Seventeenth Annual Conference of Pennsylvania Geologists

Bryn Mawr College, June 1,2,3, 1951

GUIDEBOOK

ILLUSTRATING THE GEOLOGY OF THE PHILADELPHIA AREA

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by

E. H. Watson and Dorothy Wyckoff
Bryn Mawr College

H. E. McKinstry of Harvard University contributed the unpublished material on the Avondale-West Chester area. Other work incorporated is: A.W. Postel (U.S.G.S.), on the Springfield granodiorite and Mine Ridge; E. Armstrong (mylonites); Judith Weiss (Wissahickon schist); C.S. Ch'ih (granitization and Wissahickon schist); G. W. Stose (mapping in Chester Valley). All the geology of this region rests on the pioneer work of Florence Bascom.

Bibliography at end of the Guidebook.

All figures drawn by Dorothy Wyckoff.

GEOLOGIC HISTORY OF THE PHILADELPHIA REGION
(Alternative interpretations in parallel columns)

TRIASSIC	Faulting Diabase dikes Red sandstones and shales	
APPALACHIAN REVOLUTION	Folding, mylonitization and slight metamorphism	Folding, mylonitization and metamorphism most intense in southeast, where accompanied by igneous activity: pegmatites granodiorite (granitization) gabbro pyroxenite
TACONIC REVOLUTION ? ?	Martic overthrust	
O	Octoraro phyllite? Conestoga limestone	Peters Creek schist Octoraro phyllite = Wissahickon schist Conestoga limestone = Cockeysville marble
EARLY PALEOZOIC €	Elbrook limestone Ledger dolomite Vintage dolomite Antietam quartzite Chickies quartzite	Elbrook limestone Ledger dolomite Vintage dolomite Antietam quartzite } = Chickies quartzite } Setters quartzite
LATE PRE-CAMBRIAN	Folding, metamorphism, intrusion of igneous rocks: pegmatites granodiorite (granitization) gabbro pyroxenite	
GLENARM SERIES	Peters Creek schist ? Wissahickon schist Cockeysville marble Setters quartzite	

EARLIER PRE-CAMBRIAN

older diabase

major deformation and metamorphism, intrusion of igneous rocks:
- pegmatites
- granodiorite and granite
- gabbro and norite
- pyroxenite and anorthosite

Franklin marble
Sedimentary gneiss with graphite = Pickering gneiss of Mine Ridge

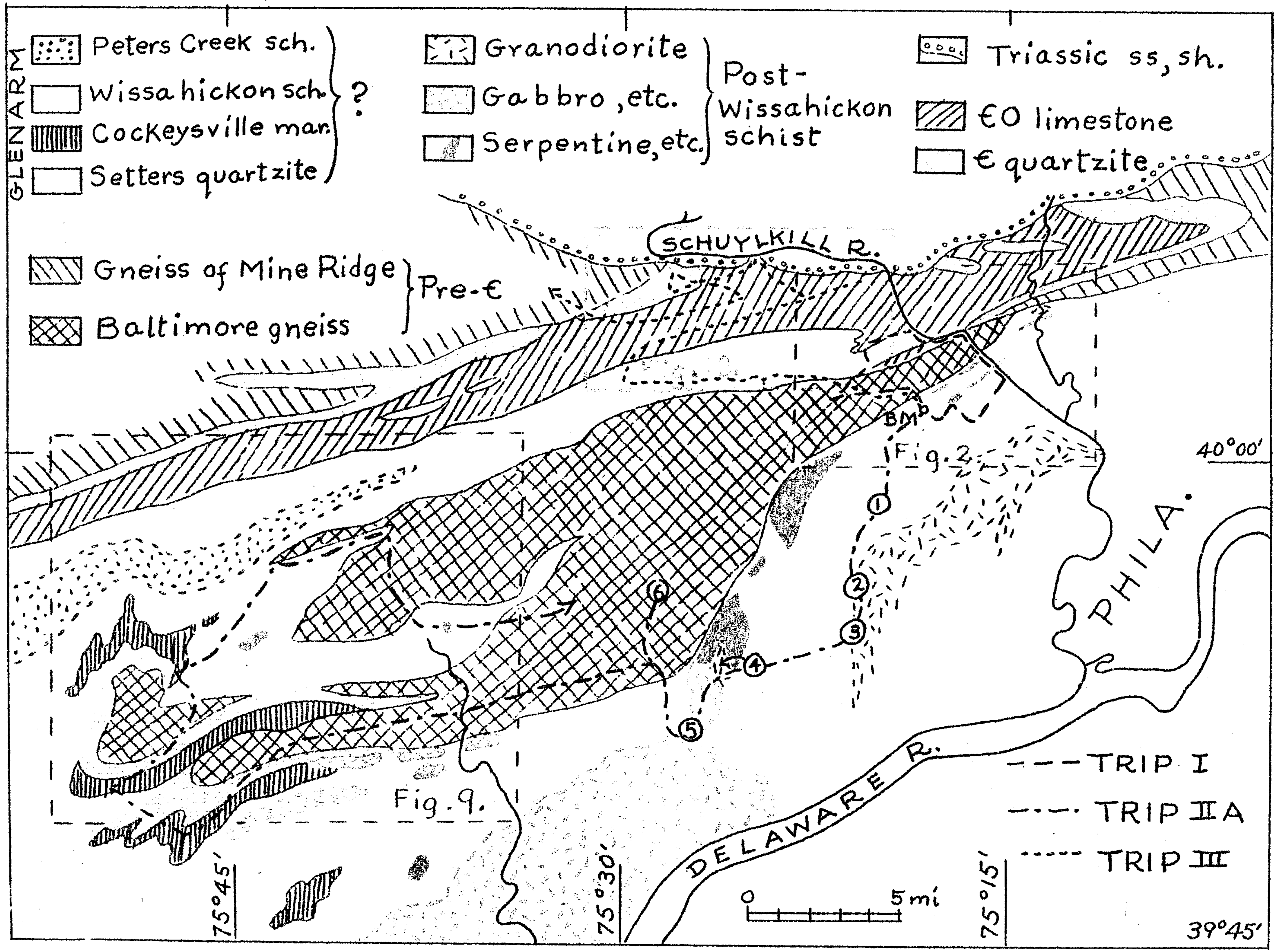
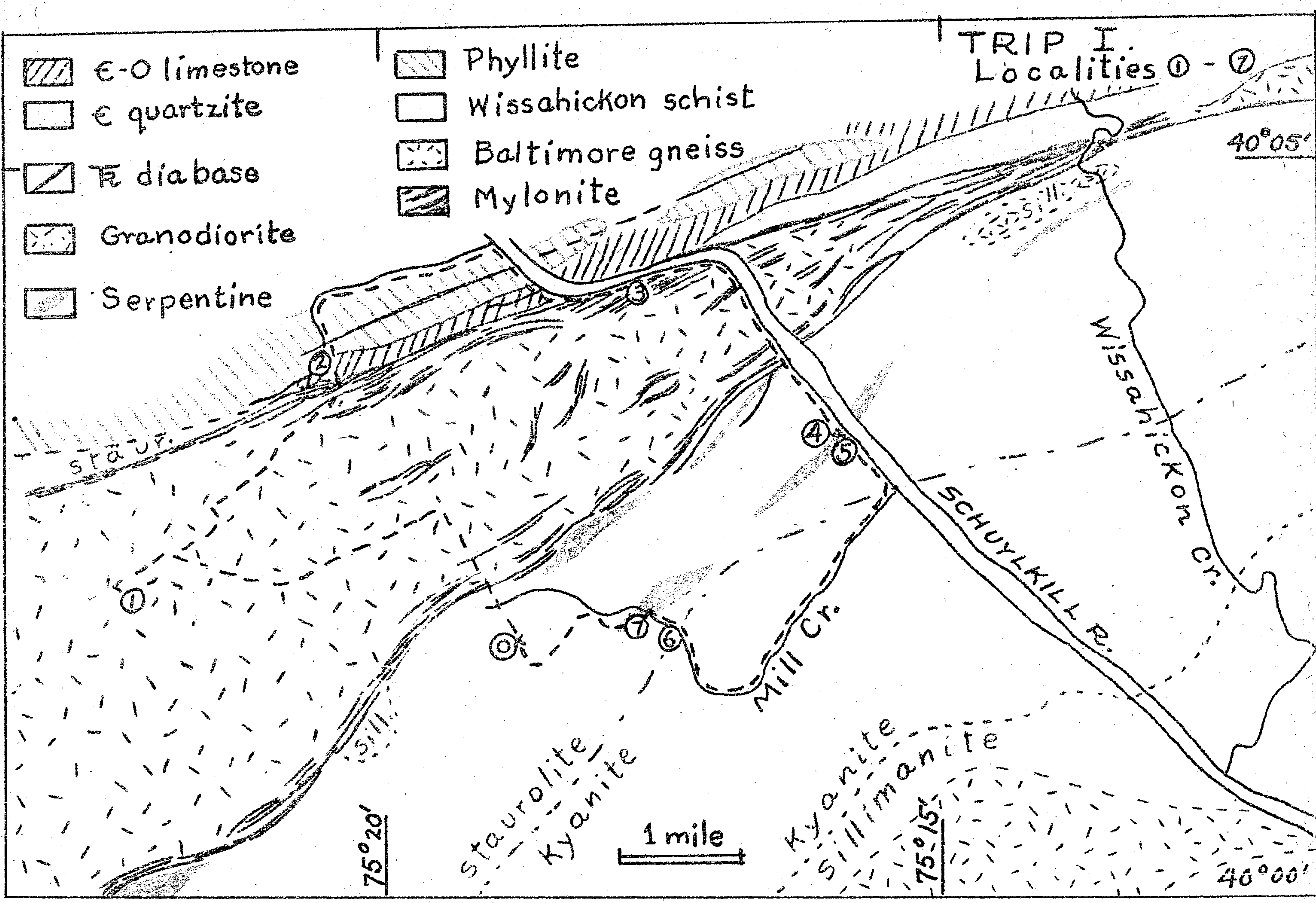

GLENARM
Peters Creek sch.
Wissahickon sch.
Cockeysville mar.
Setters quartzite
?
Granodiorite
Gabbro, etc.
Serpentine, etc.
Post-Wissahickon schist
Triassic ss, sh.
€O limestone
€ quartzite
Gneiss of Mine Ridge
Baltimore gneiss
Pre-€
SCHUYLKILL R.
BM
Fig. 2
Fig. 9.
40°00'
PHILA.
DELAWARE R.
TRIP I
TRIP IIA
TRIP III
0
5 mi
75°45'
75°30'
75°15'
39°45'
1
2
3
4
5
6

Fig. 1.



TRIP I.
Localities ① - ⑦
Є-O limestone
Є quartzite
Ʀ diabase
Granodiorite
Serpentine
Phyllite
Wissahickon schist
Baltimore gneiss
Mylonite
40°05'
40°00'
75°20'
75°15'
Wissahickon Cr.
SCHUYLKILL R.
Mill Cr.
staur.
sill
Staurolite
Kyanite
Kyanite
Sillimanite
1 mile
①
②
③
④
⑤
⑥
⑦

Fig. 2.

ITINERARY FOR FRIDAY, JUNE 1

Miles	
0.0	Park Hall, Bryn Mawr College Left on Gulph Road.
1.3	Left on Pa. 320 (Spring Mill Road).
1.7	Cross Montgomery Avenue.
2.4	Villanova College on the left.
2.7	Turn right on U.S. 30 (Lancaster Pike).
3.7	Go past traffic light, 200' beyond and turn left on Ivan Avenue.
4.2	Turn left on dirt road by stream into Old Radnor Quarry.
4.4	STOP 1. Radnor Quarry. Turn around and park cars in lot.

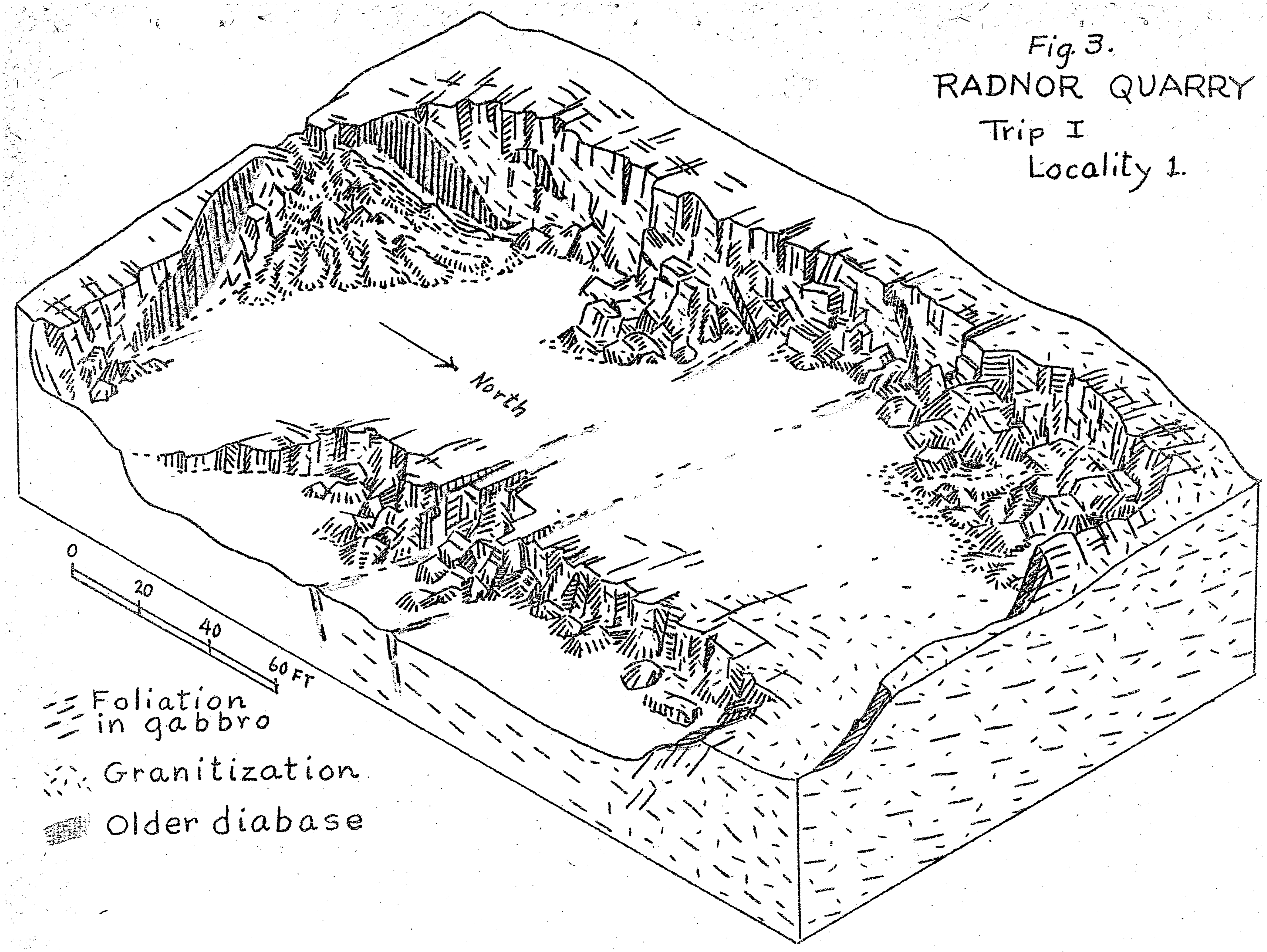
The Baltimore gneiss throughout this general region (see figure 2) shows the following sequence of events:

1. Rare traces of sedimentary rock
2. Mafelsic gabbro
3. Mafic gabbro
4. Anorthositic gabbro
5. Granitization: migmatites, granites and pegmatites. Major deformation and metamorphism, syntectonic.
6. Older diabase
7. Crushing (mylonites), and minor hydrothermal alteration.

Various parts of this sequence are found in different localities and the whole series can seldom be seen at any one place. The Baltimore gneiss, as defined in the Philadelphia folio, refers to the granitoid rocks and the mylonites into which the mafic rocks were thought to be intrusive. Just the reverse sequence, given above, is believed to be true and the term Baltimore gneiss as used here refers to the whole complex.

Radnor Quarry represents a relatively massive part of this sequence, which has not suffered the extensive crushing which we will see at the mylonite locality at stop No. 3 (figure 2). Relatively massive and unaltered gabbro can be seen here in the southeast part of the quarry near the entrance (figure 3). Towards the north in the quarry, granitization with pegmatites occurs, producing migmatites, and deformation and metamorphism are more intense. Some of these rocks carry abundant garnet for which the recalculated analysis is approximately--almandine 56%, pyrope 32%, grossularite 10%, and spessartite 2%; specific gravity = 4.04. Many of the pegmatites here are quartz dioritic.

Fig. 3.
RADNOR QUARRY
Trip I
Locality 1.



Miles

As a much later event intrusions of diabase occurred. Some of these are in the form of dikes, but on the south wall parallel to a faint foliation in the gneiss in the form of a plunging anticline, a phacolith occurs. These intrusives still retain their chilled borders and straight-sided eruptive contacts but have been completely recrystallizaed by later thermal metamorphism. They are now made up of augite, hornblende, biotite, garnet, and andesine. However, their bulk composition remains the same as shown by the following chemical analysis of the three-foot dike exposed on the northwest face of the quarry:

SiO_2	47.02
TiO_2	0.72
Al_2O_3	15.24
Fe_2O_3	1.56
FeO	9.46
MnO	0.17
MgO	11.42
CaO	11.27
Na_2O	2.51
K_2O	0.14
H_2O^+	0.18
H_2O^-	0.18
P_2O_5	0.12
S	0.11
BaO	0.00
ZrO_2	0.01
Cr_2O_3	tr
	100.11

This analysis is rather close to that of an olivine diabase.

Elsewhere in this area these dikes may retain good relict ophitic textures, whereas at still other localities they have been crushed by the later mylonitization. Indeed, in this quarry thin metadiabase dikes have been crushed to a minor degree in the northwest corner. However, it is not yet certain that the main mylonitization preceded or followed the metadiabase. Or two periods of crushing may have occurred. In any event, all these rocks are surely pre-Cambrian, since the sequence here is very similar to that in the Mine Ridge (see figure 1) which must be pre-Cambrian.

4.6 Leave quarry. Turn right on Ivan Avenue.

5.1 Turn left on U.S. 30 (Lancaster Pike).

5.6 Turn right at traffic light (Chamounix Road).

5.7 Pennsylvania Railroad Station--St. Davids.

5.8 Turn right on St. Davids Avenue.

6.0 Turn right on Glen Mary Lane.

Miles

6.1 Turn left on Hilaire Road (which becomes Glen Mary Road).

6.5 Turn right on King of Prussia Road.

6.65 Turn left on Matson Ford Road at Radnor Station.

8.2 Turn left on Pa. alternate 23 at P & W, Conshohocken Road Statior

Cream Valley fault here. Limestone valley to north.

8.6 STOP 2. Octoraro phyllite. Park cars in gorge of Gulph Creek. Congested traffic: please park far to the right.

Limestone is exposed about 500 feet southwest of this point and a Triassic diabase dike with rude columnar jointing outcrops in the stream about 300 feet to the southwest. The phyllite is responsible for the hill here and shows a flow cleavage which is about N65°E vertical at this point. Cutting this flow cleavage is a coarse fracture cleavage which has about the same strike but dips 40° to the north. Many of these show a drag folding which indicates upthrusting from the north, in which case the term shear cleavage could be used. This fracture system could possibly be complementary to the movement on the Cream Valley fault nearby to the south which is steep upthrust from the south. The flow cleavage is not the original bedding and in the railroad cut above this point what are believed to be faint traces of bedding, commonly marked by quartz veins, show close folding with drag folds towards the northwest. As can be seen in figures 3a and 10, the phyllite is repeated at least twice across the strike in this area and each occurrence marks the positions of tight synclines plunging to the west.

Some workers believe this phyllite to be the less metamorphosed equivalent of the Wissahickon schist, and if the Martic overthrust exists in this region it is represented by the highly folded contact between the phyllite and limestone. Bascom assigned the Octoraro phyllite to the Paleozoic and made the Wissahickon pre-Cambrian.

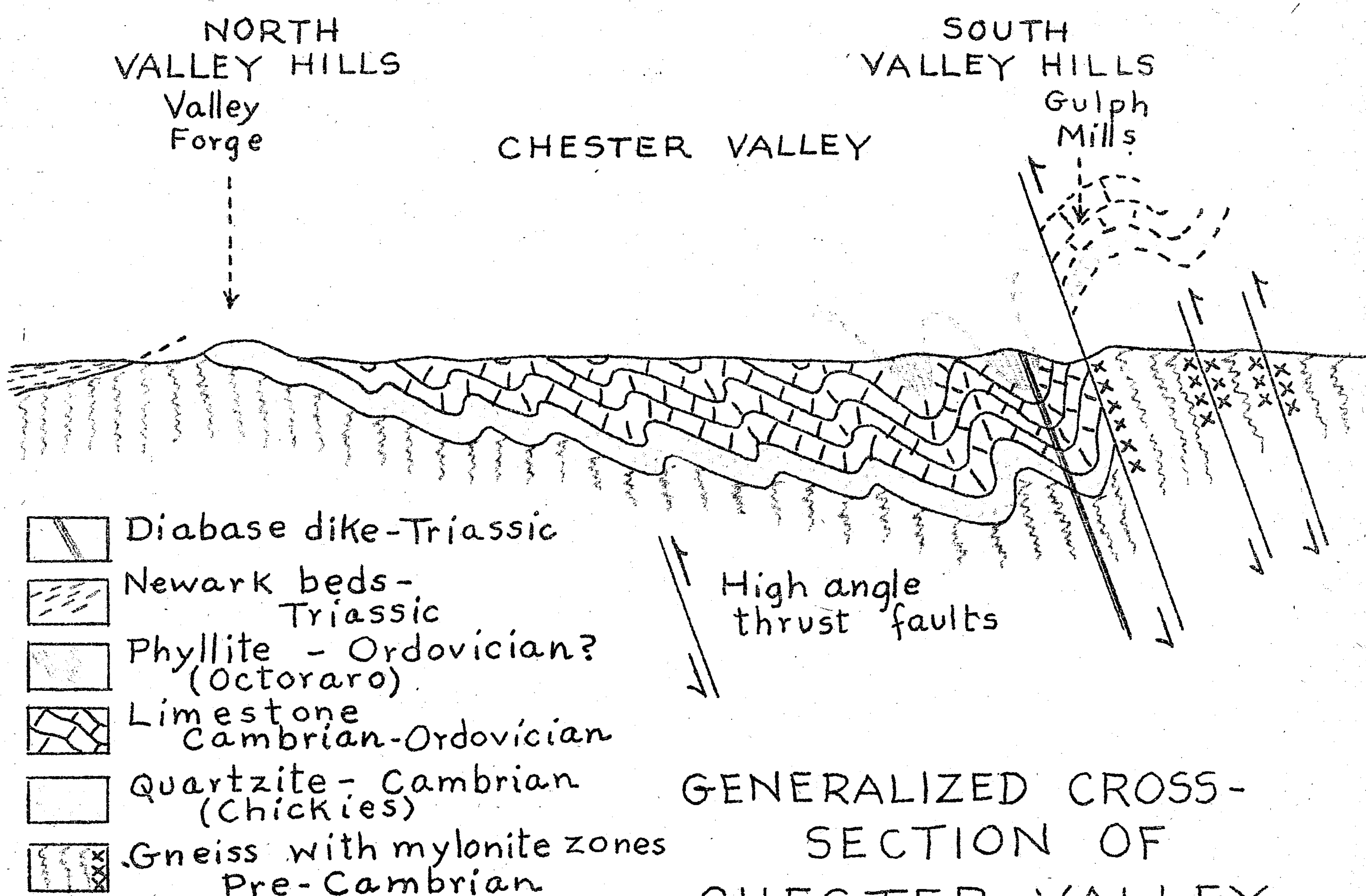
Continue along Pa. 23.

8.9 Gulph Mills.

9.0 Turn right on dirt road. Note construction for Philadelphia Throughway, extension of Pennsylvania Turnpike.
Octoraro cuts in throughway on right (south).

10.0 Exposures of Octoraro phyllite on the right.

10.1 Exposures of Upper Conestoga limestone. Between these two points the Martic overthrust would have to be present in this region.



GENERALIZED CROSS-SECTION OF CHESTER VALLEY
(Looking ENE)

Fig. 3a.

Miles

10.5 Bear right.

10.6 Outcrop on right in Conshohocken Triassic diabase. Same as noted at Gulph Mills.

10.8 Straight through at traffic light. (South end of Conshohocken Bridge).

10.9 Turn left nearly 180°.

11.0 Sharp left turn down to River Road. Bad traffic conditions. Town of Conshohocken north across Schuylkill River to left.

11.5 STOP 3. Springmill Mylonite on River Road.

The hill here is a fault-line scarp upthrust against Paleozoic limestone which underlies Conshohocken immediately north of the River. The fault is in the bed of the River. Farther to the east the fault is between the gneiss and Chickies quartzite on the north, whereas to the west a few miles, Octoraro phyllite and gneiss are on either side of the fault. The Baltimore gneiss here was originally made of the same rock units seen at Radnor Quarry, but now profoundly changed by intense cataclasis. Every gradation between uncrushed, relatively massive gneiss and true mylonite can be seen in the exposures down the River from this point, especially on the east side. The mylonite zones grade from thin microscopic stringers to masses a quarter of a mile wide. Quartz is the first, and finally the most completely, crushed mineral, followed by the feldspars and mafic minerals in order. Micas and hornblende were easily rotated and show some recrystallization. Stream-lined lens-shaped porphyroclasts of individual minerals are abundant and these grade upward in size to uncrushed remnants of the gneiss. At places minor porphyroblasts of hornblende, biotite, and epidote are late hydrothermal developments.

The larger mylonite zones are next to the faults at the boundaries of the gneiss block. Others occur within the block delimiting large lens-shaped masses of uncrushed gneiss, some of which are nearly a mile long. Locally, streams follow the mylonite zones.

The boundary faults must be post lower Paleozoic and are probably Appalachian in age. The mylonitization was possibly contemporaneous.

Continue along River Road.

12.4 River Road and Schuylkill River bear to right across strike of the Baltimore gneiss.

Miles

13.5 Rosemont fault separating Baltimore gneiss on north from Wissahickon schist on south.

13.6 Excavations at culvert show sheared Wissahickon and some anthophyllite rock altered from serpentine.

13.7 Left over Reading Railroad tracks. Watch for trains.

14.2 STOPS 4 and 5. Quarries in talc and in Wissahickon schist.

Stop 4. Two zones of ultrabasic rocks are intrusive into the Wissahickon schist: one is on or near the Rosemont fault which bounds the Baltimore gneiss on the south and the other is about a mile southeast of this. These zones extend intermittently to the southwest into the Chester quadrangle towards Media and Lima where they form much larger bodies. The larger bodies have cores of pyroxenite and other unaltered ultrabasic rocks, whereas the smaller ones are highly altered. All of them are serpentinized to varying degrees and the thinner masses may be changed to varying combinations of chlorite, talc, and anthophyllite with minor amounts of actinolite, tremolite, carbonates and iron oxides. The mass here, halfway between Lafayette and Rose Glen on the Schuylkill, is dominantly composed of talc and is only a little wider than the quarry exposure. A poor grade of soapstone was quarried here in the past. Some parts of the body are nearly pure talc, others contain actinolite, chlorite, etc., in addition. The structure of this talc schist is similar to that of the enclosing Wissahickon schist.

Stop 5. Wissahickon schist, exposed here, is a metamorphosed sediment, assigned by some to the pre-Cambrian, by others to the lower Paleozoic. (This point will be discussed in the field on Saturday afternoon).

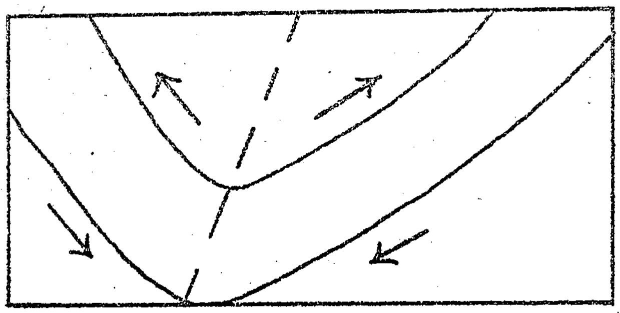
In this quarry the sedimentary character of the Wissahickon is indicated by lithologic differences between layers, representing original sandy and clayey beds (now quartzitic gneiss and mica schist, respectively).

The bedding is approximately vertical, thrown into minor folds with axes nearly horizontal. (See figure 4, nos. 2 and 3). Micaceous layers show crumpling on a still smaller scale, forming a lineation parallel to the major fold axes of the region.

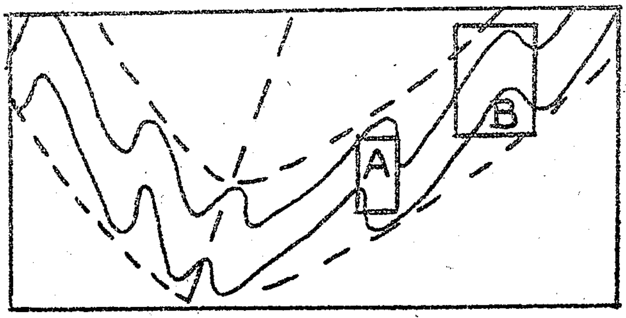
Recrystallization is complete: quartz, plagioclase (oligoclase-andesine), muscovite and biotite are the major constituents. Garnet is conspicuous in some layers: this has been calculated (Weiss,1949) from chemical analysis to have a composition

andradite	3.2
grossularite	9.9
spessartite	1.4
almandine	85.5
	100.0

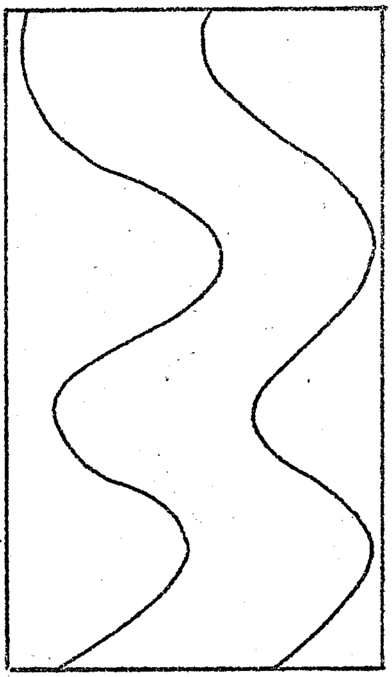
DEVELOPMENT OF FOLDS IN WISSAHICKON SCHIST.



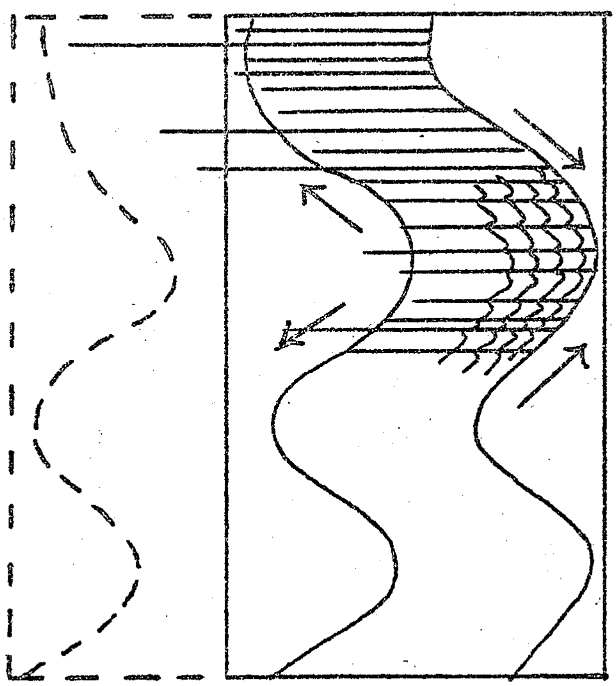
1. Asymmetric major syncline, axial plane dipping NW.



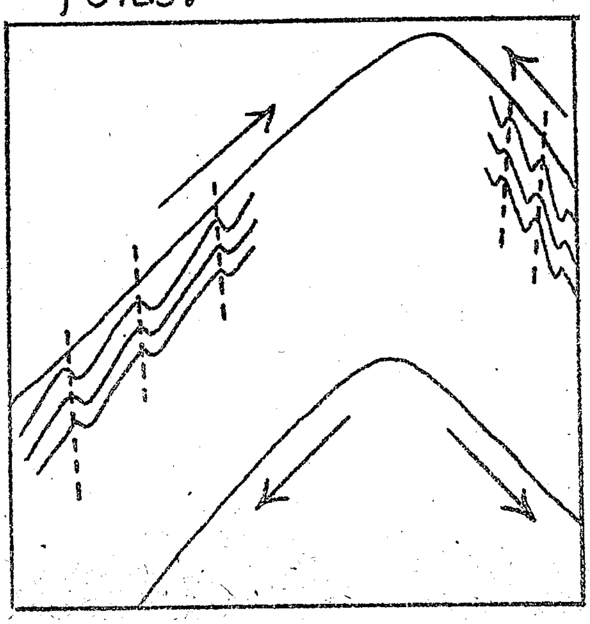
2. Development of folds on both limbs, showing overturning both NW and SE.



3. Section A of No. 2: vertical limbs thrown into minor recumbent folds.



4. Further development of crenulation in micaceous layer. Fracture cleavage extends into adjacent sandy layer.



5. Section B of No. 2: Development of crenulation and fracture cleavage on both limbs of open fold.

(Adapted from C-S. Ch'ih, 1950)

Fig. 4.

Miles

Staurolite has been detected under the microscope, and magnetite, zircon, and apatite are common accessories.

Regional metamorphism apparently increases toward the southeast, and sillimanite is found in the schist along the margins of the granodiorite bodies. Still later, hydrothermal activity has locally altered biotite to chlorite and formed needles of tourmaline.

14.4 This part of River Road is under water at high stages of the Schuylkill River.

14.9 Roseglen. Cross Mill Creek and turn right under railroad on Mill Creek Road.

15.4 Continue straight along Mill Creek Road (Gladwyn Colony Sanitarium).

Mill Creek Road roughly parallel to Wissahickon schist, exposures of which are abundant along the route.

16.2 Continue straight, Pa. 23.

16.8 Cross Mill Creek.

17.5 Bear right on Pa. 23.

17.7 Bear left keeping on Pa. 23.

17.85 Bear left leaving Pa. 23 onto Dove Lake Road.

18.1 STOP 6. Dove Lake.

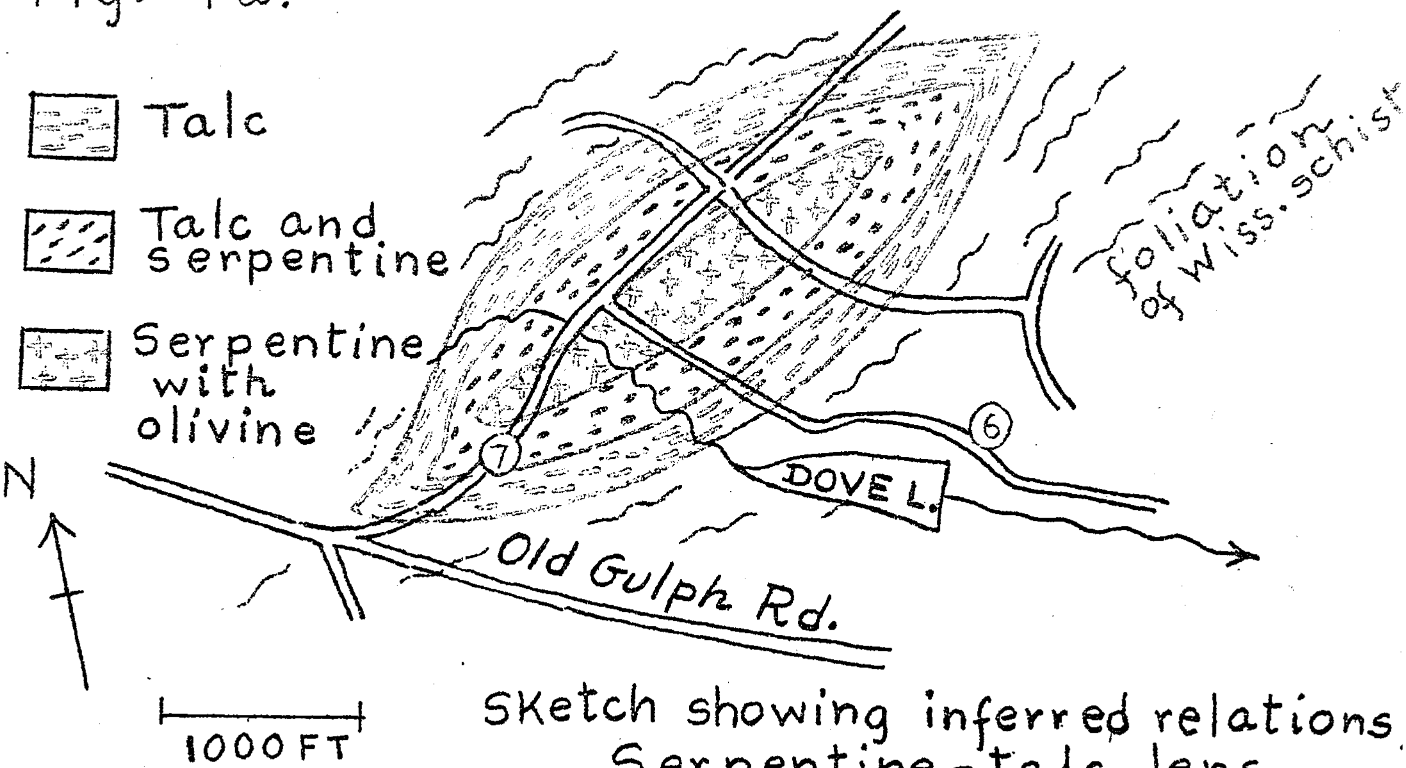
Wissahickon schist exposed along Mill Creek, shows intricate folding of the flexure-slip type, with micaceous layers thrown into drag folds which can be used in interpreting the major structures. At this point the folds are slightly overturned toward the southeast, with axial planes dipping northwest - a tendency which becomes more pronounced farther to the southeast.

The texture and mineralogy of the rocks here are similar to those at the last locality, but the microscope reveals rare, minute crystals of kyanite, as well as staurolite.

Continue on Dove Lake Road.

18.35 Turn left on Black Rock Road.

Fig. 4a.



Sketch showing inferred relations
Serpentine-talc lens
near Dove Lake

Miles

18.5 STOP 7. Black Rock.

The exposures along Black Rock Road here are within a lens-shaped mass of serpentine, as shown in the accompanying sketch, figure 4a. The center of the mass is serpentine with some relict crystals of olivine. Surrounding this is a zone in which both talc and serpentine occur, the serpentine at places appearing like xenoliths within foliated talc. A band of pure talc occurs at the border.

The original olivine and the serpentine were probably formed during the magmatic stage of the intrusion of the ultrabasic rock, and the talc developed at the time of the major deformation of the enclosing Wissahickon schist. Where the mass was very thin, as at locality No. 4 on the Schuylkill, it was entirely changed into talc. Thicker masses were more resistant and only affected at their borders. It is even possible that the deformation was intense enough to pull out the original dike into large isolated lens-shaped masses, a sort of boudinage on a large scale.

18.7 Keep around to right through five point intersection onto Old Gulph Road.

19.0 Turn left on Morris Avenue.

19.6 Turn sharp right onto New Gulph Road.

20.0 Entrance, left, Park Hall, Bryn Mawr College.

ITINERARY FOR SATURDAY, JUNE 2

Miles	
0.0	Park Hall, Bryn Mawr College. Turn right on Gulph Road.
0.3	Turn right on Merion Avenue.
0.5	Turn left on Yarrow Street.
0.6	Turn right on Morris Avenue.
0.75	Follow main road through underpass.
0.85	Keep right beyond underpass.
0.9	Turn left in front of U.S. Post Office.
1.0	Cross U.S. 30 (Lancaster Pike) travelling on Bryn Mawr Avenue.
1.35	Cross Haverford Road (U.S. alternate 30) Bear slightly to right still on Bryn Mawr Avenue.
	Continue along Bryn Mawr Avenue for several miles. We are running parallel to the Rosemont fault, which separates the Baltimore gneiss on the right (north) from the Wissahickon schist on the left (south).
3.8	Turn left on Pa. 320 (Sproul Road).
4.5	Cross Darby Creek.
5.35	Continue straight leaving Pa. 320. Broomall.
5.6	Turn left on Pa. 3 (West Chester Pike).
5.7	Bryn Mawr gravels cover hilltop around Broomall. Elevation 360'.
6.7	Turn right on Lawrence Road. Darby Creek just beyond to the east.
6.95	Turn right on Langford Road.
7.2	STOP 1. Wissahickon schist.

Wissahickon schist, in outcrops on the hillside, shows strong folding, and the development in micaceous layers, of fracture cleavage, approximately parallel to the axial planes of large folds which here dip about 50° NW (see figure 4).

Exposure at the roadside shows shearing and recrystallization along this cleavage, which has largely obliterated the earlier schistosity. Fabric analyses (Ch'ih, 1950) show that the second cleavage formed under the influence of movements differently oriented from those responsible for the folding and orientation of the micas in the earlier schistosity.

This locality lies within the kyanite zone, though no kyanite has actually been found in specimens from these particular outcrops. The presence of pegmatite and quartz veins is characteristic of schists near the granodiorites, and indicates considerable hydrothermal activity; the same process is probably responsible for replacement of biotite by chlorite and introduction of tourmaline.

Continue along Langford Road after stop.

8.2 Turn left on Pa. 320 (Sproul Road).

Upland from Broomall south to Marple covered by the Bryn Mawr gravel. Elevations 360'-320'.

9.7 Bear right on Pa. 320.

10.35 Turn left on State Road. New construction along here necessitates complicated route.

10.65 Turn right on Buttonwood Drive.

10.75 Turn left on Longview Drive.

10.85 Turn right on West Springfield Road.

11.4 Turn left onto Springfield Park Area.

11.6 <u>STOP 2.</u> Marple Quarries in Springfield granodiorite.

Marple quarry shows two types of granodiorite. (a) Porphyroblastic Springfield type, which is composed chiefly of quartz, microcline, oligoclase, biotite, and a little muscovite; the microcline is commonly conspicuous in large carlsbad twins, giving the rock the character of an augen gneiss. This has been formed by hydrothermal replacement or "granitization" of the Wissahickon schist: its foliation is parallel to that of the schist and contacts between the two rocks are gradational (see figure 5). Additional evidence on this point will be discussed at the next locality).
(b) The Ridley Park granodiorite, which is finer grained and lighter in color, with muscovite predominating over biotite. This is apparently intrusive into the porphyroblastic type, and at point A shows transgressive contacts.

This quarry also shows (at B'B) a fault, the north being the downthrow side.

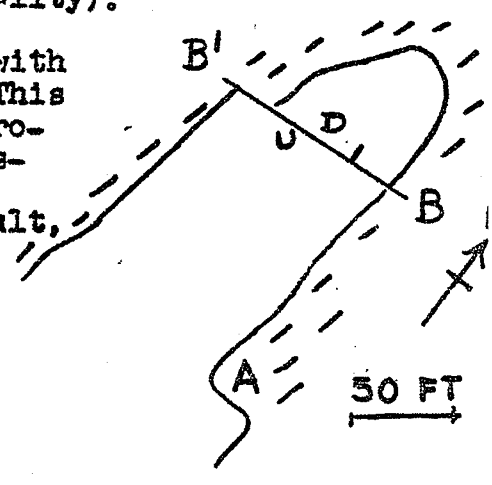
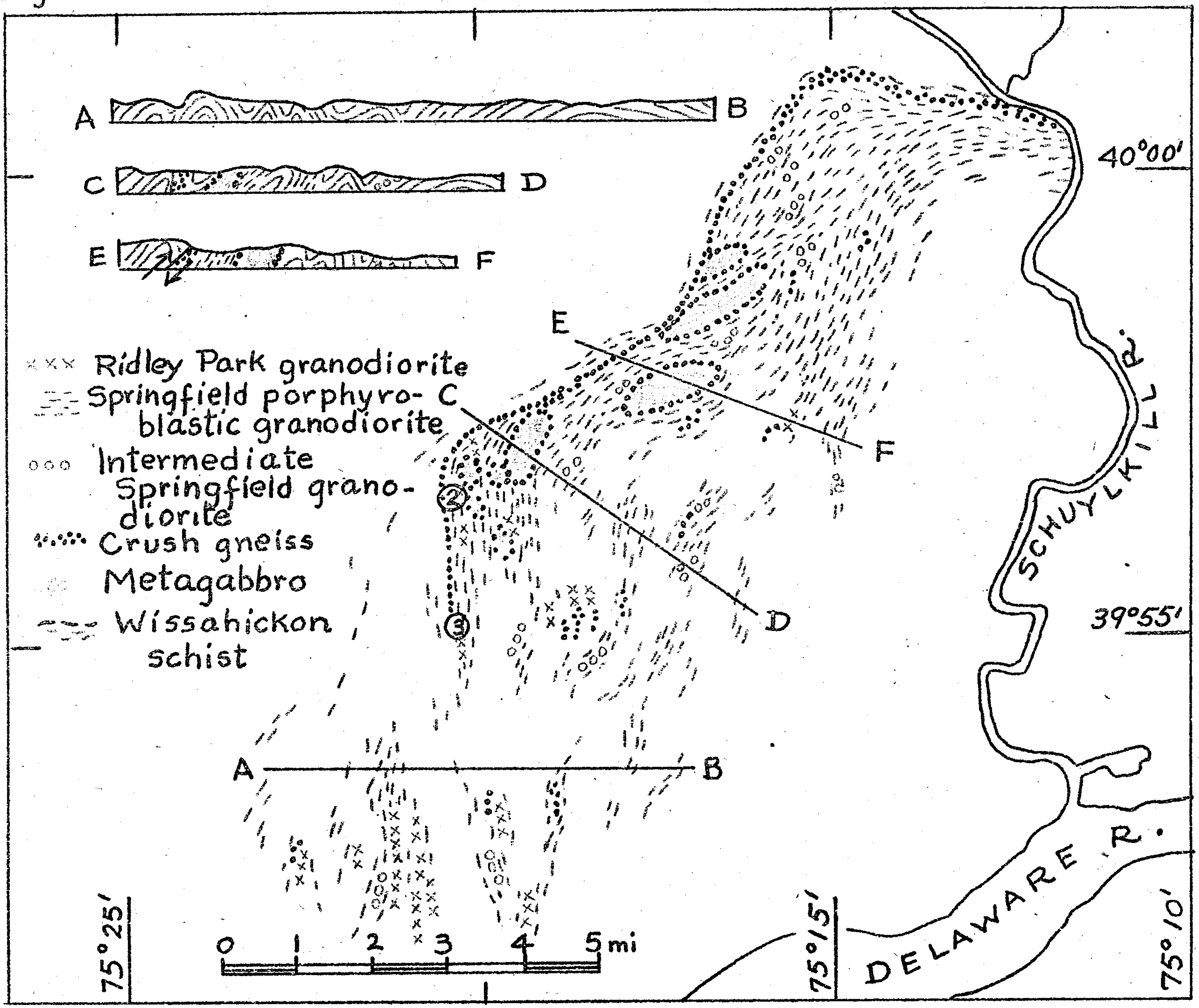


Fig.5. SPRINGFIELD GRANODIORITE. A.W. Postel.



Miles

11.7 Leave Park area. Turn left on West Springfield Road.

11.8 Turn right on Saxer Avenue.

12.35 Turn right on Powell Road. Town of Clifton Heights.

12.7 Turn left onto Pa. 420 (East Woodland Avenue).

13.05 STOP 3. Springfield Quarries. (See figure 6)

Here the porphyroblastic Springfield type of granodiorite may be studied in detail.

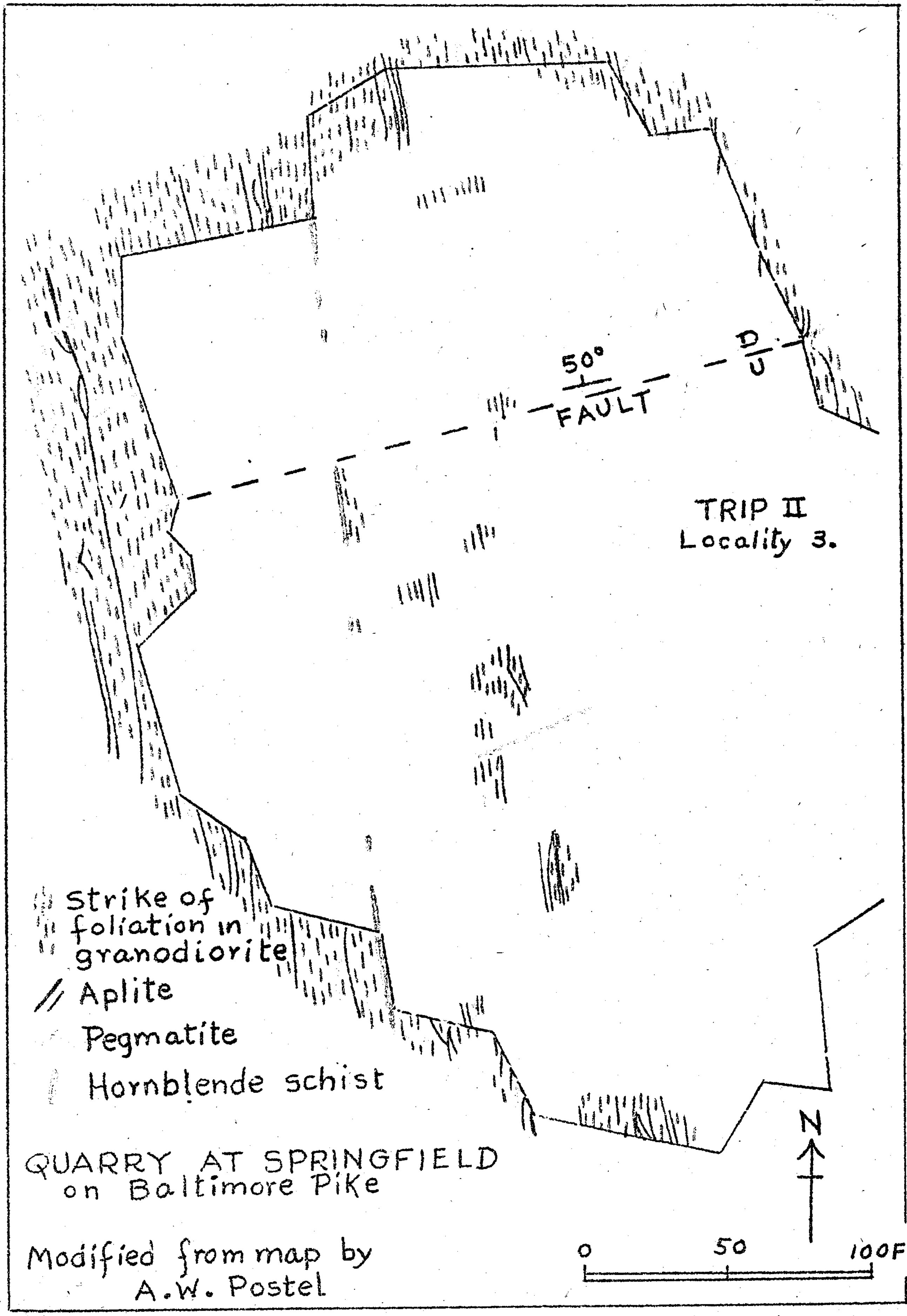
Points of interest are:

a. Foliation of the porphyroblastic gneiss, which is the same as that of the adjacent Wissahickon; some highly micaceous bands represent comparatively unaltered schist.
b. Hornblende schist layer - similar to hornblende schists elsewhere conformable with the foliation of the Wissahickon schist; borders altered to biotite-epidote schist.
c. Numerous narrow aplitic dikes generally conformable with the foliation, but locally showing cross-cutting relations.
d. Pegmatites - some parallel to foliation, some cross-cutting. The largest, in the center of the quarry, apparently occupies a cross joint.
e. Normal fault, in northern half of quarry, with sheared pegmatite.

The formation of the porphyroblastic granodiorite by replacement of the schist is indicated by petrographic as well as field evidence. The large microcline porphyroblasts have replaced, and in some cases contain remnants (in optical continuity) of, quartz and early plagioclase. The microcline is in turn replaced by myrmekite; and symplectites of epidote-plagioclase or muscovite-plagioclase, are common, the latter replacing biotite.

The aplites are similar in mineralogical composition, though finer grained and without microcline porphyroblasts. They apparently represent a late intrusion of magmatic material, similar in character to that which supplied the solutions for the granitization of the schist over a broader area.

Fig. 6.



QUARRY AT SPRINGFIELD on Baltimore Pike

Modified from map by A. W. Postel

Chemical analyses of these two rock types are given below:

	Porphyroblastic Granodiorite	Aplite
SiO_2	66.65	72.07
Al_2O_3	15.66	15.13
Fe_2O_3	1.01	0.71
FeO	3.44	1.69
MgO	1.41	0.55
CaO	3.05	1.89
Na_2O	3.43	2.59
K_2O	3.61	4.93
H_2O+	0.62	0.20
H_2O-	0.08	0.05
TiO_2	0.78	0.26
P_2O_5	0.21	----
MnO	0.07	0.04
	99.92	100.11

Petrofabric analysis (Ch'ih, 1950) confirms the idea that the porphyroblastic granodiorite is really granitized Wissahickon schist. Mica and quartz fabrics can be traced in development through a progressive series from ungranitized schist to augen gneiss; and can be correlated with the regional structures of the rocks.

Ch'ih believes that the Ridley Park granodiorite and the aplites are also replacement rocks and not true igneous intrusives. Their quartz and mica fabrics are similar to those of the surrounding rocks; and in the case of the aplites which show apparent cross-cutting relations the foliation is parallel not to the walls of the dike, but to the regional foliation in adjacent rocks.

Continue on Pa. 420

13.2 Turn right on U. S. 1 (Baltimore Pike)

13.9 Swarthmore one mile to left

14.7 Crossing Crum Creek.

15.9 Entering Media

17.2 Crossing Ridley Creek.

18.8 <u>STOP 4</u>. Lima Quarry in Lima Granite.

A small mass (smaller than shown in the Philadelphia folio) of granite crops out along Chrome Run east of Lima (see figure 1). This granite is surrounded on the north, east, and west by serpentine which it intrudes. On the south it is intrusive into gabbro near Glen Riddle. All of these rocks are intrusive into the Wissahickon schist and form the northern terminus of a large mass of intrusive rock. This is largely gabbroic and extends south from here into Northern Delaware underlying Wilmington and extending southwest into Maryland.

The rock in the quarry here is a horizontally sheeted granite gneiss; one thin section gave the following:

Microcline	47%
Quartz	24%
Sodic Oligoclase	15%
Green pyroxene	9%
Hornblende	2%
Magnetite	2%
Sphene	1%
Apatite -	accessory

The granite shows a strong foliation which is roughly north-south and vertical. In addition, it is strongly crushed, more in some places than others. A few thin (½") true mylonite zones have been noted in the northeast corner. The granite was intruded by pegmatites parallel to the foliation and these are also crushed.

Occasionally during quarrying lens-shaped xenoliths of both altered gabbro and altered serpentine are encountered. These are oriented parallel to the foliation. The gabbro xenoliths are granitized to varying degrees and some of the smaller serpentine xenoliths have been changed to masses of chlorite.

One large xenolith of serpentine was thrown out on the south side of the quarry. It was originally 8 to 10 feet across and of a rounded outline. The greater part of this xenolith is composed of massive anthophyllite with lesser amounts of chlorite, actinolite, etc. The outer rim against the granite is composed dominantly of black biotite. Between the anthophyllite core and the biotite rim at places is a thinner band of talc and actinolite. The presence of the biotite shows the reaction of the original ultrabasic material with the granite, the latter contributing potassium and iron. It is remarkable that the intense deformation which affected the granite does not seem to have deformed the xenolith to any great extent.

More work should be done on the petrography of these rocks.

Continue west on U.S. 1.

19.2 Turn left on Pa. 452.

20.4 Glen Riddle.

20.7 Chester Creek.

22.5 Take sharp right on U.S. 322 at Village Green.

23.5 Take a very sharp right from U.S. 322.

23.6 STOP 5. Fall Zone terraces near Convent.

The route from the last locality travels south along the gentle southward sloping upland surface, which at many places in this region is covered with what has been called the Bryn Mawr gravels. Whether this upland surface is to be correlated with the Schooley peneplain is debatable. The Bryn Mawr gravels are the highest of the series of so-called coastal terraces in this region. The stop near Llewellyn Mills affords a good view to the south over the Fall Zone, as shown in figure 7. The relations between the Fall Zone, the Bryn Mawr surface, and the lower terraces will be briefly discussed at this place.

Return to U.S. 322 on same road.

23.8 Straight onto U.S. 322 travelling west.

25.1 Chelsea. Turn right on Pa. 261.

25.7 West Branch of Chester Creek. Quarry on right in highly injected Wissahickon schist.

26.5 Village of Chester Heights.

27.5 Turn left on U.S. 1 (Baltimore Pike).

27.8 Turn right (north) on narrow road.

29.7 Turn right at Glen Mills.

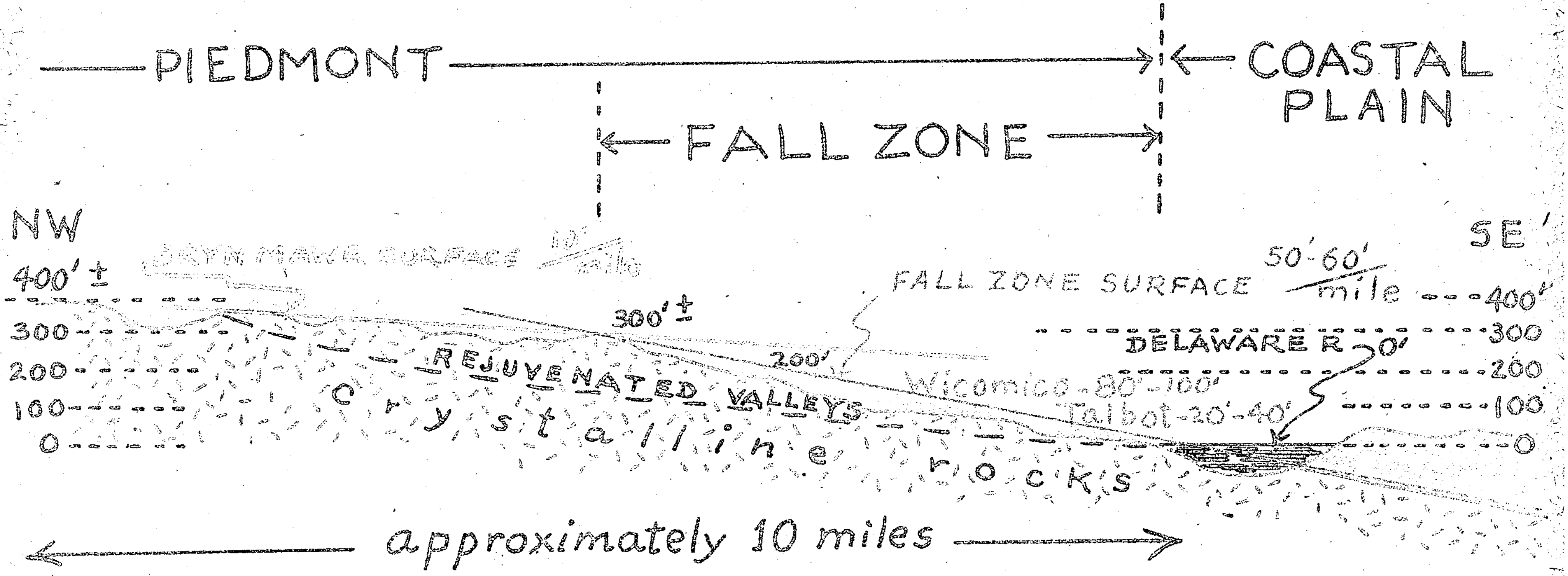
29.8 Glen Mills Station and Chester Creek.

Bear right beyond creek.

29.9 Turn right into Glen Mills Quarry.

30.4 STOP 6. Glen Mills Quarry.

This large quarry of the General Stone Company is situated within the Baltimore gneiss near Glen Mills (see figure 1). The rocks displayed are meta-gabbros, granite gneisses and pegmatites, and all intermediate mixtures of the two, producing banded migmatites. The rock now is a highly banded flow gneiss, the bands varying from a fraction of an inch to those many feet thick and in color from the nearly black meta-gabbro to very light colored granite. The graph of figure 8 shows the range in composition of these rocks. They are arbitrarily arranged to show increasing granitization. This assumption is based on observations throughout the region which show that gabbro has been intruded by granite. The granitization was probably syntectonic and flowage and crushing continued after the main granitic



GENERALIZED PROFILE ACROSS FALL ZONE
Delaware Co., Penna.

Fig. 7.

Miles

injections. Several types of pegmatite occur; one parallel to the foliation and somewhat deformed, and one which cross cuts the foliation and is slightly folded, and a final one which is completely undeformed. Quartz veins with sulphides are also present. The first type of conformable pegmatite frequently shows boudinage with isolated lenses often made of one rounded green to pink microcline crystal.

Those rocks of intermediate composition develop at some places abundant garnet giving a red cast to the whole rock. These fine-grained garnets have been separated and analyzed and the recalculated analysis gives a mineralogic composition as follows: almandine 66%, pyrope 7.5%, grossularite 23+%, spessartite 2%; specific gravity = 4.16.

The range of granitization is much greater at this locality than that at Radnor Quarry where the injected material is largely of quartz dioritic composition. This is indicated on the graph of figure 8.

The flow foliation in the quarry gradually changes from N10°E at the south to N40°W on the northwest wall of the quarry, all dips being 30°-60° to the east. Here and there a lineation plunges 55°, S35°E. The structures from this general region eastward toward Philadelphia are overturned towards the east and southeast, which is in marked contrast to the north-north-westward over-folding in the Avondale-West Chester area west of this region.

Leave quarry following same route back to U.S. 1.

30.9 Turn left.

31.0 Turn left over Chester Creek. Glen Mills Station.

31.05 Turn left (south).

33.0 Turn right onto U.S. 1 (Baltimore Pike).

36.5 LUNCH STOP. Birmingham Grille, at Painters Cross Road.

After lunch continue west on U.S. 1.

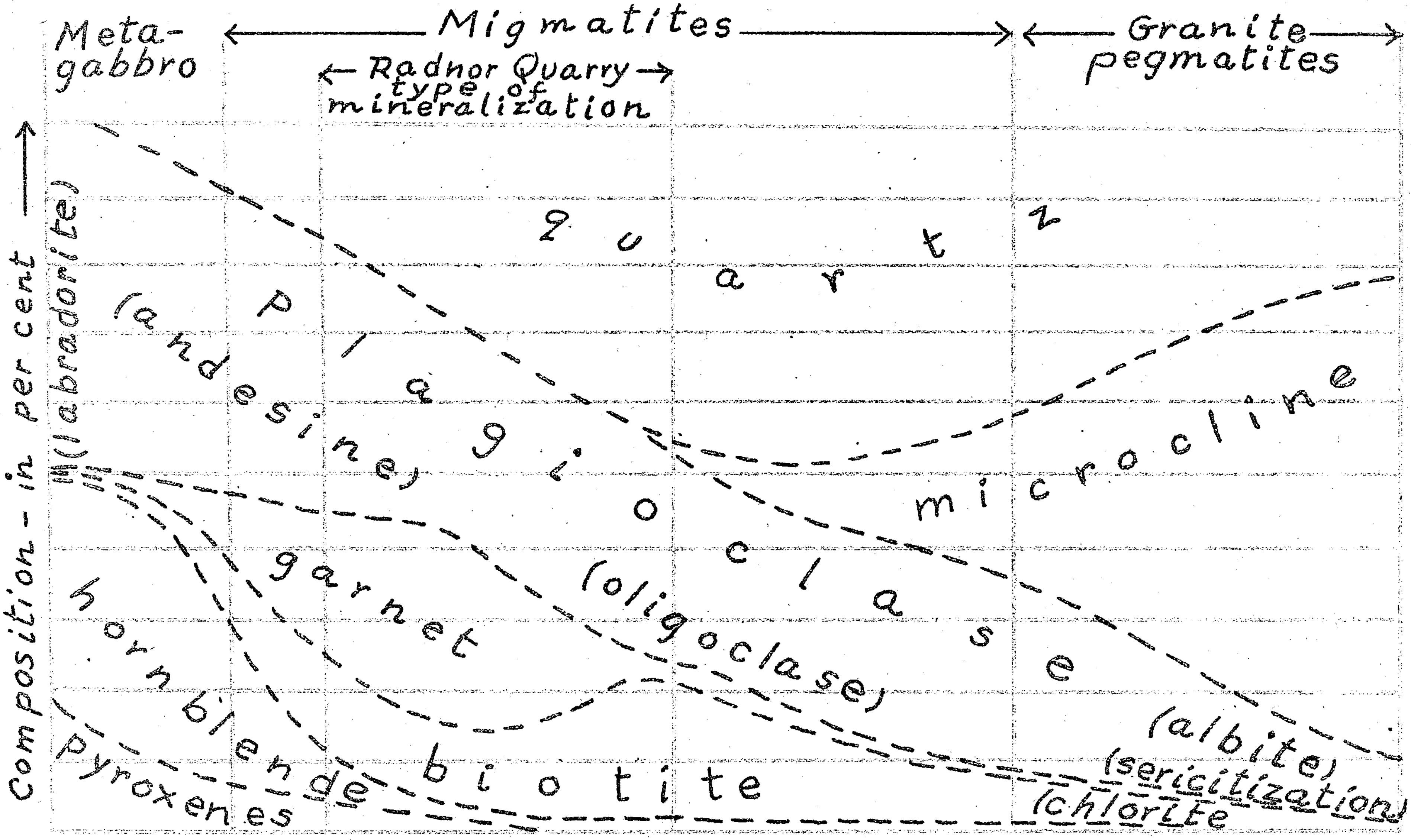
Between this point and Chadds Ford (WSW) for about 6 miles we are running just north of the contact between the Baltimore gneiss on the north and the Wissahickon schist on the south.

39.05 Chadds Ford.

39.25 Brandywine Creek.

42.75 Hamorton.

43.45 Longwood. Continue on U.S. 1.



Composite graph (somewhat diagramatic) from 14 measured sections showing progressive granitization of gabbro at Glen Mills Quarry

Fig. 8.

45.75 Entering Kennett Square on the Setters quartzite.

47.05 Valley to the left is underlain by Cockeysville marble.

47.85 Exposures of Setters quartzite. Hill to the right (north) beyond this point is of Setters. Exposed in quarries and openings at several places.

48.95 Toughkenamon.

49.95 Mushroom houses on the left. This is the center of mushroom growing in America.

NOTE: The following quoted statements on the rocks and structures of the Avondale-West Chester area are supplied by Professor McKinstry. All statements not in quotation marks made for the various localities are by E. H. Watson.

Setters Formation

"The most characteristic member of the Setters formation is hard white quartzite indistinguishable from similar members in the Cambrian Chickies formation. As in the Chickies, segmented crystals of tourmaline lie in random orientation along bedding planes. Borings of *Scolithus linearis* have been reported.

"Except for the quartzitic beds the formation consists largely of quartz-biotite schist. Where strongly micaceous it is hard to distinguish from the Wissahickon; where it has a fine-grained gneissic texture it is not easy to separate from certain phases of the Baltimore Gneiss.

Cockeysville Marble

"Saccharoidal marble containing flakes of phlogopite mica, chiefly along bedding planes. Exposed only in the middle and high grade zones of metamorphism, the marble contains sparse tremolite and sparser scapolite, microcline, brown tourmaline and other silicates, but no garnet or wollastonite. It is rarely exposed except in quarries, but being vulnerable to erosion, its location is marked by valleys. The most conspicuous valleys strike easterly and are crossed by the regional pattern of drainage. The best developed valleys are:

1. An unnamed valley extending eastward from the Poorhouse quarry to Copes Lime quarry at Copeland School in the West Chester Quadrangle.
2. Green Valley, possibly but not certainly a structural continuation of (1).
3. Doe Run Valley, in the Coatesville Quadrangle.
4. Willowdale Valley, extending from Baker to Red Lion.
5. Toughkenamon Valley, extending from Avondale to Kennett Square.

Peters Creek and Wissahickon Formations

"The Peters Creek and Wissahickon are both aluminous sedimentary rocks grading with increasing metamorphism from phyllite through mica schist to mica gneiss. The Peters Creek is distinguished from the Wissahickon by presence of thin quartzite laminae; the contact between the two formations is not sharply demarked.

Igneous Rocks

Serpentine

"Rounded to lenticular bodies of serpentine up to a mile or more long are numerous in the vicinity of West Chester. Most of them are surrounded by Wissahickon formation but are near the contact with Baltimore gneiss. The serpentine bodies along a line of outcrops extending 10 miles from West Chester to Devon are strongly sheared and slickensided. In a belt south, including the outcrop at Brinton's Quarry, the rock is more massive. At Brinton's Quarry, veins and pegmatitic dikes in the serpentine are accompanied by vermiculite, chlorite, and a number of magnesian minerals (see description of Brinton's Quarry). Corundum in serpentine associated with albite pegmatite dikes was once mined 1½ miles northeast of Unionville.

Pegmatite.

"Throughgoing dikes of pegmatite are widespread in the zones of middle to high-grade metamorphism. They consist of microcline, graphic granite and mica (chiefly muscovite). Accessory minerals are black tourmaline, garnet and rarely green beryl. Aside from these throughgoing dikes, lenses and bands of pegmatitic material from a fraction of an inch to a foot or more in width are very common in the mica gneiss of the high grade zone of metamorphism.

Diabase.

"Northeasterly striking dikes of diabase of Triassic age traverse the area. Two of them are traceable for distances of 25 miles within the quadrangles and for many miles beyond. One of them (the Downingtown dike) is exposed in the cut of the Low Grade Freight Line of the Pennsylvania Railroad half a mile southwest of Downingtown. Where not artificially exposed, the diabase is indicated by black to rusty-colored boulders.

Structure.

"The broader outlines of structure suggest folding on axes that strike a little north of east and plunge southwesterly. The folds are strongly overturned toward the north so that the axial planes, and, in general, the cleavage, dip southerly at flat to steep angles. Baltimore Gneiss forms the cores of anticlines. It is flanked by the successive members of the Glenarm series. This succession is best seen north and east of Avondale, where the Glenarm formations are continuous around the nose of a westerly-plunging anticline. The complete succession is not everywhere present, however. The quartzite, the marble, or both, are locally absent; in such places the Wissahickon appears to be in contact with Baltimore Gneiss. Although the hiatus has been attributed to overlap, it is significant that several such localities are along the straight limbs of folds, where extreme attenuation and thinning out of formations would be expected. In other places, however, the formations are absent on the noses of folds as well.

"The fact that the cleavage dips gently (except in the South Valley Hills) gives a deceptive impression of simple flatlying structure. Detailed examination shows that in many places where the cleavage dips gently, the trend of bedding (i.e., the average dip as traced around recumbent minor folds) is steep, or, as indicated by sense of drag folding, is strongly overturned.

"An outstanding structural feature is the variation in dip of the axial planes of folding as marked by cleavage and by observable axes of minor folds.

"In and immediately south of the Chester Valley the axial planes are steep--from vertical to 60° southerly. As one traverses the region from north to south the axial planes become flatter, reaching 20°, 10° and, locally zero or even north dipping. Still farther south, in the Toughkenamon Valley, axial planes become somewhat steeper (about 45°). This regional variation might be described as a monocline, the term, in this sense referring not to bedding but to curvature of axial "planes".

"There is a strong suggestion that this variation in attitude has resulted from the warping or deformation of axial planes which were originally plane surfaces (or surfaces that roughly approximated planeness). In the north (i.e. just south of the Chester Valley) in the Octoraro facies, the cleavage is relatively uniform in attitude, striking N 55 to 70° east and dipping 60 to 80° southerly.

"Farther south the dip of cleavage is 40 to 60°. Strike becomes much more variable but approximates N45°E.

"The net effect of this flattening of dip of axial planes is to produce recumbent folds--in some places overturned to such a degree that the axial planes dip northward.

"The outcrop patterns of such folds are, of course, much more irregular than they would be if the axial planes were steep. In particular, the Woodville Structure, if interpreted from its outcrop pattern alone would appear to be a dome having a core of Baltimore Gneiss, flanked in turn by Setters formation, Cockeysville marble and Wissahickon formation.

"But the Woodville structure is not a simple dome; along its north flank the sequence is completely inverted. The Wissahickon formation dips at very gentle angles <u>under</u> the Cockeysville marble, which in turn dips under the Setters formation and the Baltimore Gneiss. Moreover the axial lines of minor folds plunge nearly southward, as they do in most of the region. Restoring the structure, by projecting formations in the direction of the plunge, indicates that the Woodville "Dome" is a strongly recumbent fold or nappe.

"Just how this structure is to be correlated with that of the Buck Ridge anticline in the West Chester Quadrangle is one of the local problems. It depends partly on the interpretation of structure in the vicinity of the Poorhouse Quarry, where the long prong of Baltimore Gneiss ends westward on the axis of a fold which, locally at least, plunges to the east. Is the marble of the Poorhouse Quarry in a structure continuous with the inverted syncline of Greenvalley, in which case it must also be an inverted syncline, or are the Poorhouse and Green Valley structures separated from each other by a double limb of Wissahickon formation?

"Thrust faults throughout the area are doubtless features of this complex structure. But, judging from similar types of structure in other regions, it seems likely that such faulting takes the form of stretch thrusts, which, in effect, amount to extreme thinning of incompetent formations on the limbs of folds. Although hypothetical faults could be invoked as an "easy way out" in explanation of otherwise puzzling structural relations and might, indeed, be fitted into the mechanics of deformation, any field evidence for them is chiefly circumstantial.

Metamorphism

"The degree of metamorphism increases southward and, in a broader way, eastward. Immediately south of the Chester Valley the Wissahickon formation in the low grade zone is sericite phyllite with minor proportions of chlorite and, locally, albite, On passing southward in the Wissahickon and Peters Creek formations, the index minerals: biotite, garnet, staurolite, cyanite, and sillimanite appear successively. The biotite isograd is somewhat blurred by the development of late, presumably hydrothermal, chlorite. The staurolite and cyanite zones are narrow and overlap somewhat. Together they form a belt extending from half a mile north of West Chester to Logan's quarry. Neither mineral is abundant; considerable search is required in order to find visible crystals.

"Along with the southward increase in degree of metamorphism goes a gradual coarsening of the texture of the rocks and an increase in the intensity of small-scale deformation. In the phyllitic (or Octoraro) phase of the Wissahickon formation the rock splits along cleavage which has a nearly plane surface. One to two miles farther south the cleavage surfaces become warped or wavy and the luster of the schist becomes sparkling rather than silvery. The cleavage planes are deformed by minor shears which have a more easterly strike than the northeasterly attitude of cleavage planes. As a result the rock breaks along rough surfaces which are a compromise between the remnants of cleavage surfaces and the late shears. Then, three to five miles south of the Chester Valley, the grain size as expressed by mica becomes coarser (1 to 10 mm) and the cleavage surfaces, so conspicuous farther north become unrecognizable as a result of recrystallization and deformation."

50.25 STOP 7. Setters quartzite near Avondale.

The Setters quartzite here (see figure 9a) is largely a biotite gneiss and schist. At the east end of the opening there is a large conformable pure quartz vein up to 6 feet thick. In the center and to a lesser degree elsewhere roughly conformable pegmatites occur of microcline and quartz with abundant tourmaline and showing little deformation. Fine euhedral garnets are also found in these pegmatites at times.

The bedding and foliation is N50-70°E, 25 ±°S. As shown in figures 9a we are at the southeast end of section AA' on the southern limb of the Avondale-Longwood anticline.

Continue on U.S. 1 after stop.

50.45 Enter Avondale.

50.65 Bear right on Pa. 41

51.35 Setters quartzite.

51.75 Turn left on macadam road.

51.95 Turn left on macadam road.

52.05 Turn right into quarry.

STOP 8. Baker's Quarry in Cockeysville Marble.

Sugary Cockeysville marble with minor phlogopite is exposed in beds here which have a general attitude of N70°E, 10-12°S. This plane is probably also the axial plane of folding, and recumbent folds are excellently seen from here on the west side of the quarry, showing strong overturning to the north.

This quarry is located at the southwest end of the Willowdale Valley extending from here to Red Lion and can be considered as either on the northern inverted limb of the Avondale anticline or the southern normal limb of the Chatham-London Grove side of the Woodville dome (see figures 9 and 9a).

Note solution cavities.

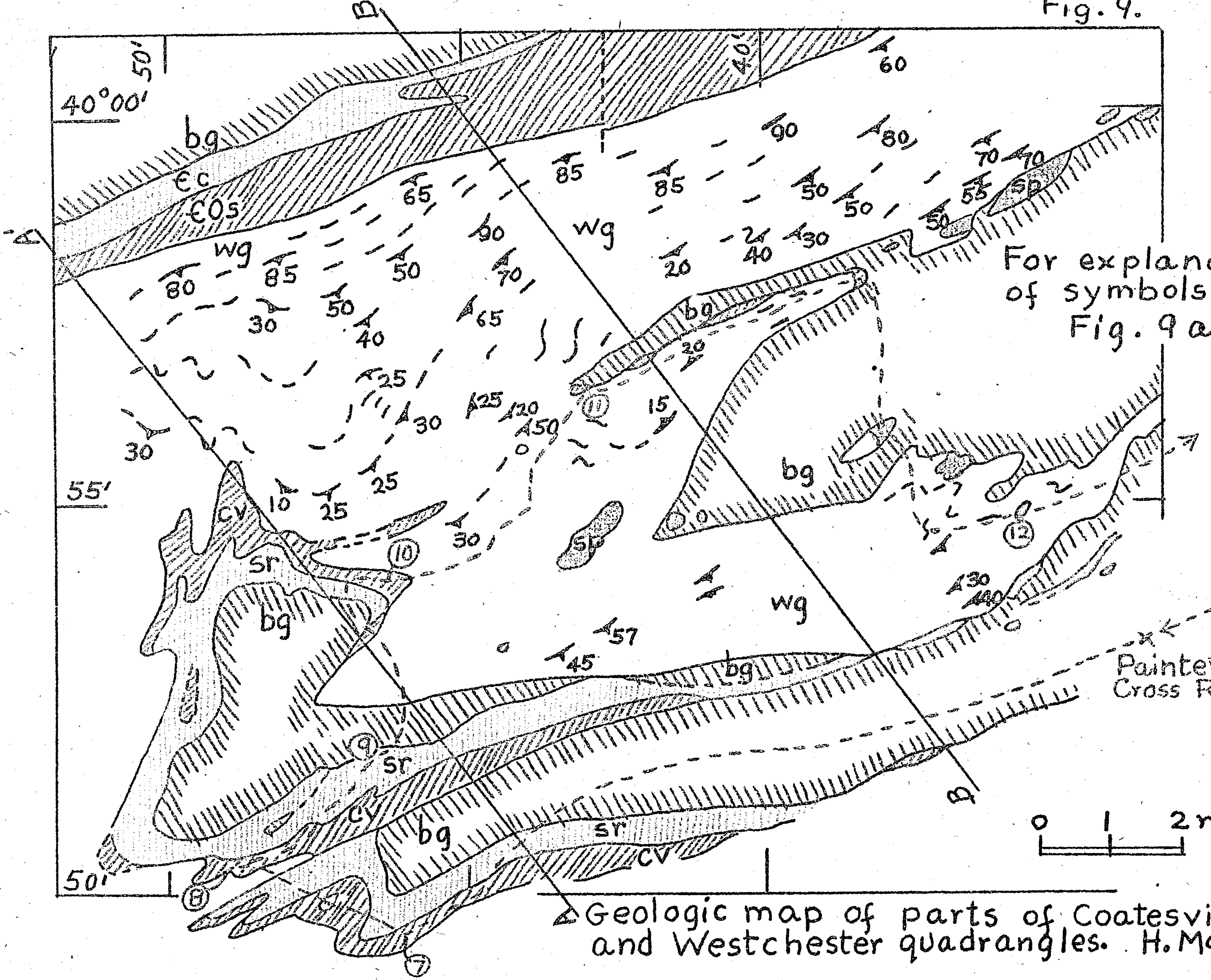
52.10 Turn left from quarry.

52.15 Turn right on macadam road.

52.40 Straight across Pa.41 onto dirt road.

53.05 Left.

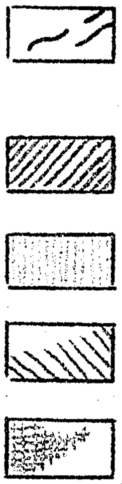
Fig. 9.



For explanation of symbols, see Fig. 9a.

Geologic map of parts of Coatesville and Westchester quadrangles. H. McKinstry.

EXPLANATION FOR MAP OF PARTS OF COATESVILLE AND WEST CHESTER QUADRANGLES (Fig. 9)



wg — Wissahickon formation and Peters Creek schist. Dashed lines indicate trends of cleavage and of axial planes of minor folds.

€Os / cv — Cambrian limestone / Cockeysville marble

€c / sr — Cambrian quartzite / Setters quartzite

bg — Baltimore gneiss

sp — Serpentine

CROSS SECTIONS

A-A' and B-B'. Same scale as map (Fig. 9)

Section lines are N 38 W. Sections look southwest.

Construction has been made by projecting formations upward or downward on an assumed average plunge of 12 degrees.

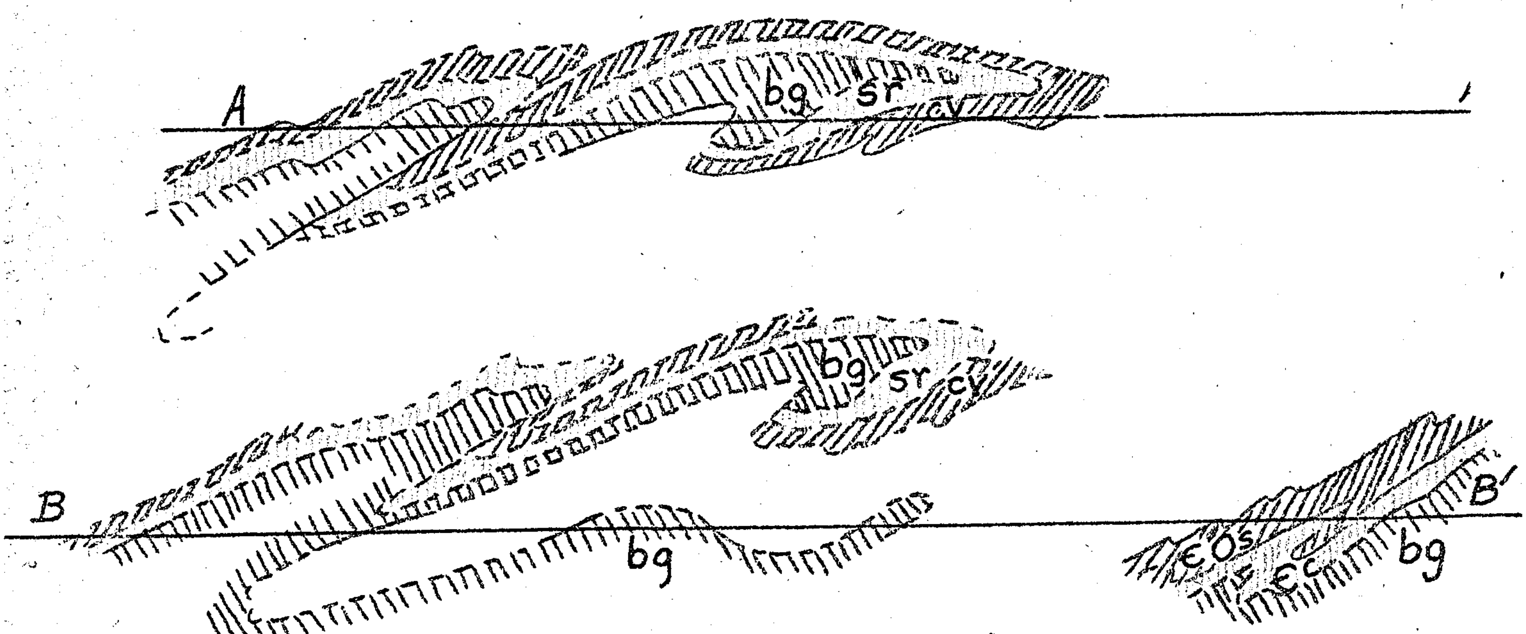


Fig. 9a.

Miles

53.2 Right. Road runs in a limestone valley for more than a mile here.

54.75 Turn left at "T" intersection.

55.05 Turn right.

55.35 Creek.

55.9 STOP 9. Quarry in Setters Quartzite.

This quarry is about one-half mile southwest of London Grove on the normal, southern, upper limb of the Woodville recumbent fold. It shows pure glassy quartzite with visible detrital grains. The bedding is N60°E 30°S. Small "stretched" tourmalines may be seen on the bedding surfaces.

56.15 Left.

56.35 Straight ahead.

56.45 Straight through and across Pa. 926.

London Grove is on Baltimore gneiss which is on the "root" side of the recumbent fold or nappe which makes up the Woodville Dome. Exposed at the left (west) side of the intersection here is a granitic gneiss. Foliation N50°E, 45°SE.

About 1/2 mile north of London Grove the Baltimore gneiss is thrust northward over the Wissahickon schist cutting out the Setters quartzite and the Cockeysville marble.

56.65 Baltimore gneiss dipping south.

56.85 Exposure in cut of very garnetiferous, highly micaceous Wissahickon just north of overthrust. Foliation N55°E, 40°SE.

57.65 Village of Upland. Cross Pa. 842 and continue north on dirt road. Still on Wissahickon.

58.35 Knoll of Baltimore gneiss on the inverted plunging limb of the Woodville dome. Setters and Cockeysville swing around this point from north to east to south.

58.45 Baltimore gneiss (migmatite) N50°E, 60°SE.

58.9 Turn right on Pa. 82. Limestone valley.

59.65 STOP 10. Logan's Quarry in Cockeysville marble.

This is located in the Doe Run Valley on the north, lower, inverted and recumbent limb of the Woodville dome. This fold plunges southwest from here under the Baltimore gneiss nose which we crossed north of Upland. The structures within this quarry are somewhat variable and confusing, but

Miles

	the bedding is in general N60°E 30-50°SE. Folds show a plunge S20°W 25°S. Minor bedding plane faults and boudinage occur.
	The large rock pieces on the south side of the quarry towards the road are of pegmatite gneiss with abundant tourmaline (to 3") and less garnet.
	After stop continue on Pa. 82.
61.35	Junction Pa. 842-82. Keep straight.
61.6	Unionville. Turn left (north) on Pa. 162. On the Wissahickon schist.
63.25-63.85	Exposures of Wissahickon schist and pegmatites. Old corundum locality east of here.
63.65	Keep right.
64.05	Cross West Branch Brandywine Creek.
64.45	Embreeville Station.
65.15	Keep straight on Pa. 162.
65.75	Chester County Home.
66.1	Turn left onto dirt road into Poorhouse Quarry.
66.25	STOP 11. Poorhouse Quarry.

The following is an account of this locality supplied by Professor McKinstry.

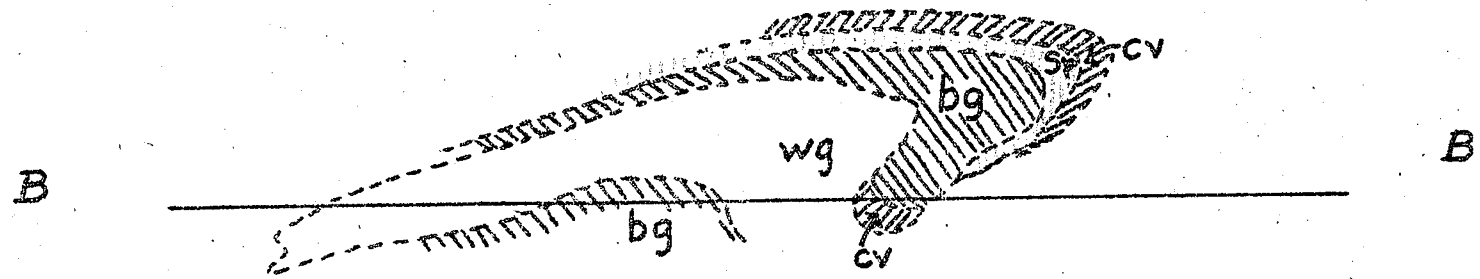
"This quarry, in Cockeysville marble, was formerly worked for building stone and agricultural lime. The attitude of the marble is transverse to regional structure, as the beds strike N20° to 45°W and dip 10 to 20° northeast. This northeasterly rather than northwesterly strike (dip?-EHW) may be attributable to a local easterly plunge of folding. Drag folds in the overlying gneiss plunge northeasterly at 5 to 10° and similar plunges of minor folds appear in the schists along the Brandywine half a mile southward.

"The high land beyond the valley south of the quarry is underlain by Wissahickon formation; rocks containing blades of kyanite have been found in the fields. The hill back of the quarry, i.e., to the north and east, is the west end of a long ridge composed of hornblendic rock which is identical with a common marginal phase of the Baltimore gneiss. Note that continuation of the trend of the marble

Miles

would carry it under the hill of Baltimore. Whether the rock that can be seen overlying the marble in the quarry is a biotitic phase of the Baltimore or Wissahickon is a critical question in the local structure. It is a feldspathic gneiss with abundant mica. Mineral composition: biotite, quartz, microcline, plagioclase (An_{30}) and muscovite, with accessory apatite. Proportions of mica vary in different bands. Some of the more feldspathic bands show conspicuous augen structure (augen 3 to 5 cm. or exceptionally 10 cm.). Interbanded pegmatitic bands consist of pink feldspar and quartz.

"The quarry acquired fame among local mineralogists as the type locality for chesterlite, a new mineral described by Dana a century ago and named for Chester County. Later, Descloizeaux used chesterlite as one of his types in setting up the species microcline and relegated chesterlite to varietal status. When the quarry was operating, good crystals of chesterlite could be found in lenticular gashes of klüfte in the marble, accompanied by crystals of calcite, dolomite, and quartz. Chesterlite can still be seen but the chances of finding good crystals are meagre."



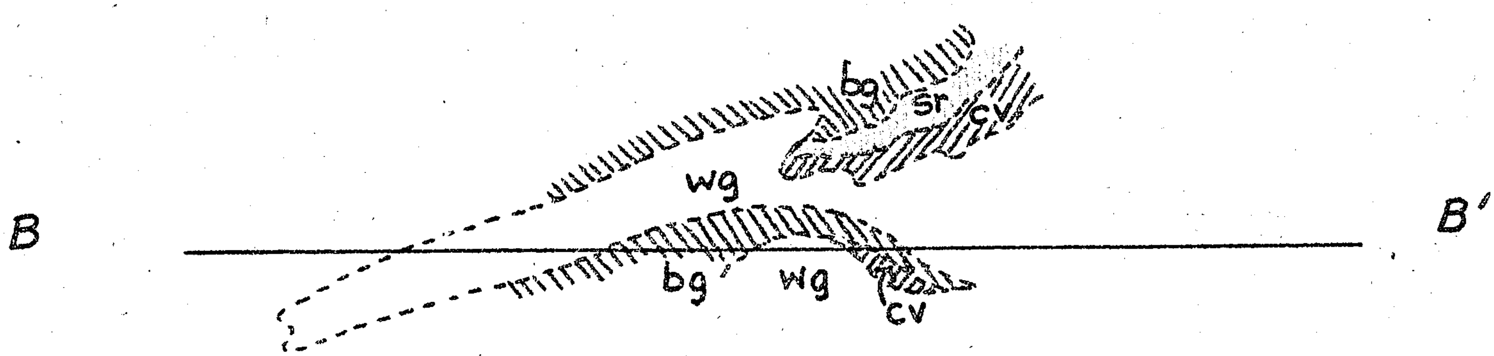


Fig. 9b.

Miles

McKinstry's cross-section BB' crosses this ridge of Baltimore gneiss about a mile to the northeast of the Poorhouse quarry, which is about 9 miles from the left hand (southeast) "B" on his section (figure 9a). As shown there the Baltimore gneiss exists as an overturned fold wrapped around by Wissahickon schist. No limestone is shown and this section is plausible only if it be assumed that the rock in the upper part of the Poorhouse quarry is Wissahickon schist.

We believe that it is quite possible that this rock is Baltimore gneiss, in which case it would be locally thrust over the marble. Two possible alternative interpretations of the structure are given herewith in the figure 9b. In the upper figure of 9b, it is assumed that the higher, recumbent Woodville dome plunges downward again to the northeast and is just caught by the level of erosion at the Poorhouse quarry. This idea is supported by the axial plunge in this area, which is to the northeast. The lower section is drawn under the assumption that a nappe-like overthrust has moved forward from the main mass of Baltimore gneiss on the south. In either of these alternate assumptions the Baltimore gneiss here may be a partially developed klippe. (Mr. McKinstry may have good reasons for objecting to these ideas!)

Return to Pa. 162.

66.3 Turn left onto Pa. 162.

66.85 Wissahickon hill on right (south). Limestone valley to left (north). Baltimore gneiss hill beyond to north.

68.25 Marshallton. Bear left on Pa. 162.

69.9 Brandywine Creek (Copes Bridge). Large Triassic diabase dike goes through here. A continuation of the Conshohocken dike. Indeed Triassic dikes along this strike can be followed from the Delaware River to the Potomac.

Beyond Copes Bridge we turn south down Brandywine Creek into the Baltimore gneiss which is thrust northward here over the schist.

70.25 Leave Pa. 162. Turn right on road to Lenape.

71.15 Exposure of gabbro within Baltimore gneiss.

71.8 Straight through.

71.85 Join Pa. 842.

74.35 Turn right on Pa. 52-100.

Miles

74.55 Lenape. Go straight on Pa. 100. Do not cross bridge over the Brandywine.

Lenape is again on the Wissahickon between two large masses of the gneiss to the north and south of it, which converge toward the northeast into the main mass which crosses the Schuylkill River near Bryn Mawr.

We enter here the general area of the Battle of the Brandywine.

75.85 Pocopson. Turn left on Pa. 926.

75.95 Turn left on Pa. 926 (Street Road), leaving Pa. 100.

77.35 Straight on Pa. 926.

77.75 Left. Then left into Brinton's Quarry.

77.85 STOP 12. Brinton's Quarry.

The following is by Professor McKinstry.

"Brinton's quarry was worked for building stone, probably beginning in Colonial times, but most actively about 1870 when the attractive green stone was in popular demand. Serpentine from this quarry was the stone used in four of the older buildings of the University of Pennsylvania, in the original walls of the Academy of Natural Sciences in Philadelphia and in some twenty churches in Philadelphia and Baltimore. But as the rock disintegrates in city atmosphere and many older buildings have had to be repaired or refaced it has gone out of use, although country farmhouses more than a century old are still well preserved. Disintegration has been attributed to the action of sulphurous and sulphuric acid on included grains of magnesite.

"Mineralogically the quarry is of interest for its crystals of chlorite (var. clinochlore) and vermiculite (var. jeffer-isite, named for a West Chester mineralogist, William Jefferis). The vermiculite occurs in the serpentine adjoining veins containing pearly muscovite and triclinic feldspar. Shipments of vermiculite for commercial use were made about 20 years ago.

"The principal unusual geological feature of Brinton's quarry is a dike of tourmaline-bearing albitite which has been intruded into the serpentine. The dike is bordered successively by vermiculite, tremolite (partly altered to talc) and, finally, nearly pure talc, which adjoins the serpentine. These bands or zones were interpreted (Gordon, A.N.S.P. 1921, pt. 1) as due to reaction between the pegmatitic magma and the serpentine, whereby the albitite became contaminated by magnesia (now represented by vermiculite) and the serpentine acquired alumina to form

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amphibole and talc. Larsen (Econ. Geol. vol. 23, pp.398-433, 1928) attributed the zones to the action of hydrothermal solutions rich in alumina and poor in silica.

"Other minerals that have been found in the quarry include:
Apatite (in jefferisite adjoining the albitite)
Beryl (in the dike)
Chromite
Chrysotile (asbestos)
Deweylite
Magnesite
Magnetite
Quartz (drusy) (also variety amethyst)".

77.95 Right out of Brinton's Quarry.

78.1 Left onto Pa. 926 (Street Road)

79.05 Straight through. Across U.S. 202-322.

80.75 West Town Station.

81.35 Straight through on Pa. 926. Chester Creek.

83.25 Straight through on Pa. 926.

84.45 Exposures of serpentine within the Baltimore gneiss for some distance.

84.9 Bear right on Pa. 3. (West Chester Pike). Note serpentine exposure on right.

85.3 Ridley Creek.

87.15 Edgemont. Straight through.

87.65 Castle Rock. Mass of anthophyllitized serpentine within Baltimore gneiss holds up hill to the right(south).

87.85 Crum Creek.

90.05 Newtown Square. Straight through.

90.5 Turn left on Bryn Mawr Avenue.

The route from here into Bryn Mawr (5 miles) roughly parallels the Rosemont fault which separates the Baltimore gneiss on the left (north) and the Wissahickon schist on the right (south).

92.25 Darby Creek.

92.65 Straight through.

95.15 Cross Haverford Road, bearing slightly left on Bryn Mawr Ave.

Miles	
95.45	Cross Lancaster Pike. Continue on Bryn Mawr Avenue.
95.55	Turn right in front of U.S. Post Office.
95.6	Turn left through tunnel.
95.7	Turn right after tunnel on Morris Avenue.
95.85	Turn left on Yarrow Street.
95.95	Turn right on Merion Avenue.
96.15	Turn left on Gulph Road.
96.45	Entrance left. Park Hall, Bryn Mawr College.

ITINERARY FOR SUNDAY, JUNE 3

Miles	
0.0	Park Hall, Bryn Mawr College. Turn left on Gulph Road. Out New Gulph and Old Gulph Roads (NNW).
1.2	Turn left on Pa. 320 (Spring Mill Road).
1.75	Straight across Pa. alternate 23.
2.65	Turn right on Lancaster Pike (U.S. 30).
4.9	Straight through center of Wayne.
6.9	Devon. Straight through.
7.6	Exposures of Octoraro (Wissahickon?) phyllite on right.
8.1	Berwyn. Straight through.
10.1	Turn right at east end of Paoli, north onto U.S. 202.
10.7	STOP 1. Octoraro phyllite. Keep cars in line off pavement. Watch fast traffic.

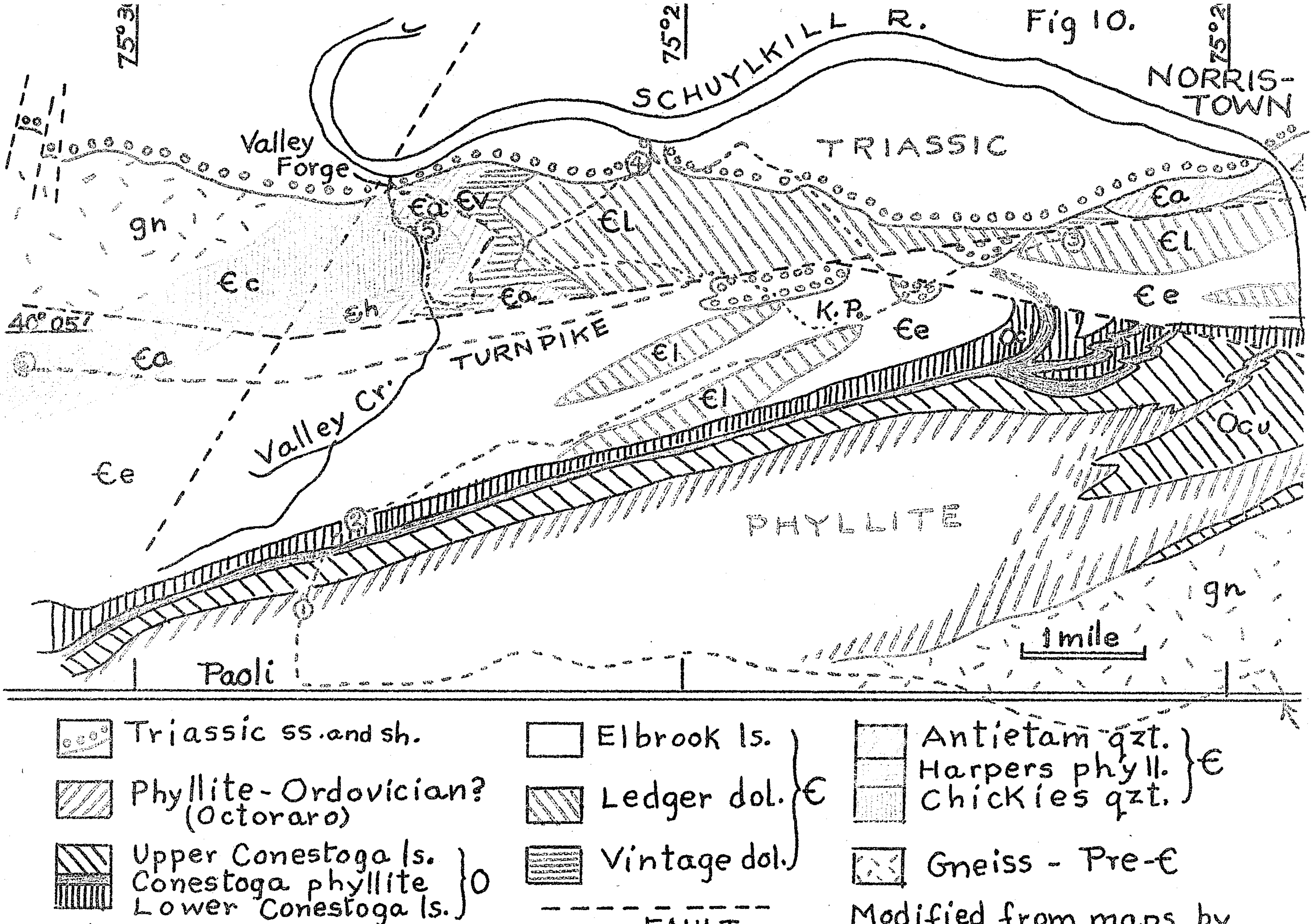
This exposure shows the phyllite of the South Valley Hills. The rock is fine grained, composed of scales of chlorite and muscovite, with quartz; locally small porphyroblasts of albite occur, and farther south some layers contain chloritoid; pyrite is a common accessory.

The rock is of sedimentary origin, but metamorphism, although of low grade, has destroyed the original textures and structures. Bedding may be faintly indicated by local differences in color and by quartz veins, but the conspicuous structure is a foliation resulting from metamorphism (N50-60°E 45°SE). A second (fracture) cleavage intersecting the foliation is conspicuous at some localities, though not here.

The age and structural relations of this rock are matters of controversy. It appears to rest conformably upon the Conestoga limestone, and was therefore assigned to the Ordovician (Bascom, 1909) and named the Octoraro schist. Miller (1935) has summed up the evidence for this interpretation.

Farther to the southwest, however, this phyllite appears to grade into the more highly metamorphosed Wissahickon schist. If the latter is of pre-Cambrian (Glenarm) age, and this phyllite is a part of the same formation, its apparent conformability on the limestone must be deceptive, and is explained by the presence of the Martic overthrust (Knopf-Jonas, 1929). The phyllite is then to be interpreted as a phyllonite (phyllite-mylonite), having suffered retrograde metamorphism

Fig 10.



Modified from maps by Bascom and Stose.

Miles

(diapthoresis) during intense shearing along the sole of the Martic thrust sheet: it represents a crushed, lower grade facies (chlorite-albite facies) of the Wissahickon schist, which has been thrust northward over the Paleozoic rocks.

Leave quarry.

10.9 P.R.R. Trenton cut-off. Chester Valley ahead.

11.45 Howellville.

11.6 Turn left into quarry along entrance nearest U.S. 202.

11.8 STOP 2. Howellville Quarry. Turn cars around in line on quarry floor.

About 330' of the lower part of the Conestoga limestone (Orodivician) is exposed here. About one-half is high-calcium limestone and the remainder is dolomite or calcium-dolomite. Stose assigns the lower (to the north) 20 feet to the Elbrook formation although no clear reason can be seen for this. The upper part of the lower Conestoga is exposed in the adjacent large quarry just to the west, where it is overlain by a phyllitic member 100 feet thick. Overlying this in turn is the impure micaceous limestone of the upper Conestoga which forms the low ground immediately to the north of the South Valley Hills.

The beds here strike N70°E 75°S. Striking across the quarry is a transverse steep thrust fault which moved up from the east with a component towards the south. This interpretation of the movement is based on the drag fold which may be seen on the south wall of the quarry, the axis of which plunges about 50° to the east. The fault plane itself is N30°W 76°NE. On the south wall of the quarry the fault plane is a sharp one, whereas on the north wall it is represented by a striking brecciated zone about 15 feet thick.

Leave quarry.

12.0 Turn left out of quarry and left onto U.S. 202.

13.9 New Centerville. Straight through.

The larger part of the center of the Chester Valley here is underlain by the Elbrook formation which is rarely exposed nor commercially exploited.

The three units of the Conestoga can be traced for many miles along the valley as is shown in the figure 10. Eastward, near King of Prussia, the mid-Conestoga phyllite thickens and then flares out into three prongs as shown in figure 10. Each of these probably represents a tight isoclinal syncline bounded on either side by the underlying lower Conestoga.

Miles

Within one of these infolded prongs of lower Conetoga limestone, near Henderson Station, along the P.R.R. Trenton cut-off, is a locality where a few Ordovician fossils were found.

16.8 King of Prussia. Straight through on U.S. 202.

18.7 Turn right and then immediately left on road down into quarry.

STOP 3. Bridgeport Quarry of the Bethlehem Steel Co.

This large quarry is in the Ledger dolomite (Cambrian) and is composed of massive light-colored nearly pure dolomite with relatively obscure bedding striking about east-west and dipping 45-50° to the south. This formation is of considerable commercial importance in the Chester and Whitemarsh Valleys where it is quarried for a variety of purposes. Units several hundred feet thick of pure dolomite alternate with more silicious dolomite.

About a million and a quarter tons are moved from this quarry a year, 40% of which is used as a refractory and 20% as a flux stone, both for the operations of the Bethlehem Steel Company. The remaining 40% is used as general crushed stone. The ereal limits of the quarry have about been reached, but it is planned to continue operations for something of the order of 10 years by deeper quarrying.

Excellent solution pinnacle structures may be seen just above the north wall of the quarry. A marked shear zone that may represent faulting strikes N40°E 80°NW across the center of the quarry and obscures the bedding at places.

19.0 Turn around in line at bottom of quarry.

19.35 Leave quarry and turn left(west) on U.S. 202 (Swedesford Rd.)

20.75 Turn right on Allendale Road.

21.5 Hill on left is Triassic outlier on limestone, faulted along its north side (see figure 10).

22.2 Beginning of Triassic lying unconformably on Paleozoic limestone.

22.25 Left on Valley Forge Road.

22.7 Trout Creek.

23.6 Port Kennedy. Go straight across first road and then go left on road parallel to railroad track.

Entering Valley Forge Park.

Miles

23.7 STOP 4. Port Kennedy Quarry. Leave cars in line.

The quarry wall shows strikingly the unconformity between the Ledger dolomite and the overlying Stockton formation of the Triassic. The beds of the Ledger stand about E-W and vertical, whereas the Triassic dips gently to the north. The contact is an irregular one rising to the west across the quarry and probably represents pre-Triassic weathering into solution channels.

In the last century quarrying into the limestone here encountered a cave from which were collected bones of a great number of Pleistocene mammals.

The white amorphous material on the floor of the quarry is calcium carbonate rejected by the Ehret Magnesia Company, whose operations are a short distance to the west. Apparently the finely divided and hydrated condition of this material prevents its use for any other purpose.

Continue on same road.

24.3 Ehret Magnesia Company, plant and quarry on the right, working Ledger dolomite.

25.0 Turn right on Pa. 23.

25.8 Schuylkill River and one of its settling basins ahead.

26.2 Turn left on Pa. 83 up Valley Creek.
Valley Forge. Washington's Headquarters to right 200 yards.

26.5 STOP 5. Exposure of Chickies quartzite.

The Chickies quartzite here, which is a hard, glassy quartzite is responsible for the North Valley Hills. At this locality it strikes N10°W and dips 25-30° to the east. It is interbedded with phyllites. Stose has mapped the North Valley Hills near Valley Forge as an anticline plunging to the east as shown in figure 10 and has subdivided the original Chickies of the Philadelphia folio into the: Chickies quartzite, Harper's phyllite, and Antietam quartzite in ascending order. The phyllitic bands to the north here are possibly Harper's followed by Antietam to the south, with Chickies exposed in the middle part of the gorge, and the whole succession repeated to the south.

The course of Valley Creek here is unusual as can be seen on the topographic map and in figure 10. It enters the Schuylkill by striking abruptly north across the ridge at Valley Forge rather than taking the easy course down the valley to the east. Trout Creek, which enters the River at Port Kennedy will capture it at some future date. Stose attributes this aberrant course to the former course of the Schuylkill River, which was later taken over by Valley Creek.

Miles

There are several objections to this idea: (1) Valley Creek now slopes to the north whereas the former Schuylkill ran south through the gorge; (2) Several other streams (e.g. Gulph Creek) have similar courses over resistant ridges and the Schuylkill could not have gone anywhere. (3) Stose assigns the gravels in the center of the Chester Valley to the old channel of the River, but similar gravels are found at many other places in the Valley, even well up on the sides. An alternative explanation for these unadjusted small streams occurring locally in this region is to assume that they were let down from a Pleistocene cover of gravel which buried the present topography.

Continue up Valley Creek.

27.3 Bear left on Pa. 83.

27.7 Turn left leaving Pa. 83 into Valley Forge Park on macadam road.

28.0 Straight.

28.05 Straight.

28.4 Turn right on Pa. 23.

28.7 Wooded area on right probably on Antietam quartzite.

29.1 Memorial Arch to Continental Army.

29.3 Leave Valley Forge Park.

30.2 Turn sharp right before underpass and join Turnpike.

30.35 Pennsylvania Turnpike.

33.9 Valley Forge ticket booth.

34.5 North Valley Hills, Chickies quartzite to right (north). South Valley Hills, Octoraro phyllite to left (south).

35.0 Cuts through here show hillside wash of Chickies.

35.5 <u>STOP 6.</u> Chickies Quartzite near Cedar Hollow.

The quartzite on the south side of the Turnpike here has a bedding which is N80°W 55°N and a close spaced cleavage, which is N70°E vertical to 80°S. This structure would imply that the Chickies is dipping under the pre-Cambrian rocks just to the north and that the Mine Ridge anticline here is overturned to the south. This interpretation appears to be borne out by other data in the Mine Ridge area and is in contrast to the northward overturning of the rocks in the Avondale region to the south.

36.5 Chickies on right (north). Warner Company, Cedar Hollow Plant, working the Ledger dolomite to left (south).

Rough Provisional Sketch:
Pre-Cambrian geology of cut
on Pa. Turnpike, 4.7 miles west
of Downingtown Interchange
(E.H.W.)

Rocks in Eruptive Sequence
(Pickering sed. gneiss not present here)

1. mafic-rich gb. (schlieren and inclusions)
2. anorthosite (an 40% ±) - (xenoliths)
3. gabbro-augite, brown hornbl.
4. microperthite granite
5. migmatite and syenite
6. pegmatite
7. metadiabase

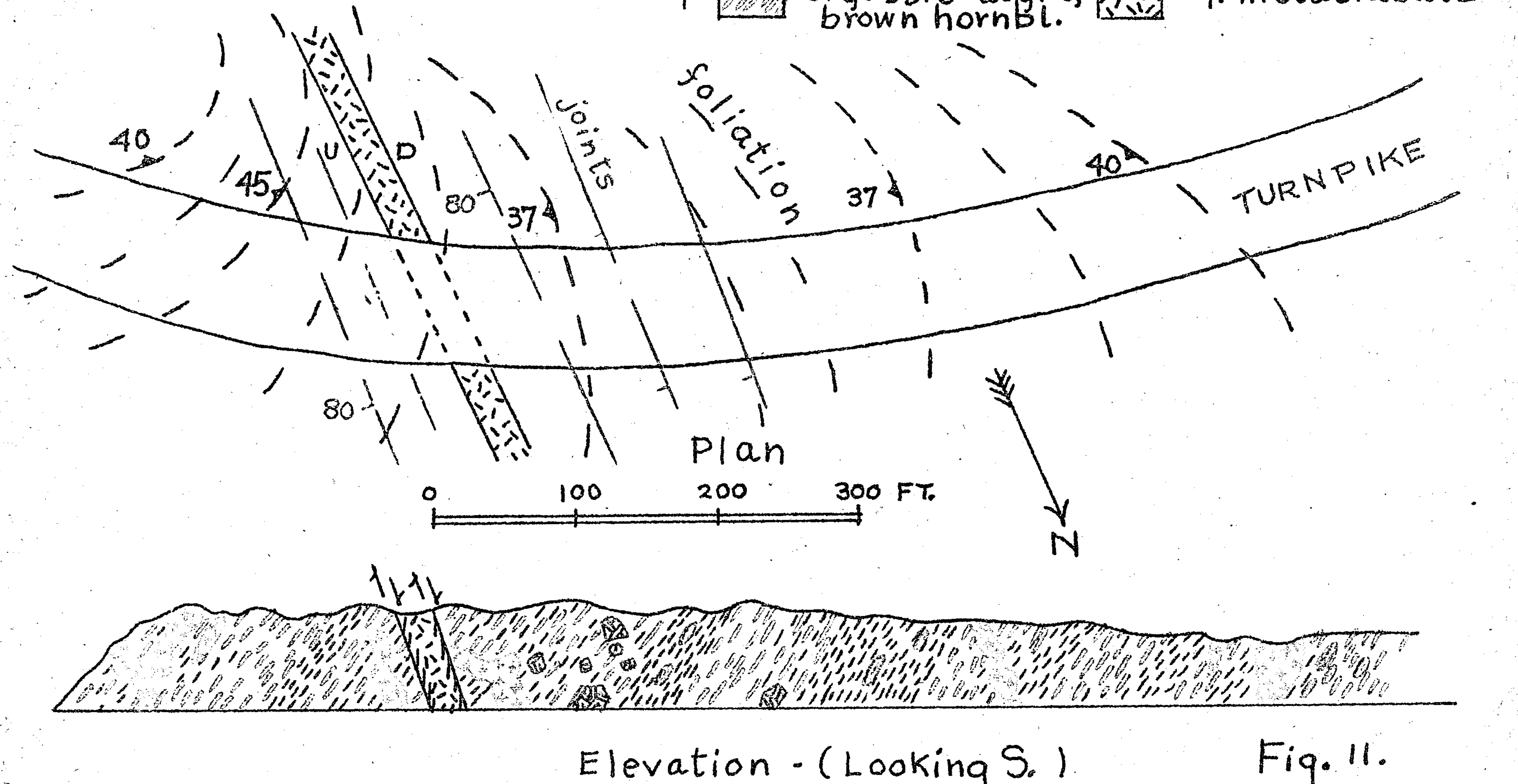


Fig. 11.

Miles

38.5 Climbing North Valley Hills.

44.4 Downington Exit.

49.1 STOP 7. Mine Ridge pre-Cambrian Complex.

This cut is located 4.7 miles on Pennsylvania Turnpike west of the Downingtown interchange, and along Marsh Creek about one mile north of Wallace, Phoenixville quadrangle.

An excellent display of the pre-Cambrian geology of the Mine Ridge is displayed here. The only rock type missing is the Pickering sedimentary gneiss into which all of these rocks were intruded. The magmatic succession is given on figure 11, as well as a very tentative cross-section and map. This locality is just east of the large anorthosite mass mapped on the Honeybrook quadrangle, and is one of the few places where the eruptive relation between the anorthosite and the other rocks can be seen. It is remarkable that the anorthosite remains relatively massive even in small xenoliths. These xenoliths are surrounded by a zone of white altered plagioclase carrying garnets. The major deformation and metamorphism which impressed the foliation on the rocks probably occurred at the time of granitization and just before the intrusion of the coarse graphic-granite cross-cutting pegmatites. The metadiabase dike was a later event accompanying normal faulting, although still pre-Cambrian. Thermal metamorphism has affected the dike. The similarity of this sequence to that of the Baltimore gneiss nearer Philadelphia is striking.

Coarse crystals of brown hornblende and some allanite have been found.

PARTY DISBANDS. Howard Johnson restaurant 2.9 miles ahead.

BIBLIOGRAPHY

The areal geology of this region is covered by the following:

Bascom, et al., (1909) Philadelphia District, U. S. G. S. Folio 162

Bascom and Stose (1932) Coatesville-West Chester Folio, U. S. G. S. Folio 223

Bascom and Stose (1938) Honeybrook-Phoenixville Quadrangles, U. S. G. S. Bull. 891

Additional references on some of the problems discussed are given below:

Armstrong, E. J. (1941) Mylonization of Hybrid Rocks near Philadelphia, Bull. G. S. A., v. 52, pp. 667-694

Bailey, E. B. and Mackin, J. H. (1937) Recumbent Folding in the Pennsylvania Piedmont, Am. J. Sci., ser. 5, v. 33, pp. 187-189

Ch'ih, C. S. (1950) Structural Petrology of the Wissahickon Schist near Philadelphia, with special reference to granitization, Bull, G. S. A., v. 61, pp. 923-956

Cloos, E., and Hietanen, A. (1941) Geology of the "Martic Overthrust" and the Glenarm series in Pennsylvania and Maryland, G. S. A. Spec. Paper no. 35

Gordon, S. G. (1921) Desilicated Granite Pegmatites, Proc. Acad. Nat. Sci. Phila., part 1, pp. 169-192

Hawkins, A. C. (1924) Alternative interpretations of some crystalline schists in southeastern Pennsylvania, Am. J. Sci., ser. 5, v. 7, pp. 355-364

Jonas, A. I. and Bliss, E. (1916) Relation of the Wissahickon mica gneiss to the Shenandoah limestone and the Octoraro schist of the Doe Run-Avondale region, Chester Co., Pa., U. S. G. S. P. P. 98, pp. 9-34

Knopf, E. B. and Jonas, A. I. (1929) McCalls Ferry-Quarryville District, Penna., U. S. G. S. Bull. 799

Larsen, E. S. (1928) A Hydrothermal Origin of Corundum and Albitite Bodies, Ec. Geol., v. 23, pp. 398-433

Mackin, J. H. (1935) The problem of the Martic Overthrust and the age of the Glenarm series, Jour. Geol., v. 43, pp. 356-380

__________ (1950) The down-structure method of viewing geologic maps, Jour. Geol., v. 58, pp. 55-72

McKinstry, H. E. (1916) The Minerals of Brinton's Quarry, Chester Co., Pa., Am. Min. v. 1, pp. 57-62

________________ (1949) Mineral isograds in southeastern Pennsylvania, Am. Min., v. 34, pp. 874-892

Miller, B. L., (1935) Age of the schists of the South Valley Hills, Bull. G. S. A., v. 46, pp. 715-756

Postel, A. W. (1940) Hydrothermal emplacement of granodiorite near Philadelphia, Proc. Acad. Sci. Phila., v. 92, pp. 123-152

Swartz, F. M. (1948) Trenton and sub-Trenton of outcrop areas in New York, Pennsylvania and Maryland, A. A. P. G. Bull., v. 32, pp. 1493-1595

Weiss, J. V. (1949) Wissahickon Schist at Philadelphia, Bull. G. S. A., v. 60, pp. 1698-1726

1951

FIELD CONFERENCE OF PENNSYLVANIA GEOLOGISTS

Trip B: Stratigraphy of Coastal Plain of New Jersey

Saturday, June 2, 1951

Leaders: Meredith E. Johnson, State Geologist of New Jersey.
Lincoln Dryden, Bryn Mawr.

Leave Bryn Mawr headquarters at 8:30 a.m. (by bus). Take the following roads to Stop I: Montgomery Avenue, City Line Avenue (U.S. Routes 1 & 13 bypass), Hunting Park Avenue, Roosevelt Boulevard (U.S. Routes 1 & 13). Turn right on Levick Street (U.S. Route 422), cross Delaware River (onto Route S41) and just beyond railroad underpass turn right on River Road (first stop-light) & proceed 1/2 mile to dirt road and entrance to sand pit of

STOP I Russell W. Ward, Inc.
0.0 miles Here the following fine section of the Pensauken and Raritan formations will be seen (see Columnar Section):

a. 10-30 ft. yellow-brown, cross-bedded, fine to coarse sand and gravel. The sand is featured by black bands of limonite-coated grains, and by bedded "ironstone" in which limonite is the cementing agent. Boulders of quartzite up to a maximum size of 16 x 30 x 34 inches can be seen, although most of the gravel consists of pebbles having a maximum diameter of less than 3 inches. Note the presence of chert. This exhibits all stages of weathering. This feature, and the more common occurrence of ironstone and the black, limonite-stained bands, are some of the criteria by which the Pensauken formation can be differentiated from the younger Cape May formation. . . . . . . Pensauken formation

b. A marked unconformity separates the Pensauken and the underlying white sand and clay of the Raritan formation (about 10 ft. exposed at present). The clay is composed chiefly of kaolinite and is a good fire-clay. The sand is mostly fine-grained and has met specifications for filter sand. . . . . . . Raritan formation.

Return to Route S41, turn right (southeast) and proceed 5.0 miles to

STOP 2. Wm. Graham Brick Manufacturing Company. Maple Shade
5.0 mi. The section here is as follows:

a. 8 to 10' clayey yellow gravel containing pebbles of quartz, quartzite, sandstone, chert and ironstone. Because of the unaltered character of the pebbles, the mineral and rock varieties represented, and the low elevation (± 45 ft. A.T.), this Pleistocene deposit is assigned to the Cape May formation

b. 5 ft. weathered, non-glauconitic, dove-colored clay.

c. 3 ft. glauconitic clay (in part weathered to ironstone)

d. 6 ft. greasy, micaceous, dark-gray clay.

Since fossils of Merchantville type have been found in "b" as well as "c" and "d", all of this clay is assigned to the . . . . Merchantville formation

THE FORMATIONS OF THE NEW JERSEY COASTAL PLAIN

	Columnar Section	Thickness	Descriptions
Quaternary	Recent	0-30'	Recent alluvium, beach & dune sands.
	Cape May *	0-30'	Yellow-brown sand and gravel.
	Pensauken *	0-60'	Similar to C.M., but usually some boulders and chert more weathered.
	Bridgeton *	0-30'	Similar to Pensauken. Chert mostly chalky.
Tertiary	Beacon Hill	0-20'	Similar to Pensauken, but caps highest hills only.
	Cohansey	100-250'	Fine to coarse, often clayey yellow sand with local clay lenses.
	Kirkwood *	100'	White, fine-grained quartz sand (type locality).
	Sh.R.-Man. *	0-36'	Sandy greensand. Fossiliferous.
	Vincentown *	25-140'	Glauconitic medium-grained quartz sand, or highly fossiliferous sand, often in consolidated beds.
	Hornerstown *	20-30'	Greensand with some clay & sand. Fossiliferous.
Cretaceous	Red Bank	0-140'	Fine-grained micaceous, clayey sand (bottom) to medium-grained glauconitic sand.
	Navesink	5-40'	Speckled, dark gray to dark green, clayey glauconite. Fossiliferous.
	Mt. Laurel *	5-60'	Fine to medium-grained, glauconitic sand.
	Wenonah	35-20'	Fine-grained, micaceous sand.
	Marshalltown *	30-40'	Black sandy clay, to greenish-black, glauconitic sandy clay.
	Englishtown *	20-140'	White to gray or yellow glauconitic sand; often micaceous and lignitic; some interbedded clay.
	Woodbury	50'	Dark gray fossiliferous clay.
	Merch. *	50-60'	Black, micaceous clay; usually glauconitic and sandy towards base. Fossiliferous.
	Magothy	0-130'	Fine-grained, gray, lignitic sand with thin clay laminae & thicker gray to black, lignitic clay beds.
	Raritan *	150-300'	White, buff and light gray sands, with interbedded gray, white or red clay.

Notes:

(1) We will see only those formations which are starred (*).

(2) The Tinton formation, which overlies the Red Bank in Monmouth County, has purposely been omitted.

(Note: Many types of fossils have been found here, including crocodile remains, a primitive lobster, crab claws, worms (Hamulus), many species of pelecypods and gastropods, a scaphopod (Dentalium) and four cephalopods. . . . "Seek and ye shall find").

Proceed southwest on Route S41 to first traffic circle and three-quarters around it, turning off in a northeast direction on road to Moorestown. Proceed two-thirds of a mile to roadside borrow pit and

STOP 3 In this pit we will see:
7.7 mi.

a. 6 inches yellow, gravelly sand . . . Cape May.
b. 6 feet fine-grained micaceous yellow sand. . . Englishtown.

The pebbles (in Cape May) here are mostly well rounded pieces of ironstone, but some quartz, ranging up to 6 inches in maximum diameter, and hard, fine-grained sandstone of Silurian or Devonian type can also be seen.

Proceed northeast about one-quarter of a mile & turn right on road through park. At first road crossing, turn right and continue past Route 38 a distance of 0.3 mile to next road crossing and turn right to Route S41. Turn left on this road & park just beyond intersection with New Jersey Turnpike.

STOP 4 The following section was recently exposed:
10.8 mi.

a.	2-5 yellow-brown sand and gravel. . .		Cape may formation.
b.	2-7 yellow micaceous, glauconitic, fine-grained sand	. . .	Wenonah formation.
c.	7 olive-green glauconite	}	Marshalltown.
d.	7 black sandy glauconite		

The pebbles in "a" are mostly quartz and under 2" in maximum diameter. A little chert, quartzite cobbles up to 5", and a block of ironstone 6 x 8 x 12 inches were also seen.

Proceed southwest on Route S41 approximately 2 miles and turn right on Evesboro-Ellisburg road. Follow this to intersection with Route 40 and continue west on that highway to first traffic circle.(intersection with Route 41) at Ellisburg. Make 2/3 turn around traffic circle and take road to Haddonfield, (Route 41). Proceed about 1.7 miles to Homestead
18.1 Restaurant (on right) & turn into parking lot beside it. . .
mi. Time out for lunch.

Proceed southwest about 1/2 mile and take left fork - following Route 41 - to Runnemede and

STOP 5a Do not dismount. A brief statement about the Wenonah
21.3 mi. formation will be made here.

Proceed southwest 0.3 mi. to

STOP 5b Mount Laurel formation
21.6 mi. 10 ft. yellow, fine to coarse-grained glauconitic sand exposed in excavation for a house. This is the upper part of the formation.

Proceed southwest on Route 41, across Route 42, past Almonesson airport, to Fairview (intersection with Route 47). Bear right on road to Sewell and at first intersection past Mantua Creek, turn left. Continue on this road to first intersection and bear left. Almost immediately turn left again on cinder road and keep left to plant and pit at

STOP 6 Inversand Company. (Note: We are permitted to make this
30.5 mi. stop through the courtesy of the Company, but all will have to sign a paper releasing the Company from liability for any injuries sustained while there.

At this pit we will see:

a. 3 ft. glauconitic sand of the — Vincentown formation
b. 3 ft. more glauconitic transition beds.
c. 20 ft. "green" greensand — Hornerstown formation
d. 10 + ft. black, clayey greensand — Navesink formation

Many fossils have been found in the greensands, including a dinosaur, crocodile bones & plates, a mososaur, shark teeth, ammonites, gastropods & pelecypods, and a sponge. Casts of Cucullaea are perhaps most common, but Ostrea larva (falcata) is not uncommon ~~in the Navesink~~.

Return to highway & turn left. Proceed 0.6 mi. and turn left at cross-road. Proceed 0.8 mi. (keep left at road fork) to intersection with Route 47 and proceed north on that highway 1.9 mi. to Fairview. Bear right on road to Blackwood, cross Route 42 and continue to pit on left of road.

STOP 7 Good exposure of:
38.6 mi. a. 2 ft. brown soil, sand, gravel & ironstone. Occasional boulders near base — Pensauken formation
b. 11 to 18 white, fine-grained sand with brown eluviation bands. Casts of 2 small pelecypods have been found in lower part of exposure.

Note unconformity between "a" and "b"

Proceed east to Clementon and immediately after crossing railroad, turn left. Turn left again at next block & proceed on road paralleling railroad about 0.6 mi. to bridge over North Branch of Timber Creek. Stop, climb over railroad embankment to

STOP 8 The following section will be seen:
41.7 mi.

a. 2 ft. fine to coarse-grained, yellow sand with at least 10% glauconite and occasional pebbles. . . . . . Cape May (?) formation
b. 10 ft. greenish, sandy glauconite with patches of gray clay and other concentrations of glauconite. Upper part sandy; lower part clayey.

The greensand is fossiliferous and on a recent visit the following were noted: Etea delawarensis, Cardium sp., Turritella sp., bryozoa.

Proceed northwest about 1/4 mi. to cross-road. Turn right, jog left and right at dead-end street, and then left on White Horse Pike (Route 43). Continue northwest to traffic circle at intersection with Route 45 & turn right on that route. At next traffic circle turn northeast on Route 25, and just beyond underpass for Route S41 turn left on ramp leading to that highway and the Tacony-Palmyra bridge over Delaware River. Return to Bryn Mawr over same routes followed in morning.

Note on the Stratigraphy & Paleontology of the Cretaceous and Tertiary formations of the Coastal Plain of New Jersey

by Henry Herpers

A table of the geologic formations of the Coastal Plain of New Jersey is included in the itinerary of the field trip.

Upper Cretaceous Formations

The series of formations beginning with the Merchantville and continuing thru the Navesink are all of marine origin, and each is conformable with the formations which overlie and underlie it. The Englishtown formation is unfossiliferous in the area of its outcrop, but the presence of glauconite suggests that it, too, is largely of marine origin. Marine fossils have been found in the Englishtown down the dip, in well cuttings. Many of the formational boundaries are locally transitional, so that the whole series may well represent the various facies of a single cycle of deposition. The paleontological record appears to support this concept, since the recurrence of characteristic faunas has been observed, and this suggests relatively minor changes in the depositional environment during the cycle. Perhaps the most important of the faunas is the Cucullaea fauna, which first appears in the Merchantville formation. The fauna reappears, to a smaller extent, in the Marshalltown, and returns again in force in the Navesink. It is rather characteristic of the more glauconitic formations. The less glauconitic, sandier formations carry the Lucina cretacea fauna, which more or less characterizes the Woodbury, Mount Laurel-Wenonah and Red Bank formations. However, new elements appear in the faunas of the younger formations, as for example, the first appearance in force of the heavy varieties of Exogyra and Gryphaea and of the genus Ostrea in the Marshalltown, and of the fossil squid Belemnitella americana in the Mount Laurel formation.

In the region of their outcrop, the formations may usually be differentiated on lithologic character, although this becomes more difficult to do down the dip where the formations thicken and where lithologic differences become less distinct. Paleontologically, the formations may be distinguished more on the basis of fossil assemblages rather than by unique index fossils.

Tertiary formations

The Hornerstown, Vincentown and Shark River-Manasquan formations constitute a conformable series of marine sediments. The contacts of these formations with one another are transitional, and recurrent faunas are present, again suggesting that the formations may be facies of a single cycle of sedimentation. In the region of their outcrop, the formations are quite readily distinguished by their lithology, and by their fossils, but down-dip, lithologic differentiation becomes more difficult.

In the area of outcrop, the Hornerstown is, in general, a bed of glauconite with a little clay and sand. The overlying Vincentown consists of two facies, viz.: a lime-sand facies, consisting largely of broken corals, bryozoans and echinoids; and a glauconitic sand facies. The two facies are found in alternate layers, although the lime-sand facies is more common in the basal portion of the formation, especially in the southwestern part of the state. The Shark River-Manasquan formation consists of a lower, greensand member and an upper sandy clay member. The Shark River, which is found only in a small area in eastern Monmouth County, is somewhat similar in lithology to the Manasquan, but may be differentiated from it paleontologically.

These formations, originally thought to be of Cretaceous age, are now considered to be Eocene. McLean has recently described paleocene foraminifera from the Hornerstown and Vincentown, and Canu and Bassler have stated that, on the basis of the bryozoan remains, the age of the Vincentown is Cretaceous.

The Shark River-Manasquan formation is unconformably overlain by the Kirkwood formation of Miocene age. The Kirkwood carries a limited marine fauna of some 160 species, of which 39 species and varieties are restricted to the Kirkwood. Down the dip, the Kirkwood formation includes two thick beds of diatomaceous clay. These beds have been penetrated by many wells, especially those in the general vicinity of Atlantic City. The larger bed is some 400 feet in thickness. So far as is known, neither of the beds is visible in outcrop.

Paleontology

An Annotated list of some of the more important fossils and fossil assemblages of these upper Cretaceous and Tertiary formations which will be seen, follows:

Upper Cretaceous

Merchantville Formation

Hamulus falcatus (Conrad) — Merchantville & Woodbury
Axinea subaustralis d'Orbigny
Cardium (Granocardium) tenuistriatum (Whitfield)
Cucullaea (Idonearca) antrosa Morton — Cucullaea fauna
C. neglecta Gabb
C. spp.
Turritella merchantvillensis Weller
Placenticeras spp.

Marshalltown formation

Hamulus wenonahensus Howell — First appears in Marshalltown
Exogyra ponderosa Roemer
Gryphaea mutabilis Morton
Ostrea (Gryphostrea) Vomer (Morton)
O. (Alectryonia) falcata Morton
also Cucullaea fauna

Navesink Formation

Hamulus wenonahensus Howell
Choristothyris [Terebratella] plicata (Say) First appears in Mt. Laurel-Wenonah)
Axinea subaustralis d'Orbigny
Cucullaea antrosa Morton — recurrent Cucullaea fauna
Exogyra costata Say
Gryphaea convexa Morton — Replaces E. ponderosa fauna of Marshalltown
Ostrea mesenterica Morton
Anchura pennuta (Morton)
Belemnitella americana (Morton) First appears in Mt. Laurel-Wenonah.
In addition, the percentage of gastropods in the fauna increases materially.

Tertiary

Hornerstown Formation

Oleneothyris [Terebratula] harlani (Morton) First appears in Hornerstown
Cucullaea (Idonearca) vulgaris Morton
Gryphaea dissimilaris Weller — First appears in Hornerstown
Vertebrate remains, Hadrosaurus, crocodiles, turtles, shark teeth, etc.

7'

Vincontown Formation

Foraminifora
Oloneothyris [Torebratula] harlani (Morton)
Axinoa sp.
Cucullaoa sp.
Gryphaoa sp. G. dissimilaris Woller — Found at Long Branch
Nomodon sp.
Ostroa (Gryphostrea) vomor (Morton) — Recurrent species
Polorthus tibialis (Morton) — A teredo
— sand facies

Foraminifora
Bryozoa
Echinoid romains
Spirulaoa [Serpula] rotula (Morton) — found in limestone facies only
— limostone facies

Shark River-Manasquan Formation

Flabollum mortoni Vaughan
Torebratulina atlantica Morton
— characteristic of formation
Caryatis vota Whitfield — Has boen found in Vincontown

Kirkwood formation

Saxicava parilis Conrad
S. myaoformis Conrad
Tollina poracuta Conrad
T. capilifora Conrad
Cymatosyrinx polycyma P & H
C. pseudoburnoa (Heilprin)
Nassarius sopora Pilsbry & Harbison
Plouroliria ultima P & H
P. ultima foxi P & H
Balanus shilohensis Pilsbry
B. withorsi Pilsbry

REFERENCES

Canu, Ferdinand & Bassler, R.S., (1933), The bryozoan fauna of the Vincontown limesand, U.S. Nat. Mus. Bull. 165

Cooke, C.W. & Stephenson, L.W., (1928), The eocono age of the supposed late upper cretaceous greensand marls of New Jersey, Jour. Geol., vol. 36, pp. 139-148.

Greacon, K.F., (1941), The Stratigraphy, fauna, and correlation of the Vincontown formation, N.J. Dept. Cons. & Dev., Bull. 52, Geologic Series.

Howell, B.F., (1943), Hamulus, "Falcula" and other cretaceous tubicola of New Jersey, Proc. Acad. Nat. Sci., Phila., vol. 95, pp. 139-166

Kümmel, H.B., (1940), The Geology of New Jersey, N.J. Dept. Cons. & Dev. Bull. 50, Geologic Series.

McLean, J.D., Jr., (1951). Paleocene foraminifera from the atlantic coastal plain, Cont. Cushman Found. for Foram. Res., vol 2, pp 20-29.

Richards, H.G. & Harbison, A., (1942), Miocene invertebrate fauna of New Jersey, Proc. Acad. Nat. Sci., Phila., vol. 94, pp. 167-250.

Weller, Stuart, (1907), Cretaceous Paleontology of New Jersey, N.J. Geol. Surv., Reports on Paleontology, Vol. IV.