THE GEOLOGY OF THE TRIASSIC LOWLAND OF SOUTHEASTERN NEW YORK AND NORTHERN NEW JERSEY

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Trip C

Location

The area covered by the Triassic Field Trip is the northeastern part of the largest Triassic basin in the United States. The route follows the sides of a triangle. Starting near Peekskill it crosses the Hudson valley over the Bear Mt. bridge and follows the west shore of the Hudson to the vicinity of the George Washington Bridge at New York City. From here the route is northwesterly as far as Suffern, N.Y., where it turns northeast toward Stony Point, N.Y. on the Hudson and thence back to Peekskill. (Plate 9, Fig. A and Plate 13).

Geologic History

The Pre-Newark Peneplane

For practical purposes, the history begins with the broad beveling of a pre-Triassic complex following the Appalachian revolution at the close of the Paleozoic Era. The evidence for this beveling can be seen on the east shore of the Hudson estuary south of Peekskill. Here the line of hill summits rises from the estuary level at an angle varying between 10 and 15 degrees until it reaches the upland level. This region is interpreted by Sharp (1929) and others as an exhumed portion of the Pre-Newark peneplane for the following reasons: (1) the slope approximates the present dip of the Newark sediments across the estuary, (2) the intersection of the surface with the estuary level is a smooth line, indicating that the basement of the Newark sediments was an even surface. The single major projection along thisshoreline is interpreted as a residual on the erosion surface. This projection is utilized as the foundation for the eastern pier of the George Washington Bridge.

The Newark Series

The episode of erosion which produced the pre-Newark peneplane eventually changed to one of deposition for reasons which are conjectural. The nature of the material in the lower part of the Newark series indicates a source to the southeast from still-ungraded areas of the Appalachian orogenic belt. Fossils indicate an Upper Triassic age.

The STOCKTON formation at the base consists chiefly of light-colored arkosic sandstones and conglomerates with interbedded red sandstone and shale. Total thickness is as much as 3000 feet. A single phytosaur skeleton (Rutiodon manhattenensis) has been collected from the base of the Palisades a short distance south of the George Washington Bridge.

The succeeding LOCKATONG formation consists of black shales, hard massive dark argillites, flagstones and in a few places very impure, thin limestone layers. Thickness estimates range up to 3500 feet. The Lockatong has yielded a few species of fish (related to the lung-fish), a small crustacean (Estheria ovata) and a few remains of land plants. The formation thins northward and is not mapped in the area visited. However, similar rocks and fossils have been found below and above the Palisades sill.

The uppermost BRUNSWICK formation consists chiefly of soft red shales and interbedded sandstones, the latter being more abundant and coarser toward the northeast. Thickness estimates range up to 8000 feet. The formation underlies the widest area of the Lowland but is often under heavy glacial cover in this locality. Massive conglomerates occur at various points along the northwestern border adjoining the Highlands, and replace beds of the previous division at various horizons.

The aspect of all these sediments is continental. This is inferred from both physical and fossil evidence. Physically, mudcracks, raindrop impressions, channel fillings, rapid variations in texture, fanglomerates indicate stream, lake, or estuarine deposits. Dinosaur foot-prints, plant remains, crocodile-like dinosaurs and ancient fresh-water fish suggest non-marine deposition but, at times, possibly affected by estuarine waters. The Newark series was probably spread over a broad piedmont plain in the form of nearly flat coalescing alluvial fans by vigorous streams that washed sediment down from the uplifted crystalline foreland. During Locatong time estuarine embayments may have covered parts of the piedmont plain to produce the even-bedded laminations of the fish-bearing argillites.

Climatic Conditions

The sediments and their fossil contents have been used to infer the climatic conditions under which they were deposited. The occurrence of fresh feldspar in the arkose and the predominently red color in the shales and sandstones together with frequent mudcracks led early workers to the conclusion that the climate was of the warm, arid type. Recent work on sediments has shown that both arkoses and red beds may be produced under a variety of climatic conditions, including warm and humid. Such features have limited value as climatic indicators.

Animals such as dinosaurs and fish may have lived in or near water bodies, i.e., along streams or in deltaic or estuarine areas. Since such water bodies may be located in either arid or humid regions, the evidence for their existence affords little clue to the climatic conditions of the broader area of deposition. (cf. the Nile River). It appears then that the only conclusion that may be drawn is that the climate was probably warm.

Igneous Activity in Newark Time

Basic lava flows are intercalated with the beds of the Brunswick formation. Three distinct flows are now recognized in the Watchung region near Paterson, N.J. Occasional volcanic plugs appear along the northwest border fault. Deeper intrusives include the major sill of the Palisades which, as it is followed north of Nyack, N.Y. becomes a distinctly curved dike cutting across the strike of westward dipping Newark beds. The Palisades sill shows distinct baking effects in the surrounding sediments and occasional xenoliths near the lower contact. The sill itself is strongly differentiated as to texture and composition. (Walker, 1940 and discussion at Stop C-3).

Deformation of the Newark Series and Associated Igneous Rocks

In the continental basin that received the Newark sediments the floor must have sloped gently westward permitting low initial dips of the sediments. These dips have been generally increased by tectonic movements so that in this region they are about 15 degrees northwest. Some of this increase is probably due to subsequent basining or downwarping as suggested by the concentric curves of the Watchung trap ridges farther south. The axial region of the downwarp lies east of and parallel to the western margin of the basin. Since the present margin lies along a major fault, it is possible that the downwarping of the basin gave way to faulting. In this region the maximum displacement along the fault is near the center of the downwarp and diminishes northeastward so that the Triassic beds are no longer present east of the Hudson.

Between the northermost lava flow near Pompton Lakes, N.J. and the extension of the Palisades near Haverstraw, N.Y. the westward dipping Newark beds strike oblique to the border fault-line, indicating either pre-fault basining as suggested above or the increase of low initial dips by the rotational element of the fault. The individual effects of these two possibilities are difficult to evaluate.

Certainly faulting near the close of Newark sedimentation produced an escarpment facing southeast. From the upthrown block on the northwest, streams cut through early Paleozoic limestones and quartzites, deploying on the downthrown block to produce a set of alluvial fans or cones made of coarse, sometimes angular to semi-rounded, blocks of these materials. The faulting is pictured as part of a general program of isostatic uplift of an orogenic belt in which the general stretching effect produced not only uplift but gravity faults. At this time this elevated region was no longer receiving sediments except along fault scarps and was now subject to erosion to a new base level.

The Fall Zone Peneplane

Some time before Upper Cretaceous beds were deposited in nearby Long Island, the Triassic basin was reduced to a surface of low relief. The evidence for this surface is extended from the New England province to the Palisades sill. Only the area between Alpine, N.J. and Staten Island, N.Y. preserves a remnant of this surface. Elsewhere in the Triassic Basin the surface has been destroyed. The present account of subsequent developments follows Johnson (1931) in supposing that the Cretaceous cover extended inland beyond its present exposure to some distance northwest of the Triassic Basin.

The covered, peneplaned rock mass was tilted southeast along an axis roughly parallel to the strike of the Cretaceous beds in Long Island. This elevated the area of the Triassic basin and permitted consequent streams to develop on the exposed Cretaceous sediments. The only trace of this original consequent drainage in the area is the course of the Hudson through the Highlands, but this too has probably been modified in succeeding cycles.

The uplift that initiated the consequent drainage also began a cycle which ended in the production of the Schooley (Upland) peneplane.

The Schooley Cycle

During the Schooley Cycle consequent streams developed long subsequents in the Cretaceous cover mass over the site of the area studied. Johnson (1931) saw evidence for such a subsequent lowland in certain broad-floored wind gaps in the Palisades and the Watchung Mountains. He supposes that an ancestral Hudson became superposed on crystalline rocks of the Highlands but had been captured by a subsequent working headward from the southwest in a weak belt of the Cretaceous above the site of the Triassic basin. (This would be similar to a river like the present Susquehanna turning right at the present Fall Line). The subsequent thus established extended from the headwaters of the present Croton river to the vicinity of Summit, N.J. Later in the same cycle (according to Johnson) this subsequent became superposed on the Triassic sediments and associated igneous rocks.

At this time the ancestral Hudson is pictured as emerging from the Highlands along its present course, having undergone some adjustment since its southeast consequent direction was established. Actually, the Hudson gorge trends generally north-south following local weaknesses in rock structure, and emerges at the tip of the Triassic basin. Thompson (1936) on the basis of this adjustment has suggested an entirely different history, namely, that the river simply worked by headward erosion up the Triassic belt between the Palisades and the New York crystallines and kept going through the Highlands. The writer is willing to grant that the course of the Hudson through the Highlands was produced by headward erosion along weak belts in the crystallines, but only to modify a less favorable course of a stream superposed from the Cretaceous cover.

To resume the narrative, the adjusted Highlands course led into a superposed subsequent wandering broadly over the Triassic basin cutting across the strike of both sediments and igneous bodies. This ancestral Hudson was joined by the Croton river, also a superposed subsequent, but on various types of crystalline rocks.

The Harrisburg Cycle

Uplift initiated the Harrisburg cycle which reduced less-resistant rocks to a low relief surface. This surface is preserved in the ridge summits of the Newark series and in the floors of Sparkill, Paterson, Milburn and other wind gaps. The ancestral Hudson is pictured as still flowing over the Triassic basin during the Harrisburg cycle, becoming graded and meandering through broad water gaps in the igneous bodies. The present wind gap floors are roughly two miles wide (from north to south) and must have held meandering streams. Traces of the Harrisburg peneplane have also been recognized as rock terraces in the Hudson gorge at Bear Mt. Inn and at West Point. The elevation of this surface is now roughly 200 feet.

Post Harrisburg Erosion

During the Harrisburg cycle, the Cretaceous beds must have been eroded back to a point far south of Sparkill Gap, thus uncovering the Triassic belt between the Palisades and New York. Resequents draining the Fall Zone developed subsequents along this belt. By the time the present Long Island Sound valley was developed, one of these subsequents captured the ancestral Hudson at Sparkill Gap, diverting it to its present course. Since the diversion, the Hudson widened its valley below Sparkill until the floor attained a width of one mile. This is in sharp contrast to the two mile width of the Tappan Zee north of the Gap. This greater width may be explained by broad meandering during the Harrisburg Cycle when the course south of the Gap had not yet been developed.

Glaciation

In the area studied only evidence of the Wisconsin glacier is visible. Striae on the Palisades indicate that the glacier crossed the Fall Zone Section and the Hudson Valley from northwest to southeast. Elsewhere in the Lowland, the glacier moved essentially parallel to the strike of the tilted Triassic sediments. This is indicated in part by the festooning of the moraines farther south.

During glacial wastage, and partly during glacial advance, ridge-forming belts of the Triassic received a heavy cover of ground moraine so that bedrock outcrops are scarce. Ponding of water in front of the receding ice edge was wide-spread. The largest lake was south of the area visited between the Watchung Mtns. and the border fault (Lake Passaic). Other lakes were formed in the Hackensack valley and its tributaries. Farther north, smaller lakes

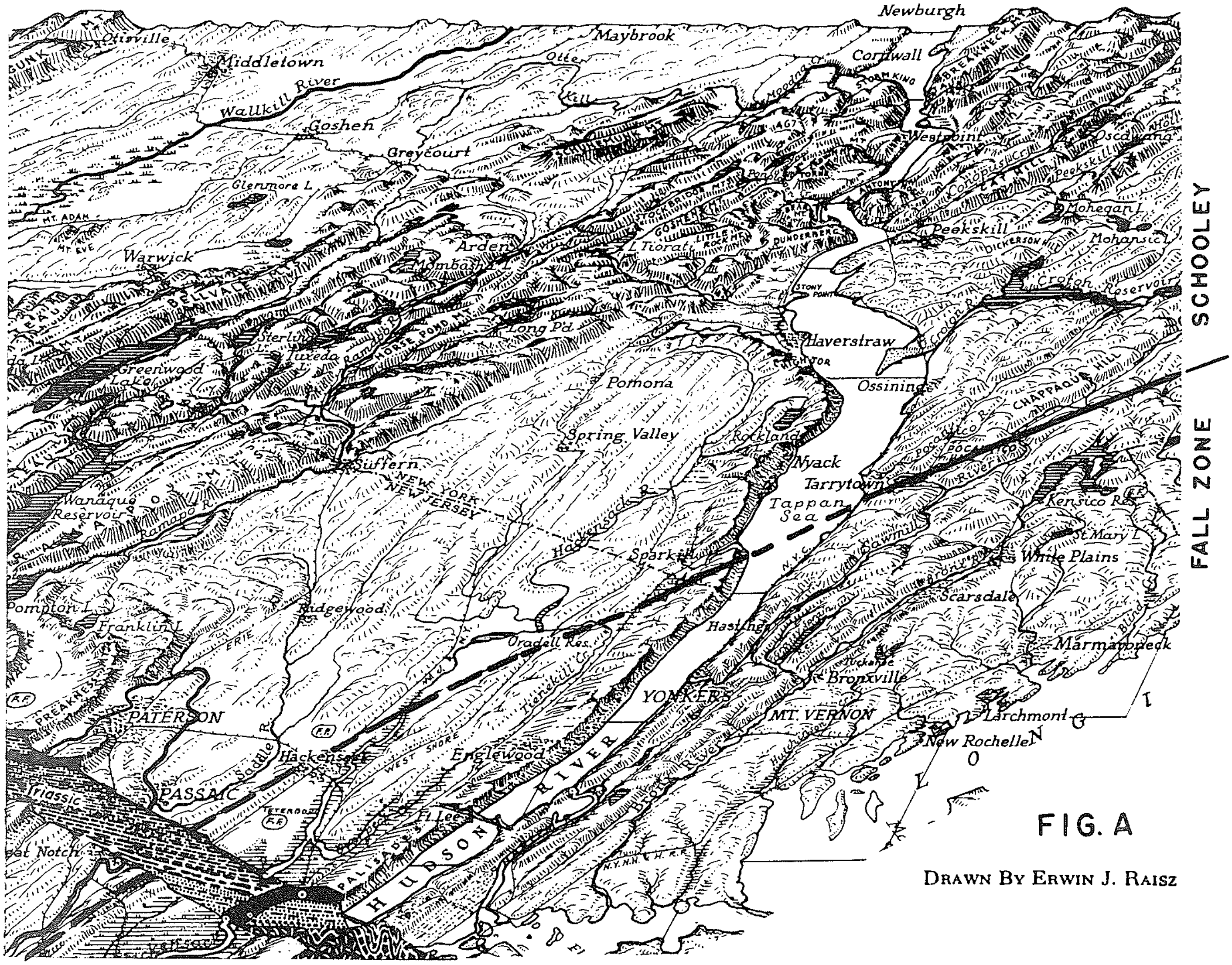

FIG. A

Drawn By Erwin J. Raisz

PHYSIOGRAPHIC DIAGRAM OF THE NEW YORK REGION

The Geographical Press,

Columbia University,

New York

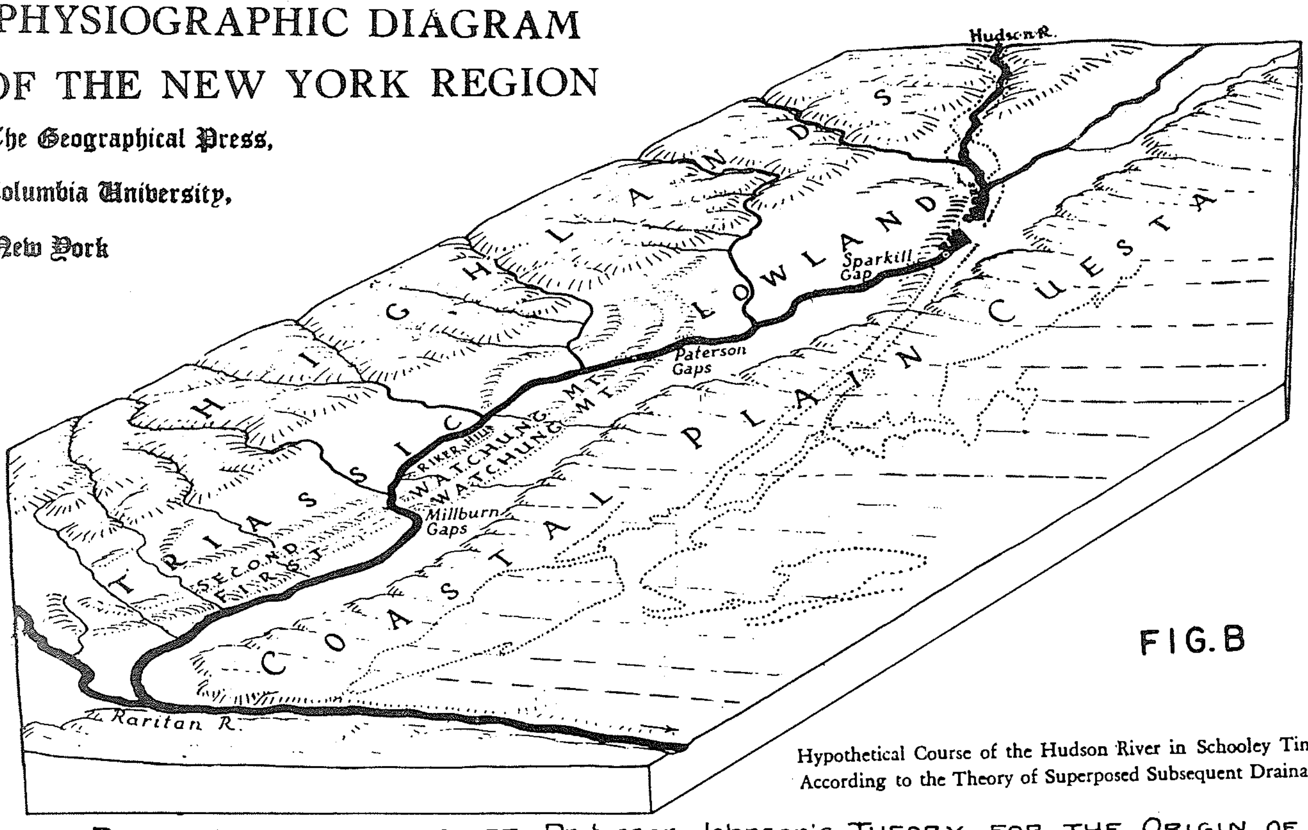

FIG. B

Hypothetical Course of the Hudson River in Schooley Time, According to the Theory of Superposed Subsequent Drainage

DIAGRAM TO ILLUSTRATE Professor Johnson's THEORY FOR THE ORIGIN OF THE GAPS IN THE WATCHUNG RIDGES. (Drawn by E. J. Raisz for Johnson: Atl. Slope)

produced deltas at the tip of the Palisades dike (Stop C-8). Complete removal of the glacier drained the lakes, and left the deltas as hills or terraces.. Since then, post-glacial stream erosion has modified the landscape but slightly.

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NORTHEASTERN SECTION OF THE TRIASSIC (NEWARK) BASIN IN NEW YORK AND NEW JERSEY

Trip C

Route Description

Mileage	
	Note: The first part of the trip (9.3 mi. to Bear Mt.) including Stop No. C-1 is the same as that of Trip D.
0	Shustin's Locust Manor (headquarters) -left (N) on Locust Ave.
.9	left (SW) on Oregon Rd.
2.2	pass under Bear Mt. Pkway.
2.3	right (W) on Pemart Ave.
2.5	right (N) on Highlands Ave. passing again under Bear Mt. Pkway.
3.0	roadcut through Gallows Hill; Annsville phyllite (Cambro-Ordovician Hudson River pelite group; see Trip 1, Stop 1-2).
3.3	pass under US-9 and turn sharp left (W) on approach road to US-9
3.4	straight (W) on US-9 following north shore of Peekskill Hollow Creek; note remnants of glacial deltas along both valley walls
4.3	right (N) on US-6-202
4.6	road starts climbing Highlands escarpment (fault line scarp); continuous exposures of Highlands crystallines (Pre-Cambrian gneisses, schists and granites) from here to Bear Mt. Bridge
7.4	Anthony's Nose lookout point

STOP No. C-1:

The Hudson River has cut a gorge through the Pre-Cambrian crystallines below the Schooley peneplane level, here shown by the hilltops. The rock bench on which the Bear Mt. Inn is located is interpreted as a remnant of the Harrisburg peneplane level formed by the Hudson River when it meandered at this level. Since Harrisburg time uplift permitted the stream to cut to lower levels before the valley floor was drowned. Glacial modification of the valley is indicated by its fiord-like walls and the shortcut east of Iona Island.
The crystallines form an upthrown block of the fault associated with the Triassic Lowland to the south. See description of Trip D, Stop 1.

7.4	continue (N) on US-6-202
8.2	left (W) across Bear Mt. Bridge

Excellent views crossing bridge:

Left (S): Iona Island and southeastern gateway of Hudson gorge; prominent notch at Timp Pass (SW) where major thrust fault crosses Dunderberg-West Mtn. ridge crest

Ahead (W): North side of bridge: Mouth of Popolopen Creek (drowned); Hell Hole fault notch between Bear Mtn. (left) and The Torne (right); Crown Ridge extending northeastward from The Torne; all these owe their topographic prominence to the Storm King granite

Right (N): Southern portion of the Hudson gorge; Sugarloaf Hill on east shore (3 mi.) (Canada Hill granite phase); Livingstone Island (east shore, 1 mi.) and Cons Hook (west shore, 2 mi.) are separated from the shore by abandoned channels of the Hudson; bedrock terraces, particularly prominent on west shore.

Mileage	
8.6	toll booths at west end of bridge
8.8	traffic circle; 3/4 around circle and then (S) on US-9W-202
9.3	pass under foot-bridge and bear left (do not turn right into road leading to Bear Mt. Inn)
10.3	Iona Island and abandoned river channel at left (E); Doodletown Brook (subsequent stream on Timp Pass-Hudson River thrust fault) at right (W); fault crosses road at this point
10.6	White, graphitic marble (Greenville ?) at right (W)
10.8	View of Hudson gorge and gateway to left (N)
11.8	Hudson River Reserve Fleet (ship "graveyard" of World War II) at left (E)
12.5	Verplanck Point quarry (Pre-Cambrian or early Paleozoic Inwood marble) across River at left (E)
13.4	Tomkins Cove quarry (Cambro-Ordovician Wappinger limestone) at left (E)
13.9	Wappinger limestone outcrop at left (E)
15.2	Stony Point traffic light; continue straight (S) on US-9W
15.3	cross bridge over Cedar Pond Creek; Triassic redbeds along both walls of gorge below
17.9	US-202 from right (traffic light); continue straight (S) on US-9W
18.2	traffic light; Haverstraw railroad station at left (E), Palisades (High Tor) at right (W)
19.4	right (SW) on NY-304 through deep roadcut in Palisades diabase
19.5	left (E) on road leading to Haverstraw quarry; bear right after leaving NY-304
19.8	level with crusher and loader at right (pick up Company guides)

STOP No. C-2: Haverstraw Quarry of the N.Y. Trap Rock Corp.

buses follow quarry road to left and take middle road (SE) at fork of roads; gentle uphill grade

20.1 Lower Quarry Level (appr. elevation 238 ft.):
The quarry, extending in a NW - SE direction, is in the intrusive diabase forming the northern arc of the Palisades. Here the strike of the diabase body is oblique to the strike of the Triassic sediments to the southwest indicating a cross-cutting relationship of the tabular igneous mass.

The prominent columnar structure of the diabase changes in attitude from nearly vertical (in the northeast quarry face) to easterly dips of 45° to 50° (in the northwest and southeast quarry faces). This feature suggests a rather abrupt change in the attitude of the intrusion with respect to the country rock from a gently dipping (15° SW) sill-like body to a steeply dipping (45° SW) dike. Preliminary results of recent extensive diamond core drilling on the Company's property bear out this contention (Fig. 2). It is not yet known whether the sill-like portion (Upper quarry level and Little Tor) is a true sill or a low-angle dike transgressing across the equally gently dipping Triassic sediments. The true thickness of the diabase intrusion appears to be approx. 700 ft.

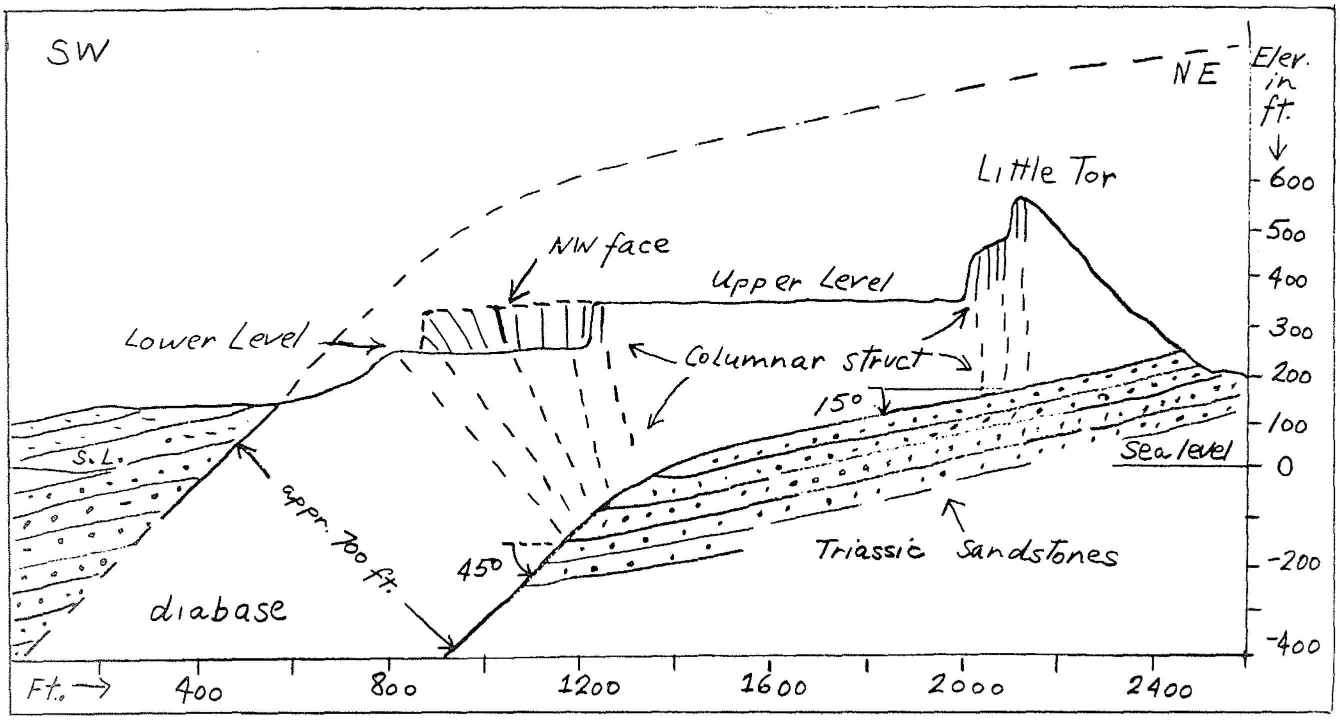

Fig. 2 Generalized Cross-section at Northwest End of Haverstraw Quarry

(New York Trap Rock Corp., K. E. Lowe, Geol. Consultant)

Farther south the upper contact of the steeply dipping diabase dike can be seen cross-cutting the Triassic sediments at the portal of the West Shore Railroad tunnel (mileage 22.7). No stop will be made at this locality.

Also observe occasional oblique shear planes with narrow zones of brecciation in the northeast quarry face.

20.2 return (NW) to crusher level

20.5 sharp right (SE) turn on road leading to upper quarry level; steep grade

20.9 Upper Quarry Level (appr. elevation 340 ft.):
On a clear day, a fine view of the Triassic Lowland shows the low sandstone ridges striking toward the observer and oblique to the diabase dike. The ridge line at the back of the quarry extends southward for several miles showing the mature dissection characteristic of the Schooley peneplane remnants. In the far distance (S) the even summit area of the Palisades is characteristic of the early mature dissection of the Fall Zone peneplane remnants. Sparkill Gap near the boundary of the two surfaces is hidden from view. The headwaters of the Hackensack River have been impounded to form the Lake DeForest reservoir seen directly south.
Turning toward the impressive northeast quarry face, osbserve extensive mass wasting aided by the near-vertical columnar structure and joint (shear) planes dipping toward the quarry floor. A 50 ft.

Mileage

wide bench at approx. 430 ft. elevation, indicating the earliest quarry level, has been almost buried under weathered debris. This represents one of the hazards of quarry operation, overcome in part by leaving ever wider benches on successively lower levels (thus reducing the rock volume that can be quarried).

20.9 return (NW) to crusher level

21.3 sharp left (SE) and then right (SW) road (downhill) at fork

21.6 left (SE) on macadam road

21.8 left (E) at intersection

22.4 right (SW) on US-9W; unusually well-developed, polygonal columnar structure at left (SE)

22.7 passing over West Shore Railroad tunnel; portal at right (S) below road shows steep upper contact of diabase dike cross-cutting the Triassic sediments

23.0 intersection with NY-303; straight (SE) on US-9W

24.8 cross Lake Rd. at Congers, N.Y.

26.9 roadcut through Palisades diabase

28.8 Nyack, N.Y.; left (E) at 2nd traffic light onto NY-59 (Main St.)

29.3 right (S) on Broadway

30.2 sharp left (E) on Cornelison Ave.

30.3 right (S) on Piermont Ave.

30.7 pass under N.Y. Thruway

30.9 Triassic redbeds (arkose of the Stockton formation) dipping gently NW (into cliff) at right (W) (behind bottling plant); top of outcrop approx. 150 ft. above sea level; Tappan Zee at left (E)

33.1 center of Piermont, N.Y. (Ash St.)

33.2 cross railroad tracks

33.3 buses turn right on Piermont Ave. and park

STOP No. C-3: Sparkill Gap

Note: Take your belongings, because the party will not return to buses until after lunch (approx. $1^1/_2$ hrs.)

As the Gap is approached from the north along the Hudson River several outcrops of the Stockton formation (mileage 30.9) extend up the valley wall to about 150 ft. above sea level. The contact with the diabase is not visible at these localities, but must be above 150 ft. elevation.

Walk across bridge into Tallman Mt. Section of the Palisades Interstate Park. Follow shore road southward. Here the diabase is first seen extending to sea level. Although the contact is not exposed at this point, its position can be estimated from the location of the olivine zone about 30 ft. above sea level. Elsewhere, this zone is known to lie about the same distance above visible contacts. It is interpreted as the result of magmatic differentiation by gravitative settling of early olivine crystals in the still fluid diabase magma. The olivine concentration in the zone is up to 25%.

Continuing along the shoreline past the swimming pool, an outcrop of arkose holds up a low terrace a few feet above sea level. A ledge at the back of the terrace is indurated arkose near the igneous contact, which is not exposed. The higher slopes expose fine-grained diabase and farther up the olivine zone.

Farther south, at a place not to be visited, the contact rises to over 10 ft. above sea level. It is evident, therefore, that there is a sag in the base of the sill at Sparkill Gap which may be associated with faulting. That a thickening of the diabase is not involved, is indicated by a distinct narrowing of the width of outcrop at the Gap.

We now walk back up the automobile road to the level of the Gap floor (some 200 ft. above sea level). Here coarser diabase outcrops nearer the interior of the sill. We are close to the north side of the Gap which extends southward for about 2 miles before the slopes rise to the summit at 500 ft. elevation (see mileage 36.1 to 36.7).

To the north, we look down on the water gap of the Sparkill. An offset of the diabase on the west side of the gap indicates that this creek follows a cross fault. It is the only stream cutting through the Palisades for its entire length from Haverstraw, N.Y. to Bayonne, N.J. On the other (N) side of the Sparkill the diabase slopes rise to rounded hills reaching heights of 700 ft. Care must be taken to distinguish between the actual water gap of the Sparkill and the interpreted earlier wind gap of broader dimensions and greater height (Plate 9, Fig. A).

Johnson (1931) interpreted the wind gap as a part of the former course of the Hudson River established as a superposed subsequent during the Schooley cycle. Later the river cut a water gap through the Palisades sill during the Harrisburg cycle. This water gap was abandoned when capture diverted the Hudson into its present course southward. At this time a reversal of drainage through the gap established the Sparkill as a tributary to the Hudson along the fault line mentioned above. (Plate 9, Fig. B).

Lunch in picnic grounds at north end of Tallman Mt. State Park return to buses via the same route

33.3 board buses and continue (SW) on Piermont Ave.

34.1 left (S) on Valentine St.

34.2 straight on Union Ave.

34.3 left (W) on US-9W sign

34.5 straight (S) on US-9W

35.8 cross road leading to Lamont Geological Observatory of Columbia University (left -E)

36.1 US-9W climbs south wall of Sparkill Gap

36.7 cross New York - New Jersey border

37.0 pass under Palisades Interstate Pkway.

40.0 pass Alpine Rd. (underpass at left - E)

40.7 intersection with NJ-201; continue straight (S) on US-9W

45.2 turn off road to right in front of large (burnt-out) road house
Pause (if time permits): Discussion of Fall Zone peneplane level

45.7 cross NJ-503; straight (S) on US-9W

47.2 right (SW) on US-9W

Mileage

47.9 right (W) at Turnpike sign on overpass; keep right (N) on US-4

49.0 right)NE) before reaching overpass

49.1 left (W) over bridge (overpass spanning US-4)

49.2 park at right beyond bridge; buses will make U-turn facing east

STOP No. C-4: Flatrock Brook, N.J.

The outcrop of diabase near the road is close to the upper contact of the Palisades sill. It is fine-grained and cut by thin acidic dikes. The hill-slope down toward the Brook approximates the dip-slope of the upper contact. The contact zone appears in the Brook as the diabase gives way to light-colored baked shales with low northwesterly dips. The actual line of contact is obscured by cover. Similar baked shales are found at the lower contact near Edgewater, N.J. but of much darker hue. The baked shales of the upper contact continue south along the strike of the sill. Their most impressive exposure is in Granton Quarry at North Bergen, N.J. where they underlie a subsidiary sill of diabase. Fossil fish (coelacanths) and a small crustacean (ostracod) have been collected from that locality. Both the lithology and fossil content of these beds strongly suggest the Locatong formation, although they occur many miles north of the main outcrop area of this formation.

Looking east from the road outcrop, one sees US-4 descending a valley which runs oblique to the upper contact in a northerly direction. The valley follows a fault line of the gravity type with downthrow on the east. The vertical displacement is approx. 100 ft. and appears to be related to adjustments connected with the emplacement of the magma.

Looking west, one sees the drowned valley of Overpeck Creek and beyond, the low sandstone ridges of the Brunswick formation, approx. at the Harrisburg level. The skyline ridge is the First Watchung Mountain, a lava flow (fissure type) approximating the Schooley level. It should be possible to make out the Paterson wind gap which is similar in form and origin to the Sparkill Gap.

49.2 re-cross bridge (E)

49.3 right (S)(downhill)

49.4 right (NE) on US-4

55.7 right on approach road to NJ-17

55.8 straight (NW) on NJ-17

60.0 cross Linwood Ave. (traffic light) and turn right (NE) on Van Emburgh Ave. keeping straight ahead at blinker light

61.4 straight (E) on Washington Ave. (traffic light)

62.1 follow curve to left

62.5 straight (N) on Woodcliff Heights Rd. (uphill) paralleling the Garden State Pkway. (right -E)

62.7 park buses near top of hill

STOP No. C-5: Woodcliff Lake area - Brunswick Formation

Construction of the Garden State Pkway. below produced this new road and outcrop. These are rather typical sandy beds of the Brunswick formation. The shaly beds are usually found in the valleys. The brown sandstones here contain a few pebble beds which could be stream channel deposits. Conglomerate cobbles similar to those found near the border fault (Stop C-6) in alluvial fan deposits suggest a westerly source. This outcrop is about 8 miles from the border fault.

63.5 left (W) on Saddle River Rd.

63.7 left on Chestnut Ridge Rd.

64.0 left into Woodcliff Lake Rd.

64.7 straight ahead, crossing Chestnut Ridge Rd.

65.0 left on E. Allendale Rd. (downhill)

65.6 cross bridge over Saddle River

66.3 right (N) at traffic light on NJ-17

69.0 straight (N) on NJ-507 (Franklin Turnpike)

71.7 US-202 from left (underpass); continue straight (N)

71.8 right (NE) at road fork on Washington Ave., Suffern, N.Y.

72.3 cross Lafayette Ave. (traffic light)

72.4 cross railroad tracks

72.7 right at stop sign under N.Y. Thruway onto US-202

72.8 park at right (on US-202); outcrop along road (uphill) at left (NW)

STOP No. C-6: Triassic Border Fault (Suffern, N.Y.)
The outcrop consists of badly sheared, Pre-Cambrian (granite) gneisses. Many slickensided surfaces are parallel to the surface of the border fault. The lineation (fault striae) approximates the direction of relative motion along the fault. While this is not considered to be the actual fault plane (dipping steeply southeast with downthrow of Triassic sediments to the south), it is probably within the fault zone. From a high point one sees the escarpment (Ramapo Mts. of the Hudson Highlands) extending beyond the Thruway toward the southwest. This escarpment is the product of differential erosion along the fault whose relative motion dropped the Triassic beds down on the southeast in contact with the Pre-Cambrian crystallines. The whole mass was deeply eroded by the time the Schooley peneplane was produced. The escarpment was developed later as a consequence of regional uplift.
Looking southeastward toward the Triassic Lowland, a prominent hill just across the Thruway is an eroded plug-like intrusion of diabase (now being quarried for crushed rock).

73.3 US-202 swings away (S) from fault line proceeding on the rocks of the Triassic basin

75.2 Y-intersection with Viola Rd. (Antrim Playhouse sign); park in triangular plot at right of US-202; outcrops on both sides of road

STOP No. C-7: Triassic Border Conglomerate
These outcrops are about 1/4 mile east of fault line. Here the Mahwah River has etched a valley along the fault zone in Triassic beds. The outcrop at left (NW) side of road indicates former alluvial fan which was banked up against the original fault scarp. The presence of early Paleozoic cobbles, sometimes only slightly rounded, and the absence of the crystalline cobbles lead to several conclusions: (1) streams cutting into the upthrown block were relatively short, (2) the upthrown block was much higher than at present and contained a thick Paleozoic cover, (3) as the streams cut into this

cover they nowhere reached the Pre-Cambrian basement, and (4) the upper surface of the fan must have been higher than the present Schooley level.

What we see now are a few remnants of this fan showing typical torrential cross-bedding and rapid changes in grain size. Cobbles consist of Cambrian quartzite, Cambro-Ordovician limestones and Silurian-Devonian conglomerates. None of these rocks are now present on top or within the Pre-Cambrian crystallines of the Hudson Highlands directly to the northwest. Some have been preserved, however, as inliers to the west (along the New York-New Jersey border and in the New Jersey Highlands). They also outcrop abundantly in the Great Valley beyond the present Highlands to the north and northwest.
On the east (SE) side of the road, pebble beds decrease and a more normal Brunswick aspect appears, similar to that seen at Stop C-5.

75.2 continue (NE) on US-202

76.1 Lime Kiln Rd. at right (S); fine-grained diabase; intrusions of diabase outcropping intermittently along south (right) side of road for the next $1^1/_2$ miles are presumed to be one or more plug-like bodies or dikes; rare contact exposures show cross-cutting relationships.

76.4 coarse border conglomerate at right (S)

76.7 coarse border conglomerate on both sides of road

76.9 to 77.1 fine-grained diabase with columnar structure at right (S)

79.5 park at entrance of sand and gravel pit at left (N) side of road

STOP No. C-8: Mt. Ivy Glacial Delata
This appears to be a fairly normal delta deposited in a periglacial lake, with typical top and foreset beds. No varved clays are exposed. The elevation of the delta top is 400 + ft., which indicates that it was a local lake feature not connected with the Hudson River 4 miles to the east.

79.5 continue (E) on US-202

79.7 pass under Palisades Interstate Pkway.

82.3 View of Palisades ahead to right (E); westerly end of hook-shaped Palisades ridge (dike) rising from beneath Triassic sediments (Plate 13)

83.1 sharp left (NE) downhill on shortcut to US-9W (sign at right)

83.2 traffic light; left (N) on US-9W

85.3 cross bridge over Cedar Pond Brook (see mileage 15.3)

85.4 Stony Point, N.Y. traffic light; straight (N) on US-9W

86.0 right (NE) downhill at entrance to Stony Point Battlefield Reservation (Park Rd.)

86.2 Y intersection; park at right side of road

STOP No. C-9: Triassic Fanglomerate at Stony Point, N. Y.

This remarkable remnant of another alluvial fan consists almost entirely of semi-rounded Wappinger limestone (Cambro-Ordovician) pebbles poorly cemented by calcite and hematite. The source formation can be seen in place along a road to the north (mileage 86.5) and has wide exposure in the Tomkins Cove quarry $^1/_2$ mile to the north. The occurrence of the Cortlandt complex and some gneisses of dubious age at Stony Point to the east suggest some complicated step-faulting in the region.

86.2 take left fork at Y (Park Rd.)

86.3 sharp left (W) uphill

86.5 roadcut through folded Wappinger limestone (Cambro-Ordovician); this belt of limestone widens northward where it is quarried at Tomkins Cove ($^1/_2$ mile)

86.6 right (N) on US-9W

Note: Return trip from here to Peekskill headquarters follows the same route as taken in the morning (except Stops C-1, C-2 and C-3)

90.1 entrance to Hudson River Reserve Fleet at right; US-9W starts climbing Highlands escarpment (fault line)

91.1 View of Hudson gorge to right (N)

93.2 Bear Mt. bridge traffic circle; right (E) on US-6 and across bridge; turn right (S) at east end of bridge

97.7 left (NE) on US-9 along north shore of Peekskill Hollow Creek

98.6 right (SE) turn-off to Highlands Ave. and Annsville (Gallows Hill) roadcut

99.5 left (E) on Pemart Ave. after passing under Bear Mt. Pkway.

99.7 left (NE) on Oregon Rd. again passing under Pkway.

101.1 right (SE) on Locust Ave.

102.0 right at headquarters.