacent to it and in the same linear position at least two localities west of it are deposits of limonite similar to those adjacent to the limestone north of the hydromica.

North-west of the limestone lies the Conshohocken trap dyke, well exposed at the west bank of the Schuylkill, where it is nearly a quarter of a mile from the limestone,\* hydromica schists intervening. An excellent photograph of this outcrop by Mr. E. B. Harden will be seen in the heliotype plate.

It continues S. W. in an almost straight line nearly parallel to the edge of the hydromica schists, not often visible in place, but continually evidenced by abundant loose masses.

Close to the Schuylkill the hydromica schist hill is quite narrow, and the trap has been transported down both slopes to the valleys on the south-east and north-west, half a mile from the river, and thence westward it is solely on the south-eastern flank.

It crosses the Gulf road near the base of the hydromica hill, and is well exposed, with columnar structure, in the dam of the Gulf mills in which it is utilized as a base for the dam. It crosses the Montgomery-Delaware county line; also the Radnor and King of Prussia road close to, and north of Gulf creek; south-west of this it appears S. of the creek. The Pennsylvania railroad crosses it about 1000 feet west of Wayne station, where it is in or south-east of the "altered primal" and S. E. of the eurite, and it appears in approximatively the same line beyond the townships under consideration. So much stress is frequently laid upon the influence of dykes of trap in altering adjacent rocks that it may be interesting to note that in the passage of this dyke through the "altered primal" (Wayne R.); the limestone (Gulf Mills, L. M.); † the hydromica schists

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\*Directly across the river and perhaps less than half mile distant in the cut of the Schuylkill Valley railroad the trap dyke is within less than 100 feet of the limestone and south-east of it, with either decomposed hydromica schists or decomposed very schistose limestone between.

†South-east of the Gulf and not Gulf Mills P. O., which is at McFarland's Mills, on the north-west side.





HELIOGRAPHIC PRINTING CO.,

BOSTON.

TRAP DYKE AT WEST CONSHOHOCKEN, LOOKING WEST.



FROM NEGATIVE BY E. B. HARDEN.

south-east of Rebel hill or Mechanicsville,  $\frac{1}{2}$  mile north-east of the Gulf mills; and in the cut of the Schuylkill Valley railroad at Conshohocken, not the slightest change, mechanical, chemical or physical due to the dyke is apparent. It has even been asserted that the serpentine is probably due to an alteration of the hydromica schists by this dyke. If so the energy of the dyke south-eastward must have passed through several hundred feet of rocks without affecting them to act upon the rock converted into serpentine while hydromica schist in contact on the north-west is unaltered.

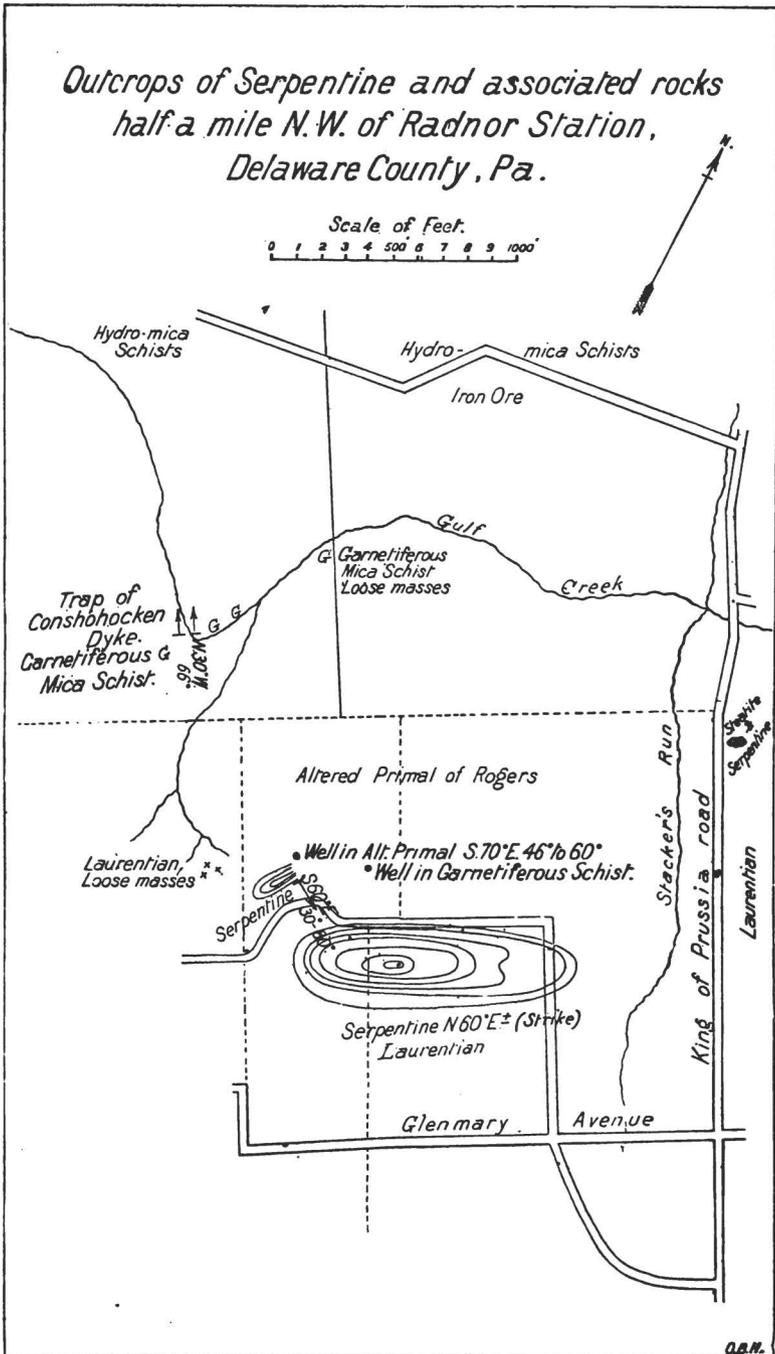
The sequence of the rocks described is certain, but there are others of which the position is uncertain.

1. *Hornblendic rocks* flanking the serpentine belt east of Radnor station on the north are probably Laurentian, certainly bounded by Laurentian rocks on the north. Hence the serpentine is wholly within the Laurentian at this point.

2. *Two distinct Serpentine belts* which will be considered more in detail hereafter. The southerly and most extensive and important one beginning, at its eastern end, on the property of Hon. D. J. Morrell, 6 miles east-north-east of Radnor station. It is composed almost entirely of a very dark green, almost black, serpentine, and is apparently in contact with the Laurentian on both sides, and is certainly on the south-east of the "altered primal" of Rogers.

The northerly belt is small in comparison, and contains much steatite. It shows outcrops east of Gulf road and in the same road south of the Mattson's Ford road; in and also north of the Mattson's Ford road, east of the Delaware-Montgomery county line road, and on the property of Judge Hare and of Lewis T. Brooke (R) It occurs also north-west of these roads, about 3000' north-north-east of Radnor station, and about 1500' north of the easterly end of the southern belt, and on the Radnor and King of Prussia road about 500' S. of Gulf creek and again 4 miles from Radnor station.

3. *Garnetiferous mica schists*, almost certainly two distinct horizons, the southerly closely resembling the wood-like schists near the Soapstone quarry on the Schuylkill



at Lafayette and vicinity ; the northerly, harder, less wavy, forming large masses and containing large garnets, also staurolite. See plate p. 1586 .

The southerly exposed on the Mattson's Ford road, about 500' E. of the Delaware county line (L. M.) are close to the steatite, and are also close to the steatite outcrop on the property of Judge Hare.

On the property of H. A. Geisse,  $\frac{1}{2}$  mile north-west of Radnor station and about 300 feet north of the southerly belt of serpentine (see plate p. 1586) a well was sunk and exposed this garnetiferous schist, with a steep southerly dip. Another well about 300 feet S.  $85^{\circ}$  W.  $\pm$  from the last, or approximately 100 feet across the strike was sunk in decomposed "altered primal" dipping S.  $20^{\circ}$  E.  $46^{\circ}$  to  $60^{\circ}$ . North-west of this there is abundant evidence of the altered primal in addition to its exposure in two small quarries. About 1600 feet N. W. from Geisse's occur a number of masses of the harder mica schist, some of them containing many cubic yards. It is compact, not wood-like, the mica surfaces are smooth and brilliant, the garnets few in number and large, many well crystallized ; and occasionally staurolite occurs. These masses are along the Gulf creek and may not be in place, but the same rock occurs, undoubtedly in place, on the land of Frank Fenimore, about  $\frac{1}{2}$  of a mile a little north of west of Radnor station, near and south-west of the Gulf creek. Its exposure is not very satisfactory, but it appears to strike about N.  $60^{\circ}$  E. and to dip about  $66^{\circ}$  north-west. About  $\frac{1}{4}$  of a mile nearly due west of the Fenimore locality were a number of loose but very large masses of the same rock on land of Childs & Drexel, formerly owned by L. Lewis. It occurs also in considerable quantity further west in Willistown and East Goshen, Chester county, also north of the serpentine north of West Chester and thence south-west it may be seen between the two outcrops of limestone on C. Cope's farm,  $1\frac{1}{2}$  miles N. W. of West Chester.

East of the Radnor outcrop it may be seen N. of the Mattson's Ford road  $\frac{1}{2}$  of a mile E. of the county line (L. M.) on the property of the late Moro Phillips, south of the

Ford road, east of the Gulf road, west of the Merion furnace in West Conshohocken, where it lies between two outcrops of limestone, an exact repetition of the outcrop north-west of West Chester, (though the schist here appears destitute of garnets). Also in the bed of Arrowmink creek, where it is well exposed, some strata garnetiferous, some not so, and also along the road parallel to the Schuyl kill north-east of Arrowmink creek.

On Arrowmink creek may be seen a bold outcrop of the "altered primal," dipping S. 20° E. 85°, followed on the northwest by the schists dipping S. 25° E. 80°.

On the last mentioned road going north-west the Laurentian is crossed ending with a dip S. 30° E. 73°, then obscure with a broken up sandy rock breaking into small angular fragments, dipping to the south-west, followed by the schists, here not very garnetiferous, but resembling the spangled mica schist on the south west slope of the Laurentian with dips S. 60° E. 86°.

At this point, as also north-west of West Chester, these schists are visible for a width of at least 300' and probably extend much further.

The quarry exposures on Cope's farm, northwest of West Chester, have several points of interest. To the S. E. of the limestone lies a region of Laurentian. The south-east wall of the larger (southerly) quarry appears to be Laurentian, with interbedded limestone, reasonably supposed by Dr. Frazer to be not really Laurentian, but a more recent rock composed of fragments of the Laurentian. The dip varies, but is to the south-east. Bounding the limestone on the north-west is the garnetiferous schist conformable dipping S. 50° E. 55°, the contact is plainly visible. This schist continues about 150 feet, when limestone again appears apparently rising in an anticlinal overlaid by the schists.

About 500 feet N. 50° to 65° E. of the two limestone quarries, is a narrow bed of steatite, or talc schist, about two feet wide, underlaid by Laurentian and overlaid by the schists (not garnetiferous) the whole forming a small synclinal.

Further east is the extensive serpentine belt north of

West Chester; within 500' to the south-east of it, is undoubted Laurentian dipping N. 35° W. 30°. The serpentine dips with considerable regularity about S. 45° E.  $\pm$  43° and to the north of it is the garnetiferous schist, in some places containing much staurolite.

In C<sup>4</sup>, p. 66, the garnetiferous schists in Chester county, are stated to be altered hydromica schists.

“The slates along the southern edge of the belt are somewhat garnetiferous and at two places in Willistown and E. Goshen turn into a true garnetiferous schist.”

In Radnor and Lower Merion this garnetiferous schist, which cannot be distinguished from that at the localities in Chester county, seems to be entirely distinct from the hydromicas, which everywhere preserve their distinctive character and there is no evidence of a change of one into the other.

In brief, we find north-west of the Laurentian, in Lower Merion and Radnor, a valley known locally as Cream valley, less than a half mile in width, bounded north-west by the hydromica schists of the South Valley hill, its bottom limestone with iron ores, with no visible stratified rocks between the limestone and the hydromica schists, except at Brooks quarry; but between it and the Laurentian occurs a variety of rocks, one of them probably Potsdam sandstone. A striking feature is the narrowness of these areas. Except close to the Schuylkill, the limestone does not appear to be over fifty feet in width, the eurite probably only a few feet, and the mica schists not visibly much more. There is no evidence of a fault. The limestone outcrops north-west of West Chester lie in the same relative position to the hydromica and the Laurentian, as does also the Potsdam in West Marlborough, and seem to be identical with those of Cream valley, as certainly are the limestone and Potsdam of Spring Mills, in the same line north-east of the Schuylkill. The drainage, like that of the Chester valley, does not follow the valley. The Gulf creek rising north of Wayne, flows down the valley to Gulf Mills, where it bends abruptly to the north and flows through a deep gorge in the hydromica schist ridge, thence along the northerly slope of the

ridge to the Schuylkill, resembling the passage of the Valley creek through the North Valley hill at Valley Forge. A small creek rises north-east of the gulf and follows the valley to the Schuylkill.

In this valley the iron ores (limonite) which occur, have been mined at three places at least; one, the most extensive, about a mile from the Schuylkill (L M), one, on the farm of Peter Pechin, three-quarters of a mile N. W. of Radnor station (R), and the third west of the road from St. David's church to Valley Forge, on the line between Delaware and Chester counties, about a quarter of a mile S. of the Pennsylvania railroad, now included in the Devon inn property.

None of these mines have been wrought for some years.

Iron ore fragments occur at the crossing of the Eagle road over the Pennsylvania railroad west of wayne, and about two hundred yards north-west of the eurite outcrop, in the same general line with the deposits mined.

If Mr. Hall's conclusions are correct, and the hydromica schists are of Hudson river age and overlie the Chester county limestone, then the limestone and eurite of Cream valley are the limestone of the Chester valley and the Potsdam of the North Valley hill rising on the south-easterly leg of the synclinal. The extreme thinness might be explained by a deposition in shallow waters on the shores of the Laurentian highland. This hypothesis seems best to agree with the exposures in Cream valley.

It seems unquestioned that E. of the Schuylkill, going N. W. from the Laurentian syenite, Potsdam sandstone is met with close to the river, (C<sup>4</sup>, p. 110\*), then limestone and then hydromica schist; and also that in E. Marlborough, Chester county, about twenty-four miles S. W., the syenite and hydromica being continuous for the whole distance, there is precisely the same sequence of rocks, though there may be, in the latter section, rocks between the Laurentian and the Potsdam.

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\* In C<sup>4</sup> these outcrops are referred to the North Valley hill, but they border the Laurentian on the north-west and are *between* it and the limestone as clearly shown on the map in C<sup>4</sup>. Beyond the limestone is the hydromica of the South Valley hill, then the limestones of the Chester Valley, and beyond them the Potsdam of the North Valley hill.

Between these two extremes good exposures are rare, hence, if at intervals the Potsdam and the limestone *are* found is not the conclusion irresistible that the formations are practically continuous, and that whatever is the structure east of the Schuylkill, is that west of it? The only difference being that the hydromica schists are very largely developed, the Potsdam and limestone very thin.

It must be admitted that this theory does not explain the sandstone on and west of Samuel Tyson's, near King of Prussia (U. M.). On this farm, close to and west of the Radnor and King-of-Prussia road, a small stream flows northward through the hydromica schists into the Chester valley. The banks of this stream, at the foot of the (hydromica schist South valley) hill, are lined with masses of sandstone, some of tons weight, evidently transported from an outcrop clearly traceable along the hill near its base, accompanied by a ferruginous sandstone, or conglomerate, passing into an iron ore, of which a considerable quantity has been mined. To the eastward of the stream hydromica schists appear, but not a trace of the sandstone. Further westward traces of it may be found for at least a mile, beyond which I have not traced it; but Rogers mentions it as occurring along the valley to the west, and he regarded it as Potsdam, the continuation of the North Valley hill rock under the Chester valley. Were this the structure, we ought to find in Cream valley, the Potsdam between the hydromica and the limestone, and not as it really occurs, only between the limestone and the Laurentian.

#### *Rocks south-east of the Laurentian.*

Between the Laurentian and the Delaware river is a wide expanse of gneisses and mica schists, divided by Rogers into his first and second belts, and by Mr. Hall into three, his intermediate or Manayunk belt comprising the northwesterly part of Rogers' first and the south-easterly part of his second. The remainder of Rogers' second has been conveniently termed by Mr. Hall the Chestnut hill garnetiferous schist group characterized by "silvery micaceous garnetiferous schists, bright-colored, thin bedded sandy

gneiss, the rock breaking into long narrow chunks comparatively smooth on their sides, but excessively ragged on their ends, a style of fracture strongly resembling that of half-rotted fibrous wood." In this occurs the steatite belt, and in it or north-west of it the Lafayette serpentine belt. These will be considered hereafter.

Mr. Hall's intermediate belt is described by him as containing alternations of gray schistose gneiss, and a predominance of sandy gneiss, also mica schists and hornblendic slate alternate with finer grained gneisses.

Rogers' first belt comprises gray schistose gneiss composed of quartz, feldspar, black or brown mica and occasionally garnets, occasional beds of black hornblendic slate and fine-grained sandy gneiss.

Sub-divisions of these belts may be easily traced over considerable distances, and there seem to be some rocks not fairly included in these descriptions. Going south-eastward from the Laurentian we find :

1. A rock which I have termed *Spangled mica schist*. This is sometimes a gneiss ; its characteristic feature being that part of the mica appears to be in small separate curved imperfect crystals, of which the surfaces, or the cleavage surfaces, remain brilliant on exposure. These mica crystals (?) resemble the crystals of feldspar in a porphyry, and at one locality, S. W. of and near Darby creek, the rock is distinctly porphyritic. This rock, while probably less than a hundred feet in width in most places, is abundant and persistent from the Schuylkill to beyond Darby creek. It lies immediately north-west of the Lafayette serpentine belt. I have not found it anywhere on the south-east, the schists there being fine-grained mica schists, often garnetiferous.

This spangled mica schist may be observed in loose fragments almost continuously, but outcrops in place are not abundant nor are they distinct. It may be seen at Rosemont on the road parallel with the Pennsylvania railroad, close to and south of the railroad ; on the road bearing north from the Roberts road ; east of the Gulf road and on the Roberts road, about  $\frac{1}{4}$  of a mile south-west of Rosemont station. There was an outcrop of

the Lafayette serpentine about 500 feet north-east of Rosemont station, a small quarry, filled up and built over in 1885. In a well close to it, and north-west of the serpentine this rock was found. It bounds the same serpentine on the property of Col. J. F. Tobias, on the Roberts road, 1700 feet (along the road) S. W. of the old Lancaster road, and here seems to form quite a hill with some included granite, which has a strike N.  $20^{\circ}$   $25^{\circ}$   $30^{\circ}$   $32^{\circ}$  E.; the only dip observed was S.  $58^{\circ}$  E.  $80^{\circ}$ . In the Roberts road the serpentine rocks are exposed, with the spangled mica schist on the north-west, dipping steeply to the S. E., while the garnetiferous mica schist on the S. E. of the serpentine dips about  $60^{\circ}$  north-west. If these dips can be depended upon they are evidence that here the serpentine lies in a narrow synclinal trough, but the exposures are not satisfactory. A loose mass of garnetiferous mica schist found S. E. of the steatite contained crystals of staurolite.

A remarkable occurrence of this spangled mica schist is upon Bryn Mawr avenue, between the Radnor and Chester road and Darby creek. Bryn Mawr avenue, south-west of the Radnor and Chester road, bears S.  $65^{\circ}$  W. and is in enstatite, which, with serpentine and allied rocks derived from it, occupies the ground about 400 feet reaching nearly to the Roberts road, and quite to it at the westerly end. Near its south-west end Bryn Mawr avenue bears more westwardly, and here post-holes showed the spangled mica schist with enstatite on both sides of it. Unfortunately the exposure is very poor.

On the road from Bryn Mawr and Coopertown to Newtown Square, south-west of Darby creek, and immediately north-west of the serpentine outcrop on Moro Phillips' property, the spangled mica schist is exposed, together with porphyritic gneiss, with a strike N.  $65^{\circ}$  to  $70^{\circ}$  E. and a steep dip to south-east. North-west of this point, strata of hard schists strike N.  $50^{\circ}$  E.  $\pm$  followed by abundant Laurentian fragments. About 150 feet north-west from the spangled mica schist is a small quarry in hornblende Laurentian gneiss, strike N.  $62^{\circ}$  E., dip probably south-east but uncertain. The rock is very massive and heavy bedded.

I have observed no other rock in place and persistent between the Laurentian and the serpentine, but in places as on the Schuylkill and about two miles west of it, fragments of a rock closely resembling the "altered primal" occur. Masses of it are built into the wall of Dr. Williams' property on the Roberts road (R.) about a mile south-west of Rosemont, derived, as I am informed, from loose surface masses. I could not find it in place. This is close to the spangled mica schist, south-east of the Laurentian, and three miles, at least, from any outcrop on the north-west side.

South-east of the serpentine, mica schists, often garnetiferous, often wood-like, containing some hornblende schists and beds of white quartz, extend for about half a mile to the steatite belt, and beyond about two miles, but in the north-west edge of these schists, close to the Serpentine, occurs a rock that may possibly be Potsdam sandstone. These mica schists are well exposed in the cut of the Reading railroad, on the Schuylkill between the Lafayette serpentine and the steatite, (L. M.) where they dip steeply to the N. W. ; also on the Roberts road north-east of the Pennsylvania railroad, and also on the Gulf road east of the Roberts road (L. M.) On the Gulf road close to the Roberts road, hence 300 to 400 feet south-east of the line of strike of the serpentine, their dip is S.  $45^{\circ}$  E.  $62^{\circ}$ , at  $\frac{1}{2}$  of a mile south-east of the road, just W. of Taylor college S.  $48^{\circ}$  E.  $50^{\circ}$  and  $\frac{1}{4}$  of a mile beyond S.  $57^{\circ}$  E.  $57^{\circ}$ .

On the old Lancaster road 50 feet east of the Roberts road they dip S.  $58^{\circ}$  E.  $65^{\circ}$  ; in the cut of the Pennsylvania railroad, at Bryn Mawr, S.  $25^{\circ}$  E.  $\pm 70^{\circ}$ , and on Bryn Mawr avenue, south-east of the above, the strike is N.  $33^{\circ}$  E. nearly vertical.

In this part of the belt the schists are not contorted, but quite smooth and regular in their bedding ; there are also beds of hornblende schists. They are not so garnetiferous as those further east, they are more quartzose and less distinctly micaceous and contain beds of quartz, masses of which are abundant in the fields. They closely resemble schists, adjacent to the Potsdam north-east of Wayne, above mentioned.

The sandstone is best seen in the old Lancaster road, 500' north-west of the Roberts road and in the latter  $\frac{1}{3}$  of a mile south-west of the Lancaster road.

In the old Lancaster road it dips S.  $57^{\circ}$  E.  $50^{\circ}$  and S.  $52^{\circ}$  E.  $50^{\circ}$  and on the Roberts road S.  $60^{\circ}$  E.  $47^{\circ}$ , the mica schist south-west of it S.  $60^{\circ}$  E.  $50^{\circ}$  to  $52^{\circ}$ . The rock is a friable feldspathic sandstone, very closely resembling the eurite of Barren Hill, but the characteristic tourmalines are not visible. It is in nearly the same position, I believe, in which Prof. H. C. Lewis found itacolumite, east of the Schuylkill, and in which undoubted Potsdam occurs further to the north-east. The same rock is exposed upon a road at right angles to the State road near the house of Wm. Shalle (L. M.),  $1\frac{1}{2}$  miles north-north-east of Bryn Mawr and south-east of, and near the serpentine, close to, and south-west of, the corner of the Gulf road and the Roberts road (L. M.). It is to be hoped better exposures of this rock may be found.

On the south-east of and near the serpentine may be found in many places loose fragments of a very hard syenitic gneiss, its surfaces smooth and parallel, and studded with small crystals of hornblende. It has been found near the Schuylkill; also about a mile west of it; near Bryn Mawr, and on the Radnor and Chester road, near Darby creek. Its only outcrop in place, to my knowledge, is in the Roberts road at the crossing of the old Lancaster road, where it appears as a stratum about  $2\frac{1}{2}$  inches wide in the soft mica schists. If this is its extent, in width, it is remarkable that it should be so uniform over so great a lineal distance. Its strike is N.  $35^{\circ}$  E. nearly vertical.

In the mica schists, and chiefly within one or two hundred yards of the serpentine are hornblende schists. They may be observed on the Gulf road south of the Roberts road, and at Bryn Mawr; much decomposed, on the old Lancaster road south-east of the Roberts road, and in a quarry just south of the serpentine on the north side of the Philadelphia and West Chester road (Newtown). At this place the hornblende is apparently changing into serpentine.

The garnetiferous mica schists appear to bound the stea-

tite belt on both sides, though at the old soapstone quarry, on the Schuylkill (Philadelphia), the south-east wall is hornblende and actinolite apparently passing into chlorite.

In these mica schist rocks there seems to be a stratum characterized by staurolite. Though the exposures are not constant, they are approximately in line. It may be seen at Magarge's mills, Wissahickon, Fairmount Park, Philadelphia, on the Old Lancaster road near the road leading to Wynnewood station and in the latter road. Also about a half mile south-west of Wynnewood, (H. & L. M.) and near Darby creek in cuts for the Chester County railroad near Church Lane (H).

Unlike the Laurentian, and the porphyritic gneiss next described, these rocks do not widen south-westward from the Schuylkill, but apparently become somewhat narrower, being about 6 miles wide at the Schuylkill and about 5 miles at Darby creek.

These mica schists are bounded on the south-east and separated from the Fairmount gneiss and overlying mica schists by a prominent and extensive belt of porphyritic gneiss. This, except the Laurentian, is the most uniform and characteristic rock of the region. This is within the area of Mr. Hall's intermediate belt, or Manayunk mica schists and gneisses, but it is so very well defined, and so distinct in its character and boundaries as to entitle it to be considered separately; the rock of which it is composed is hardly within the descriptions heretofore referred to. It is a very hard, compact, heavy-bedded gneiss, usually gray in color, sometimes nearly black, and is generally porphyritic. It contains much feldspar and little mica. Owing to its hardness, it forms throughout most of its course, a well defined ridge, or table land. Its outcrops are almost continuous. The imbedded feldspar crystals (twins) are sometimes minute, when the gneiss resembles the Fairmount gneiss, sometimes two or three inches across. Its dip is mostly obscure.

There are two principal varieties.

1st, and most abundant, a fine grained gneiss of a greyish color containing numerous twin crystals of orthoclase

distributed uniformly through the mass, from very small up to two inches in diameter.

2d, a similar gneiss containing much less mica and very few or no feldspar crystals, forming a homogeneous rock, sometimes almost a felsite, with conchoidal fracture and very hard. The mica is sometimes replaced by hornblende in which case the rock, especially when the feldspar crystals are not numerous, bears strong resemblance to a trap, which resemblance is aided by the weathering into rounded masses lying upon the surface of the ground.

On its north-western border are hornblendic gneisses and coarse granites.

North-eastward it appears on the Schuylkill as a narrow belt at the Falls, Twenty-eighth ward, Philadelphia, at which point its outcrop in the river caused rapids, giving the village its name. This was the head of tidewater before the erection of the Fairmount dam. These rocks are now covered almost entirely by the back water from Fairmount dam, and part of them have been removed to improve navigation. The fine stone arched bridge of the Reading railroad over the Schuylkill is built of it.

There is a remarkable quarry, either in this belt or immediately north-west of it, on the west bank of the Schuylkill. The rock is a gneiss, but the proportion of the respective ingredients vary in the most remarkable manner and give rise to a greater variety of rocks than in any other quarry of the region. Quartz crystals, with interesting modifications, kroidolite and epidote, and it is said rhodonite have been obtained here, and upon one occasion in it was seen a natural *ink* formed by the wash or sap from trees above flowing over decomposing pyritous rocks.

The width here across the strike is probably but two or three hundred feet, but the belt widens rapidly, and within about two miles, at the Pennsylvania railroad cut, it extends from the crossing of the Lancaster pike  $\frac{1}{2}$  mile E. of Overbrook to Elm station, measuring across the strike at least a mile and a half. South-westward it probably still increases in width, and in this resembling the Laurentian.

This belt is well exposed at the Schuylkill, but its struc-

ture is not clear. On the N. E. bank the dips are northerly from  $45^\circ$  on the north-west to  $15^\circ$  more south-east; on the S. W. bank they dip  $70^\circ$  north-west becoming steeper to the south-east, then vertical, then again north-west.

A section on the line of the Pennsylvania railroad, shows a distinct anticlinal, at the extreme N. W. outcrop in a quarry, about 1500 feet south-east of Wynnewood, with dips from S.  $50^\circ$  E.  $20^\circ$  to N.  $50^\circ$  W.  $20^\circ$ . In the cut of the Pennsylvania railroad, beginning about a half mile east of this quarry, the westernmost dips appear to be south-east, some strata nearly horizontal, apparently a succession of folds, with no dips steeper than  $30^\circ$  and much false stratification, due to decomposition. Below Merion station, the strike is N.  $35^\circ$  E. and N.  $45^\circ$  E. dip obscure, probably nearly horizontal. Below Overbrook, there is decomposed gneiss, (possibly a gneiss overlying the porphyretic) dip  $\pm 45^\circ$  N. W., becoming steeper to the south-east, followed by heavy-bedded porphyretic gneiss and then mica schist dipping  $70^\circ \pm$  to the south-east, the dips becoming steeper south-eastwardly.

South-west of this the cutting of Lansdowne avenue through this rock gives a good exposure. The gneiss is very massive and the structure obscure, but apparently in the south-eastern part the dip is to the south-west, in the middle vertical, and at the western part  $5^\circ$  to  $15^\circ$  south-east, then  $5^\circ$  to  $10^\circ$  north-west. There are coarse granitic veins, or strata, probably veins. The western end of the Lansdowne cut is not west of the middle of the belt.

This rock is deeply cut by Darby creek and its affluents, Cobb's creek and Indian creek.

On the latter the rock is well exposed at a mill about half a mile north-west of Haddington, where there is a nearly vertical cliff of some eighty feet in height. Near by, a very dense, compact, hard variety of the gneiss was quarried and also a highly feldspathic, almost white and comparatively soft variety; while further up the creek and near the line between Philadelphia and Delaware counties, a dark hornblendic, hard and heavy variety occurs in loose trap-like masses.

Cobb's creek cuts this belt, forming a valley of considera-

ble depth with banks mostly steep and occasionally precipitous. The creek descends probably 100 feet or more in three miles.

A section along the creek from Sixty-third and Market streets, Philadelphia, westward and north-westward shows as follows :

In a quarry south-east of Sixty-third and Market a very compact gneiss, not porphyritic but evidently of this belt, S. 70° E. 76° and S. 60° E. 60°.

About  $\frac{1}{2}$  of a mile north-west of this is a quarry in which the gneiss is perhaps better exposed than in any other, the rock is very regular, compact, in parts highly porphyritic, and in parts not so, and wholly unaltered. Here a satisfactory measurement S. 70° E. 85° was obtained ; there are many minor contortions in the rock not affecting the general dip.

There is another quarry on the creek about  $\frac{1}{2}$  of a mile above the State road. The rock is excessively jointed, the joints rusty and weathered, but the weathering merely superficial ; the rock very compact and hard. It has been largely quarried for road metal, for which it seems well adapted.

Along the creek above this are numerous loose masses, and near the city line, a highly hornblendic variety looking much like trap.

It may be noted that the granitic veins or beds in this belt are composed chiefly of feldspar, mostly, I think, orthoclase, with but little mica and quartz. It sometimes contains tourmaline, very rarely garnet ; in the north-east part of the belt the granite is rare, but along Cobb's creek abundant. On Kelly's lane, a road half a mile north-west of the road dividing Philadelphia from Delaware county, and near the creek, coarse granite occurs, underlaid by a schistose gneiss dipping N. 40° W. 15° and N. 50° W. 59°.

About eight-tenths of a mile above the line between Philadelphia and Delaware county there is a bold hill of this granite. Just north-west of the granite a hard schistose variety of the gneiss, in bold bluffs, narrows the valley to a gorge ; this rock is not porphyritic, in part it is almost

scythestone, and contains a few garnets. The dip is not regular, but is probably about  $30^{\circ}$  N.  $70^{\circ}$  W.  $\pm$ . A similar dip continues up the stream for 100', where there is a small bed of the characteristic granite containing tourmaline; while within two or three feet in the line of dip the gneiss or schist contains garnet, kyanite and staurolite. 150 feet further up there is a bluff, distinctly porphyritic, beyond which is a small double valley, the intermediate hill of which is the granite of this belt in loose masses but in great quantity.

Just below the crossing of the creek by the road is a remarkable outcrop of a schistose gneiss containing garnets, similar to that above-mentioned. Seen in winter, when the bare trees and shrubs permit an extended view and from a little distance looking, north-west, it would be taken for a trap dyke. It rises with almost vertical walls from 10' to 35'. The north-west slope is comparatively gentle. Observed closely it is seen to be a schistose gneiss containing a few large garnets. It is in masses of many tons weight, some of them disrupted as if by a recent earthquake. Just beyond this the same granite appears, and further up the characteristic gneiss of great hardness, well exposed in a quarry on the north side of the creek  $\frac{1}{4}$  of a mile east of the Haverford road and in the bed of the creek below the dam. One satisfactory measurement at the wall-like exposure gave  $65^{\circ}$  N.  $40^{\circ}$  W. In the quarry the dip is nearly vertical with contortions; the rock very compact and not distinctly porphyritic. West of this the soft garnetiferous Bryn Mawr schists appear and are exposed on the road crossing the creek near St. Denis Church dipping north-west  $45^{\circ}$   $\pm$ . North-east of the creek on the same road they dip  $45^{\circ}$   $\pm$  N.  $20^{\circ}$  W.

The interesting feature here is finding, clearly within this hard gneiss, strata of schists containing garnets, staurolite and kyanite, not very unlike those occurring to the north-west on the Schuylkill and Wissahickon, but entirely unlike the Manayunk garnetiferous schists, and the question arises whether they are, as they seem to be, really interbedded or whether they are overlying strata caught in sharp synclinal over-turned folds.

On the line of the (proposed) Chester county railroad, going westward from Angora station, we find mica and hornblende schists slightly exposed. The mica schist, or schistose gneiss, dips S.  $40^{\circ}$  E.  $30^{\circ}$  beneath gravel and is followed by the hornblende schists nearly vertical. After crossing Cobb's creek there is a cut through the porphyritic gneiss. At the east end of this cut the dips are N. W. ; at the middle nearly horizontal, then slightly N. W. and curved. In the next cut, at the east end, the rock dips about  $65^{\circ}$  N. W., succeeded by nearly horizontal strata the dips then becoming north-west and steep. At this point there is a large bed of quartz, in part crystallized like the so-called "Babel quartz" ; this is close to the Marshall road ; beyond it the gneiss dips N.  $40^{\circ}$  E.  $55^{\circ}$ , much decomposed. Beyond the Garrett road there is micaceous gneiss, followed by a hard compact granite, dipping N.  $20^{\circ}$  E.  $30^{\circ}$ , and north-east of the State road (two miles from Cobb's creek) a nearly white granite, weathering red, with compact and schistose gneiss dipping N.  $55^{\circ}$  W., composed of numerous layers of different colors.

North-west of the State road the porphyritic gneiss occurs in very compact masses containing much black mica, making a rock easily to be mistaken for a hornblendic gneiss, or even trap. This continues for about a mile and is succeeded by micaceous schists containing staurolite and kyanite. No dips could be obtained in the western part. Whether the granites and gneiss between the Garrett road and the State road belong to the porphyritic belt, or underlie it, is uncertain.

This gneiss continues to and beyond Darby creek, but to what distance I have not been able to ascertain.

South-east of the porphyritic gneiss belt are mica schists and hornblende schists, well exposed along the Schuylkill, and in many small quarries, underlaid by the Fairmount gneiss, properly so-called. This gneiss, upon the hill on which the Fairmount basins are placed, is a fine-grained orthoclase-albite-muscovite gneiss. It makes an excellent building stone. At Fairmount, where, on the west bank of the river, it has been extensively quarried, its laminæ are

contorted, but near Chester they are more regular, so that curbstones twenty feet or more in length are obtained.

This gneiss differs from all others of the vicinity in containing numerous veins, or beds, of granite, generally very coarse, apparently segregated, the feldspar and mica often well crystallized.

At times, however, the granite appears to fill fissures with a displacing of the adjacent stratified rock.

A remarkable instance of this was exposed when the Junction railroad was built. A short distance north of the Pennsylvania railroad there was a cut through alternating strata of hornblende and mica schist. Two nearly vertical dykes of granite penetrated these, but the displacement was very small. See plate p. 1570. It is no longer visible.

In these veins occur several mineral species not found elsewhere in the neighborhood. Opposite Fairmount, besides crystallized orthoclase, albite and muscovite, garnet, beryl, tourmaline, Autunite (lime-uranite), Torbernite (copper-uranite), bismuthinite (sulphide of bismuth), have been found.

In the vicinity of Chester, chiefly on the banks of Crum and Ridley creeks, it has been quarried very extensively; all the above minerals except the bismuthinite have been found and in addition bismutite (carbonate of bismuth) pitchblende, uranochre, thulite and siderite.

The orthoclase, albite, beryl, tourmaline, garnet and autunite are found in this belt in very fine cabinet specimens. The autunite and torbernite are found in the gneiss as well as in the granite.

The mica schists and hornblende schists, between this and the porphyritic gneiss, seem to overlie the Fairmount gneiss. From exposures on the Pennsylvania railroad and on the Chester County railroad they seem also to overlie it. Some of the finer-grained portions of the porphyritic belt bear a closer resemblance to the Fairmount gneiss than to any other rock near, and a resemblance may be traced between the mica schists and hornblende schists on each side of the porphyritic gneiss.

It seems probable that the latter occupies the crest of an

anticlinal. The very massive hornblendic rocks so largely exposed on the Schuylkill, above the Columbia bridge, do not appear on the Pennsylvania railroad. The line of strike would cross the railroad somewhere in the vicinity of Fifty-second street. The elevation of the railroad being about 150' above the river, it seems probable that these are lower rocks which are overlaid by mica schists on the higher ground.

About half a mile west of Fifty-second street, a peculiar gneiss (?) appears and was quarried for ballast for the railroad many years ago. Where undecomposed, it appears to be a felsite, full of iron pyrites, but most of it decomposes with great rapidity. A large pile of quarried stone intended for ballast, decomposed so completely in about five years that the masses which had not fallen to pieces could be crushed in the hand. In this quarry, halotrichite, the so-called iron alum, a sulphate of alumina and protoxide of iron, is a constant product of the decomposition. The same mineral occurs on the hornblendic gneiss, half a mile above the Columbia bridge, but there is no resemblance between the rocks.

At the Pennsylvania railroad this pyritous gneiss appears to occupy a synclinal, the axis of which rises at an angle of about  $30^{\circ}$  south-west either between the mica schists on the south-east of the porphyritic gneiss, and the latter; or perhaps in, but very close to the north-west border of the schists. It is between 200' and 300' in breadth.

In this connection may be mentioned another instance of the rapid weathering of a rock, due however, to the kaolinizing of an albite and not to pyrites.

This was in the Fairmount gneiss, where it was cut by the Pennsylvania railroad, north of Spring Garden street. Originally the cut was narrow, with nearly vertical walls. By the widening of the road-bed, the eastern side of this cut has been removed; the western remains, but has been reduced to a comparatively gentle slope.

In the southern part of this cut, within ten years, albitic gneiss that was so hard that it had to be drilled and blasted,

became so soft that a stick could be thrust into it to a depth of several inches.

Orthoclase and albite crystals and beryl occurred here. The orthoclase was hard and glassy, the albite often soft and chalk-like, and the beryl sometimes decomposed and softer than chalk.

A remarkable belt of gneiss outcrops in Frankford, Phila., with probably an anticlinal structure, but nearly horizontal. Precisely the same rock appears at Wayne station, Germantown (Philadelphia) and at McKinney's quarry on the Wissahickon at the bend about  $1\frac{1}{4}$  miles from its mouth. If this rock is the same, and it can hardly be doubted, the rock must underlie the mica schists, and be raised by an anticlinal at a very different angle from the strike of all the other rocks of the region. A line about W.  $4^{\circ}$  N. would connect these outcrops. This belt also is characterized by its minerals; sphene, apatite, copper pyrites and other ores of copper, molybdenite in fine crystals, molybdic ochre, stilbite, heulandite, apophyllite, hyalite colored by uranium, Randite, sunstone, epidote, calcite, orthoclase, crystalized quartz, tourmaline and biotite, have been found at Frankford, nearly all in good, and some in fine specimens; several of them have been found at each of the other localities. One crystal of molybdenite measured  $2 \times 3$  inches and weighed over a pound.

It may be but a coincidence, but it is at least noteworthy, that the strike of the tongues of Potsdam sandstone projecting into the limestone in Whitemarsh township, Montgomery county, shown on the map in C<sup>o</sup>, are almost identical in strike with this gneiss.

#### *Gravel and Clay.*

The Bryn Mawr gravel has been so well described that I can add very little to what has been published. There is one large outcrop not on the map in C<sup>o</sup> which deserves notice as being probably the most eastern exposure near Philadelphia. It lies upon a high summit of the porphyritic gneiss hill near the northerly corner of Upper Darby township and is well exposed along the road from Phila-

delphia to West Chester, about two miles west of the bridge over Cobb's creek.

A deposit of clay, used for the manufacture of bricks, lies about a quarter of a mile north of Garrettsville and about 800' S. W. of the Lancaster turnpike at the Church of the Good Shepherd, west of Rosemont, and near the east line of Radnor township.

Under the surface soil there is three feet of a yellow clay of good quality, free from stones; under this a stratum of blue clay containing much quartz, and under this, the common decomposed Laurentian. In a pit dug into this decomposed rock, for building sand, the quartz fragments are entirely unlike those of the clay and resemble those of the Laurentian elsewhere; in the clay one rolled pebble was found, the other quartz fragments were sharp and not waterworn. Rarely they contained masses of decomposing feldspar. Most of them are milkwhite; some very closely resemble the hornstone found on the south-east border of the hydromica schists.

It seems not improbable that this is a remnant of an overlying feldspathic gneiss; it is true that a sluggish stream draining the decomposing Laurentian into a lake or pond would account for the yellow clay, but the quartz fragments seem to be foreign to that formation in this region.



*Serpentine and Steatite.**The Steatite Belt in Lower Merion township, Montgomery County.*

Going westward from the steatite quarry on the hill west of the Schuylkill (*n*), the steatite is visible about 300 feet west of the quarry (*m*), the next outcrop is at a road crossing (*I*).

At both the quarry, and at the road, the north bounding rock is distinctly the *woodlike garnetiferous mica schist*.

The course from *n* to *I* is about S. 45° W. ; that of the road, S. 60° W. ; and the strike of the steatite at *I* is apparently S. 60° W.

There was formerly an outcrop at Merion Square, but I am unable to find it now.

Between *I* and *h* the ground is low. At *h* a peculiar ferruginous quartz, probably *pseudomorphous after serpentine*, is visible in the road, and westwardly becomes exceedingly abundant over a considerable area, accompanied, further west, by the "bastard soapstone," or serpentine, *pseudomorphous, probably, after staurolite*, characteristic of this belt, and giving the road its name "Black Rock" road. Here the belt is nearly a quarter of a mile in breadth.

In this vicinity cavities are to be seen, with the form of *staurolite* ; the serpentine having weathered away ; the steatite remaining, reversing the order of decomposition in other parts of the belt, where, both weathering together, but the steatite most rapidly, the serpentine pseudomorphs stand out as irregular knobs.

The direction of this road along most of its eastward portion, is S. 60° W. Its course across Mill creek, and through these rocks in their greatest exposure, is winding ; but a line from end to end of the winding part, has the direction of S. 40° W. The course of the rocks themselves is approximately S. 45° to 50° W.

At the end of the "Black Rocks" the road runs S. 45° W. for about 500 feet, and steatite appears in place in the gutter of the road at *e* near the farm house of Mr. Egbert.

The road then runs S. 60° W. About 200 feet on this course, and in a field north of the road, steatite and chlorite appear loose, but in great quantity, over a space 100 feet wide. Further on the road bears nearly due west, and the steatite showed itself in an excavation for a telegraph pole. The Roberts road crosses 200 feet further west, and on this, 200 feet south of the Black Rock road, is an exposure of steatite in place (*d*); the belt being 120 feet wide; the strike S. 44° W.; dip steep to south-east; south-east wall not visible; north-west wall garnetiferous mica schist.

From this point the belt may be traced by fragments in the field, about on the same course, to a point in the Black Rock road, at the bend just east of Mr. Charles Wheeler's place.

About 150 feet north-east of this bend (*c*), steatite and chlorite are visible in place.

West of this I know of no exposure.

If continuous, the rock should appear in the cut of the Pennsylvania railroad, which is about twenty-five feet deep and directly in the strike of the steatite. A very careful examination while the cut was being widened to make room for the fourth track failed to disclose the slightest trace of serpentine, steatite or allied minerals. There was nothing but mica schist mostly decomposed.

#### *The Lafayette Serpentine belt.*

The belt of *serpentine* in which Rose's quarry, *a* has been wrought, appears on the west side of the Schuylkill about three quarters of a mile north-west of the *steatite belt*, above described. There is also a small outcrop on the east side. It is in the main composed of a hard, very dark green, almost black, serpentine; steatite and chlorite, which make up the mass of the steatite belt, are rare in it. At Rose's quarry it may be well examined.

Its strike is S. 40° to 60° W.; its dip about 45° to 55° S. E.

To the south-east of it appears a thin bedded chlorite (?) schist.

On the south side of the quarry, and largely west of it,

occurs an *enstatite-like rock*, by the alteration of which the serpentine appears to have been formed. In fact in the quarry one bed is enstatite below, serpentine above.

Thence westward the serpentine and enstatite form a steep and very rocky hill, bearing about S. 40° W. and on the north-west side appears a rock which accompanies the serpentine westward. This rock is a "spangled mica schist" or gneiss, in which the mica is in small masses or isolated crystals, generally with curved surfaces remaining brilliant on exposure.

At a point about five-eighths of a mile from the river, and three-eighths of a mile from Rose's quarry, the serpentine is invisible except in scattered masses on the surface. Here there is a conspicuous oval knoll. At the east it consists of black hornblending rock. Immediately on the west, and within a hundred feet ( $\beta$ ) it is of steatite and chlorite, closely resembling the same minerals belonging to the *steatite* belt. Nothing but loose fragments appear, but in such abundance as to prove almost beyond doubt the underlying rock to be of the same character.

Thence the belt may be traced by surface fragments S. 40° W.  $\pm$  about 800 feet ( $\gamma$ ).

Thence S. 50° W.  $\pm$  300 feet to ( $\delta$ ) at the foot of the hill on its northern side.

Here a stream crosses, and beyond the stream the belt is very conspicuous and regular ( $\epsilon$ ) S. 47° W., bounded by the same schist rock, to a point ( $\zeta$ ).

Here the creek bottom intervenes for a distance of some 300 feet. At ( $\eta$ ) the ridge again begins.

The course from  $\zeta$  to  $\eta$  is S. 50° W., so that the belt seems to be shifted northward a short distance. It continues as a bold hill for about half a mile, running, except one curve, about S. 50° W. The hill then suddenly ends; but the rock may be traced by fragments to an exposed outcrop, in the Conshohocken road, near the house of William Schallioll, and to the south of the former line of strike ( $i$ ).

Crossing the road to Bryn Mawr, east of a small stream, with a course of about S. 35° to 40° W., it seems to curve

even more southwardly ; but as this is on a hill side it may be due to creep.

About 400 feet further on in the same direction ( $\lambda$ ) fragments are found abundantly in a field. Through this part of its course the bounding rock on the north appears to be a very thin bedded compact gneiss, with two and often three cleavages ; and also the schist before mentioned.

North of this about 250 feet, just at the crossing of two roads ( $\mu$ ) is another outcrop of serpentinous rock, or a hornblendic rock partially altered to serpentine ; and about 1,400 feet S.  $60^\circ$  W., a similar rock appears, forming a small hill ( $\eta$ ).

East of the Gulf road, and about S.  $43^\circ$  W. from the last, fragments are found in a field.

West of the Gulf road is a conspicuous bluff of serpentine dipping southwardly.

At Rosemont station, S.  $45^\circ$  W. from the last, an outcrop ( $\theta$ ) has been quarried, the rock having much the aspect of the "Bastard soapstone" of the steatite belt. This quarry has been built over (1886).

West of this (at  $\phi$ ) fragments of quartz (apparently pseudomorphous after serpentine) are found ; crossing the turnpike, no outcrop is known, I believe, until within a mile of Darby Creek,  $\tau$ ,  $\upsilon$ .

Since the above was written an outcrop has been observed on the Roberts road, about a half mile south-west of Rosemont station ( $R$ ) on the property of Joseph F. Tobias. It is not over twenty feet wide with mica schist on both sides. Between this and the Old Lancaster road fragments were found in a field.

At  $\tau$  the outcrop is very insignificant, at  $\upsilon$  it is extensive occupying nearly the whole of the space between Bryn Mawr avenue and the Roberts road ; from the Radnor and Chester road to near Darby creek, across which it again outcrops on property of Moro Phillips, where chromic iron was mined, but I believe, not profitably. Thence it extends in a wide outcrop crossing the Philadelphia and West Chester road a mile east of Newtown Square. At this point very fine stalactites of quartz were found. Thence south-

west it extends through Marple township to and beyond Crum creek.

At the Radnor and Chester road its appearance is very abrupt. On the north-east side of the road it is hardly visible, on the south-west side it is conspicuous of a breadth of two or three hundred feet. It is, at this point, largely enstatite passing into serpentine, as it is also in Marple.

If these steatite and serpentine belts be compared their unlikeness seems to point to a different origin.

As indicated by their names the former is largely steatite, the latter almost exclusively a very dark green, almost black serpentine.

The steatite belt contains numerous minerals—breunnerite, dolomite, aragonite, apatite, chlorite, chalcopyrite, magnetopyrite, millerite, magnetite, asbestos, Hallite, talc, actinolite. The serpentine belt contains very few,—varieties of serpentine, enstatite, chlorite (?), asbestos and aragonite being, I believe, the only minerals ever found in it, east of Darby creek. West of the creek chromite and some associated minerals occur.

The serpentine belt has undoubtedly resulted, in part at least, from the alteration of enstatite, as at Rose's quarry the passage of the enstatite into serpentine may be seen.

No such demonstration of the origin of the steatite belt is visible, the only clue to its origin is afforded by the serpentine crystals (pseudomorphs apparently after stauriolite) best seen where the belt crosses Mill creek (Black Rock road) Lower Merion, but not rare at the soapstone quarry. These would indicate the alteration of a schist.

There is one remarkable exception to the individuality of these belts, the outcrop of the Lafayette belt at Rosemont; the rock at this point is wholly unlike that of any other part and closely resembles the "Bastard soapstone" or black rocks of the steatite belt.

North of the Philadelphia and West Chester road, about one mile east of Newtown Square, near the eastern limit of the serpentine, is a quarry in hornblende schist like that of the Philadelphia and Manayunk belts, but the schist appears to be changing into serpentine.

*Serpentine west-south-west of Newtown Square.*

This seems to be an easterly extension of the Castle Rock enstatite converted into serpentine, but so far as I have observed, the serpentine and enstatite do not occur together.

Like the serpentines of Lafayette and Radnor it lies very close to the Laurentian, which may be seen in a distinct outcrop on the West Chester road three-quarters of a mile west of Newtown Square at a fork, the south-west road leading to the serpentine and Castle Rock. The road bears S. 70° W. the Laurentian strikes about S. 75° W. and the serpentine occurs in the road about half a mile from the fork. If the Laurentian continues of the same strike the serpentine is within two hundred feet of it. This outcrop is characterized by great quantities of quartz pseudomorphous after the serpentine, the cavities lined with crystals, colorless, bright yellow and bright red. Some of the cavities contain myriads of microscopic quartz crystals (loose in a reddish mud). Many of these are perfect doubly terminated crystals which make beautiful polarizing objects for the microscope, under which the coloring matter is seen to occupy but a small part of the crystal, the rest being colorless and perfectly transparent.

Limonite with fibres two or three inches long occurs here.

Between this and the belt east of Newtown Square, the country is highly cultivated, and exposures are infrequent, but what there are show mica schists and gneisses which do not closely resemble any others of the region.

*Radnor Serpentine belt.*

The largest and most prominent belt of serpentine in Radnor township begins, easterly, on the Mattson's Ford road about three-eighths of a mile east of Radnor station, about one-eighth of a mile west of the Montgomery county line on the western side of a small affluent of Gulf creek. (101 on the map). It forms a bold hill about 200' across. The opposite hill is steep, with Laurentian fragments, without a trace of serpentine. The outcrop crosses the road with a strike nearly west. The following dips were obtained near

the south-east edge but are probably of little value, N. 45° W. 65°; N. 25° W. 65°; N. 22° W. 80°.

The length of this outcrop is about 700' to a small valley, on the northern side of which ( $\frac{1}{8}$  mile S. 65° W.) is a second but insignificant outcrop (102).

The rock in contact with the serpentine is concealed, but on the south, east, and north the soil is filled with Laurentian fragments; and about 300' north of 101 is a quarry in Laurentian, which also is exposed in the bed of Gulf creek about 600' north with dips S. 25 E. 70° and S. 15 E. 70°. On the north-east is a hill with Laurentian outcrops, around which the road curves to the north. On the south-east side of this hill the rock dips S. 5° E. 74° and in the road near S. 8° E. 80°, strike N. 60° E. vertical N. 30° E. 70°, but these are not entirely trustworthy.

At 103, on the western side of the road from Radnor station to King of Prussia, the serpentine again appears and continues about S. 60° W. 1000'. If the line of strike of outcrops 101-102 be extended it will meet this outcrop about its centre. At the southwestern end it has been quarried (Stacker's quarry), and there were strong indications of a synclinal (see plate page 1570), but there is much doubt whether the seams are bedding planes, or cleavage lines, or irregular joints. They are very irregular, and throughout the quarry often run to thin edges, as at c-d-e. In a well, fifty-two feet deep near by, the same irregularity occurs, and no regular stratification can be seen. Near the southern edge of the serpentine, on the adjoining land of Theo. D. Rand, a mass of serpentine had a nucleus of unaltered enstatite. The serpentine hill ends as abruptly as it began, but to the north-west about 300 feet is a small outcrop on the land of Henry A. Geisse (see plate page 1586) with a strike N. 30° E. and dips 30° to 80° to the south-east. Due west from this and within 200 to 300 feet are Laurentian rocks, loose, but in large masses, while within the line of strike and within 50' of abundant continuous serpentine fragments is a well in Rogers' altered primal much decomposed dipping to the south-east, striking N. 70° E. East of it is Laurentian exposed along

the Radnor and King of Prussia road and also in a well.

At all these outcrops the rock is largely a very dark compact serpentine resembling strongly that of the Lafayette belt. It is sometimes green, but never, unless weathered, a light color. Much of it appears as if it had been an enstatite-like mineral and was not quite changed into serpentine. On Stacker's property at the south-west edge of the quarry the change of the serpentine into the honey-comb quartz, so abundant here as well as at other serpentine outcrops, is well shown. At the lower part, the serpentine is almost unaltered, above small seams appear containing quartz films; higher up these films become thicker and the serpentine becomes more disintegrated, until near the top, the quartz, is some 2" thick and the serpentine almost gone. Masses of this quartz, almost solid, and weighing upwards of 200 pounds have been found.

In the serpentine few minerals occur. At the Stacker quarry, chrysotile, asbestos, marmolite, serpentine pseudomorph after asbestos, and chlorite have been found, and at Rand's chromite, Genthite, enstatite, mountain cork and deweylite; at both, drusy quartz, chalcedony, &c.

At outcrops 103-104 the rocks immediately in contact with the serpentine are not visible but on the south-west Laurentian rocks occurred certainly within 200' and fragments are abundant in the soil. On the south-west Rogers' altered primal is exposed within about 200' north-west of 103 and 104, also in the above mentioned well, while garnetiferous mica schist was found in a well about 300 feet N. 85° E. from the last. (See plate p. 1586).

West of this no outcrops are known for about two miles, then in Tredyffrin, in the valley nearly south of old Eagle station, is the fifth outcrop, whence some stone has been quarried. The outcrop is small and the strike indistinct; the sixth, south-west of Eagle, east of and near the road between Delaware and Chester counties, is S. 70° W. from the former, the strike is S. 40° W., the dip 70° to 80° south-east. This quarry has been extensively wrought to supply building stone for the Devon Inn, and the exposure is good.

The seventh exposure is in Easttown about 300 feet west and a little north from Devon Inn and nearly due west of the large quarry. The exposure is small but the strike is very clearly S. 40° W. In a recent excavation, a surface exposure was S. 50° to 60° W. The dip 55° to the south-east.

The eighth is a little south of west of the seventh, strike and dip not distinct. The ninth, that crossing the road running south-east from Berwyn, and about a mile from that station, is at its eastern end S. 10° W. from the eighth, its strike is S. 40° W.

The extensive belt south of Paoli is in Willistown, nearly west from this, and extends thence as the wide and well-known belt passing one mile north of West Chester.

A glance at the map will show that these outcrops, though on a line bearing nearly east and west, all cross that line at angles, striking more north-east and south-west except the first. This is very evident on the ground. An observer standing on the brow of quarry E. of Devon at its south-west end, sees before him a valley bounded on the north side by the hydro-mica South Valley Hill and on the south by the Laurentian gneiss hill. In front of him the serpentine in the quarry is seen to strike towards the hydro-mica at a considerable angle; while the fifth outcrop, in plain sight, is not in line at all. The same may be seen at outcrops further west but not so distinctly.

*On the Northerly Serpentine Belt in Radnor Township,  
Delaware County and in Lower Merion, Montgomery  
County.*

The most easterly outcrop (2) is in the Gulf road, 500 feet south of the Mattson's Ford, or township line road, except a small exposure (1) of surface fragments, two or three hundred feet east of this outcrop.

Here the rock is a serpentine, dark green with portions of red; it is bounded north apparently by the hydro-mica schists of the Gulf hills decomposed (or at least they are very near); on the south by (Roger's altered primal).

The next outcrop (3) is at a small house on the Mattson's Ford road 400 feet east of the county line road (between

Delaware and Montgomery counties) and opposite the house, in the field (4); this is about S. 60° W. from the former. Near this a garnetiferous mica schist occurs. It is not visible in place.

About one-fourth of a mile S. 85° W. of this, is an outcrop on the property of Judge Hare. Here the rock was exposed by a ditch, steatite, serpentine and chlorite being found, with a garnetiferous mica schist; and perhaps on both sides of the belt and certainly on the north-west the altered primal of Rogers, thin bedded, gneissic rocks.

The same steatite rocks were also exposed in a cellar dug for a house on the Radnor and King of Prussia road about 500' south of Gulf creek. This lies about half a mile almost due west from the outcrop at Judge Hare's, almost exactly the bearing and distance of the outcrops of the larger belt to the south, and quite different from the usual strike of the region and of these rocks themselves in local exposures.

[The steatite exposure in Judge Hare's drain, was examined by Mr. C. E. Hall who reported as follows:

The steatite belt here occupies the ground south of Gulf creek and between it and one of its southern affluents which rises near Radnor station.

The outcrop cuts across the drain, in a south-west direction, and that is all that can be said of it. It was not exposed well enough to give a dip, or even the true strike; although the strike seems conformable with that of the syenite rocks of the neighborhood; and therefore in the direction of the serpentine at Mr. Rand's house; but Mr. Hall, who examined the locality, inclined to the opinion that while both serpentine and steatite were associated with the syenites, they were individually distinct members of the series; and not two exposures along the same outcrop line, with two different characters at the two points on the line. He adds:

“Although having the same strike as the syenites, it is not necessary to suppose that they are conformable. The dips obtainable at serpentine localities are worthless.

“I conclude that the serpentine group of N. E. Dela-

ware county has been deposited non-conformably upon the syenite rocks; and to an extent rolled up and contorted with them; being left in lenticular patches [of theoretically synclinal shape] parallel to the strike of the syenites.

“In all probability, there are two groups of serpentines. The above mentioned group does not seem to have slates associated with it, unless possibly the South Valley Hill slates.

“The serpentine group which extends from Chestnut Hill to Bryn Mawr and the serpentines of Delaware county are associated with schists, which do not appear any where through the northern part of Radnor township.

“The cellar excavation of Judge Hare shows syenite rock of which the upper edges appear to have been broken to pieces and the spaces filled up with surface soil.]

Comparing the rocks on each side of the Laurentian the similarity is striking, but not without equally striking differences. On the north (strictly N. W.) we find the altered primal on the south an almost identical rock; on the north mica schists and garnetiferous schists; on the south almost identical rocks. Close to these on both sides is the white sandstone, undoubtedly Potsdam, on the north side. On both sides occur also two belts of serpentine rocks, the inner of very dark serpentine resulting from the alteration of enstatite, the outer largely steatite with lighter serpentine. The serpentine is almost continuous a long distance; the steatite is not.

On the north, however the serpentine is almost certainly within the Laurentian; on the south the altered primal and spangled mica schist intervene. On the north the white sandstone is beyond the steatite; on the south it is close to the serpentine.

It does not seem possible, with our present knowledge, to construct a satisfactory section through this region from the Chester valley to the Delaware; but I think there can be little doubt that the mica schists and sandstone of Cream valley are repeated on the south-east of the Laurentian axis; and that between the two steatite belts the structure is a simple anticlinal. South-east of this the mica schists, por-

phyritic gneiss and Fairmount gneiss, with the intervening mica schists, require more study ; but it seems not incredible that the first named may be the same as the hydro-mica schists. The resemblance between the decomposing hydro-mica schists at the crossing of the Mattson's Ford and Gulf roads and the mica schists at Byrn Mawr (L. M.) is very close.

In these notes it has been my object to make an accurate record of the outcrops of the various rocks, rather than to uphold any theory, believing that if a careful thorough mapping of this region be made, advantage being taken of chance exposures in recent cuttings, wells, &c., wherever possible, the time will not be far distant when we shall no longer have to admit that we do not know the geological structure of a part of our State which has been so long studied. As a small contribution to this end these observations are offered.