Structure and Form of the Triassic Basalts in North Central New Jersey

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General Geology
Introduction

The structure and form of the Triassic basalts in north central New Jersey is exposed in the First, Second, and Third Watchung Mountains, and the Palisades Sill.

The First, Second, and Third Watchung Mountains are tholeiitic basalt flows that are topographically prominant ridges in northern New Jersey (Fig. 1). They strike N 40° E and have a gentle dip of approximately 17° NW. Their north-eastern and southwestern sections exhibit curved terminations, thus giving the ridge system a synclinal trough appearance. They are also terminated in the northwest by a border fault that separates the Triassic basin from the Pre-Cambrian gneisses that lie to the northwest. The three extrusive sheets are interbedded with Triassic sedimentary rocks (shales, sandstones, and argillites) of the Newark Group. The extrusion of the successive lava flows took place at the time of deposition of the Newark Group (Lewis, 1908).

The Palisades Sill is emplaced in a structual and stratigraphic basin called a taphrogeosyncline by Kaye (1951). It has intruded the Newark Group and where it has concordant contacts the intrusion has a general strike of N 30° E., and dips between 10° and 15° NW (Walker, 1969). The Palisades Sill also has satellite intrusions above it, such as the small laccolith or sill at Granton Quarry. The Palisades Sill is probably in part concordant and in part discordant (Thompson, 1959; Lowe, 1959).

The Palisadian Igneous Province

The igneous rocks and their counterparts in the other Triassic basins record the emplacement of basic magma on an enormous scale, 1,000 miles in length and about 200 miles wide. Significantly they correlate broadly with the vast Karoo dolerites and equivalent basic rocks in the Southern Hemisphere, and like them, apparently were emplaced during an episode of tension attending the widening of the Atlantic basin (Van Houten, 1969).

The stratigraphic sequence of the Palisadian igneous rocks within the Newark Group is:

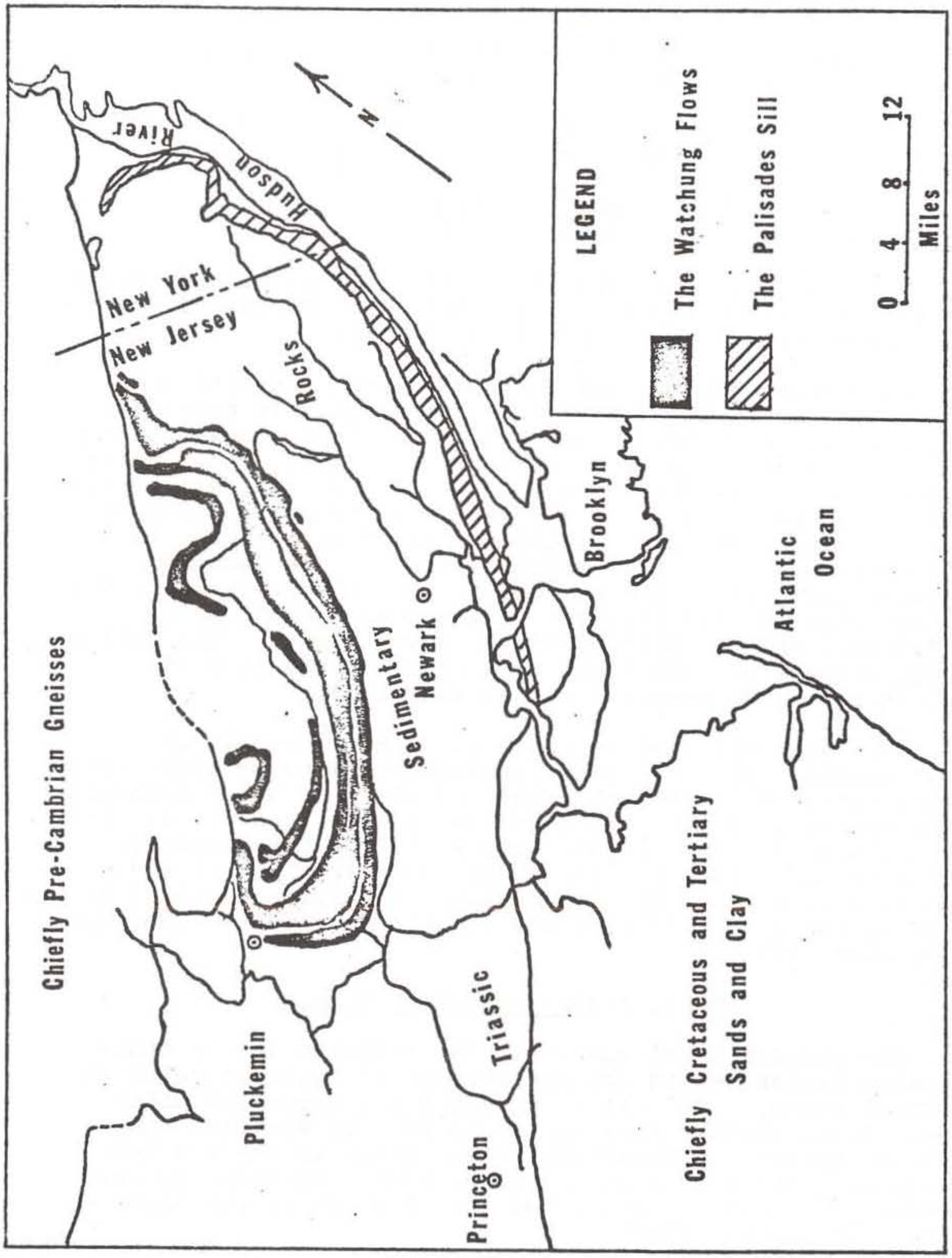

Figure 1. Index Map of Northern New Jersey, Showing the First, Second, and Third Watchung Mountains and the Palisades Sill.

TABLE I

	THE NEWARK GROUP	THE PALISADIAN IGNEOUS ROCKS
UPPER TRIASSIC PERIOD	Brunswick formation-consisting of soft red shales and sandstones	1st, 2nd, and 3rd WATCHUNG BASALT FLOWS
	Lockatong formation-consisting of red to black argillite and sandstone layers	GRANTON LACCOLITH OR SILL
	Stockton formation-consisting of gray to red arkosic sandstone, conglomerate and red shale	*PALISADES SILL

*The age of the Palisades sill has been determined by Erickson and Kulp (1961) at 190 ± 5 m.y by a K-Ar determination on biotite from dolerite at Fort Lee (Walker, 1969).

Differentiation Trends and Order of Emplacement of the Upper Triassic Watchung Flows and the Palisades Sill

It has been established that the Palisades Sill is a multiple intrusion comprising at least two magma phases, into which late-stage dikes intruded after the main phases consolidated. This seems reasonable, as the contemporaneous Watchung basalt flows, with three main basaltic successions, show that igneous activity at the time was protracted and comprised a number of phases (Walker, 1969).

The differentiation of the sill is a complex one of interacting processes, both mechanical and chemical. The conditions and processes responsible for the differentiation of the sill are outlined below:

1. temperature
2. pressure
3. magma composition
4. settling by gravity
5. upward displacement of the liquid phase
6. gas streaming
7. convection
8. flow differentiation
9. filter pressing
10. partial pressure of oxygen
11. volatile content, particularly water

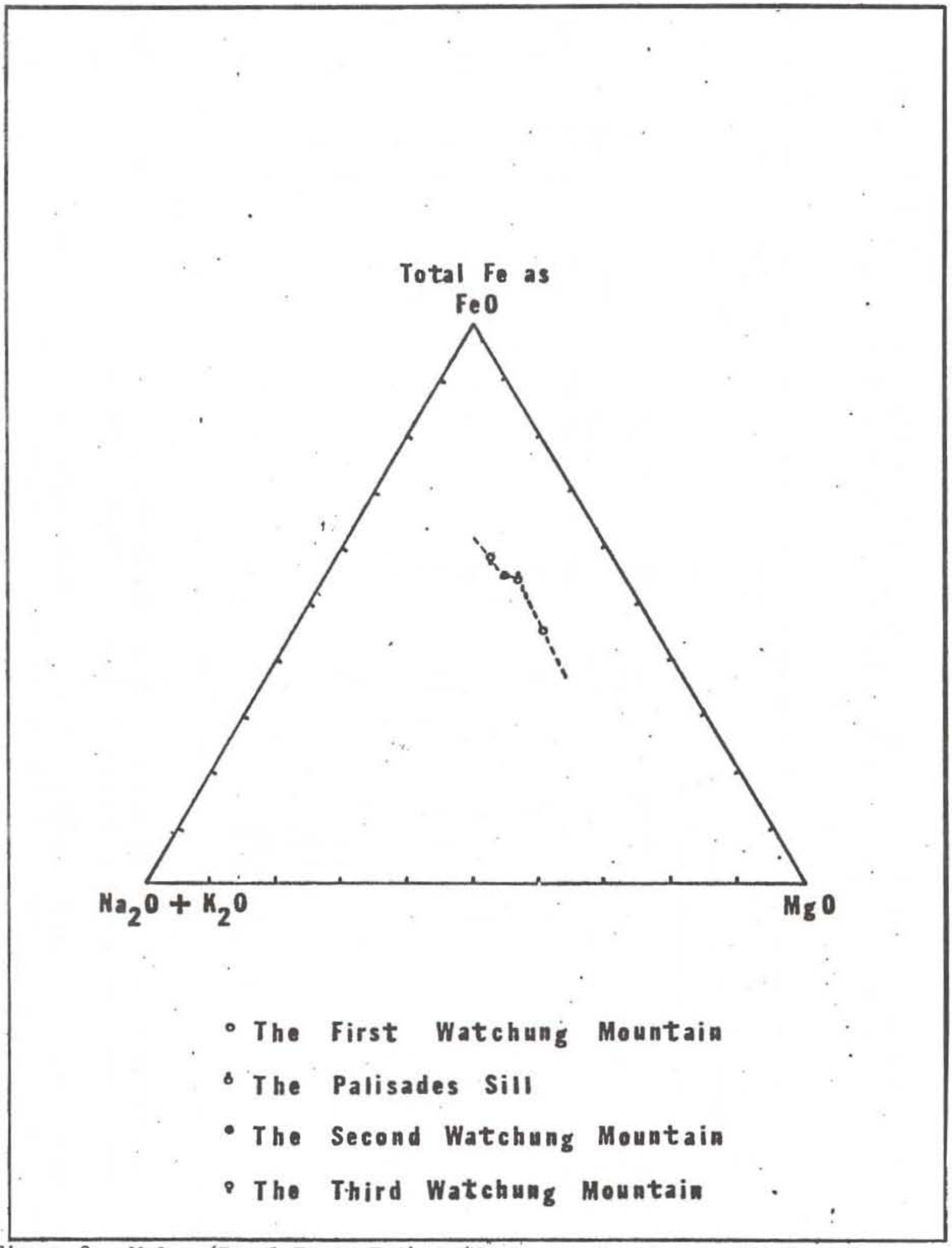

Figure 2. MgO – (Total Fe as FeO) – ($Na_2O + K_2O$) Diagram Showing the Differentiation Trend in the Palisadian Province. A quantitative chemical analysis was used for the Second Watchung Mountain data point. The percentages are as follows: Fe_2O_3 – 3.75; FeO – 7.15; MgO – 5.35; Na_2O – 2.79; K_2O – 0.85.

TABLE II

CHEMICAL COMPOSITION AND NORMATIVE MINERALS OF THE UPPER TRIASSIC WATCHUNG FLOWS, THE PALISADES SILL, AND OTHER REPRESENTATIVE BASALTS

	Chemical Composition						Norms				
Constituent	1	2	3	4	5	Constituent	1	2	3	4	5
SiO_2	50.8	52.35	51.35	47.21	49.52	Q	3.6	4.6		4.30	1.44
TiO_2	2.05	1.6	0.99		1.47	Or	5.0	5.4	3.89		4.45
Al_2O_3	14.1	14.0	14.83	13.58	13.82	Ab	18.85	21.0	20.44	19.40	28.31
Fe_2O_3	2.9	2.65	2.34	6.78	5.12	An	25.85	24.2	27.53	27.50	20.30
FeO	9.1	9.2	7.87	10.00	9.88	Di	20.0	17.1	15.15	16.20	12.56
MnO	0.2	0.15	0.11			Hy	17.25	19.3	23.51	19.22	19.95
MgO	6.3	6.15	7.72	6.39	5.65	Ol			5.40		
CaO	10.4	9.35	9.47	9.65	7.40	Mt	4.2	3.8	3.23	11.55	7.41
Na_2O	2.25	2.5	2.44	2.14	3.40	Il	3.9	3.0	1.82		2.73
K_2O	0.8	0.85	0.74		0.77	Ap	0.5	0.5			0.31
P_2O_5	0.25	0.25	0.13		0.18	H_2O	0.9	1.3	1.07	1.65	1.22
H_2O	0.9	1.3	1.07	1.69	1.22						
Totals	100.05	100.35	100.18	97.44	98.43		100.05	100.35	102.67	99.82	98.68
			Pl/Px ratio				1.19	1.24	1.22	1.33	1.49
			% An in Norm Plag.				57	53	57	55	42
			MAFIC INDEX				65.5	65.7	56.9	75.5	75.0
			FELSIC INDEX				22.6	26.4	25.2	18.1	36.0

1. Average tholeiitic basalt and dolerite. (S.R. Nockolds, Average Chemical Compositions of Some Igneous Rocks, Geol. Soc. Amer. Bull., V. 65, pp. 1021, 1954).

2. Average composition of the Palisades intrusion, composite section a planimetric estimate from 0 to 1000 feet. (K.R. Walker, The Palisades Sill, New Jersey; A Reinvestigation, Geol. Soc. Amer. Special Paper 111, P. 83, 1969).

3. Average of five analyses of the lower, middle, and upper layers of the First Watchung Mountain sheet. (J.V. Lewis, Petrography of the Newark Igneous Rocks of New Jersey, New Jersey Geol. Surv. Ann. Rep., St. 6, p. 159, 1908).

4. Average of six analyses of the Second Watchung Mountain sheet. (Thin sections 3, 9, 13, 17, 18, 29; chemical compositions determined by petrographic modal analysis).

5. Average of three analyses of separate layers of the Third Watchung Mountain shell. (Lewis, op. cit. p. 159, 1908).

In conclusion, the differentiation trend and degree of fractionation, implies that the order of emplacement of the rocks of the Palisadian province may have started with the extrusion of the First Watchung flow, followed by intrusion of the Palisades Sill into the Newark Formation of New Jersey, and then extrusion of the Second Watchung flow, which was finally followed by the extrusion of the Third Watchung flow.

ROAD LOG FIELD TRIP A-2

Leader: Michael Sichko Jr.

TOTAL MILES	MILES BETWEEN POINTS	REMARKS
0.0	0.0	Hofstra University parking. Exit parking lot, left turn for 0.1 miles, making a right turn onto Hempstead Turnpike.
1.2	1.2	Right turn to Meadowbrook Parkway North.
4.8	3.6	Bear left onto Northern State Parkway.
6.6	1.8	Right turn to the Long Island Expressway Westbound.
25.4	18.8	Toll booth, Queens Midtown Tunnel. Follow signs on 34th Street to the Lincoln Tunnel.
28.15	2.75	Right turn into the Lincoln Tunnel.
31.75	3.6	Exit, making a right turn onto U.S. 1-9 North.
34.65	2.9	Left turn from U.S. 1-9 (Tonnelle Avenue) at 77th Street into the Diana Stores Corp. parking lot. Proceed to the most northerly point at the rear of the parking lot.

<u>STOP 1: Granton laccolith or sill:</u>
In this exposure a satellite intrusion from the Palisades Sill, the Granton sill or laccolith, can be observed. The Granton sill has intruded the Lockatong formation of the Newark Group. In the easterly section of this exposure small appendages of the sill exhibit intrusive contacts with the

TOTAL MILES	MILES BETWEEN POINTS	REMARKS
		shales and sandstones of the Lockatong formation (Fig. 3).

Figure 3. Concordant and discordant contacts between the Granton sill and the shales and sandstones of the Lockatong formation.

		At the contacts the chilled diabase has an intersertal - intergranular texture, away from the contacts the diabase has an intergranular texture. The whole outcrop dips to the west at a gentle 15° to 17°.

TOTAL MILES	MILES BETWEEN POINTS	REMARKS
		Fossils have been found in the black shale layers, they include fish remains of coelacanths, Diplurus longicaudatus, Diplurus newarki and the common branchiopod, Estheria ovata (Schuberth, 1968).
		Left turn out of parking lot onto U.S. 1-9 North (Tonnelle Avenue).
37.40	2.75	Right turn to route 5 East. Continue on route 5 East into the town of Edgewater, New Jersey.
40.65	3.25	Left turn into a trailer parking lot at Edgewater, New Jersey. Walk to the west on Dempsey Avenue, make a right turn onto Undercliff Avenue to a small park on the left. Proceed up an abandoned trolley track right of way.
		<u>STOP 2: Basal contact of the Palisades Sill and the Mg-Olivine Layer.</u> Below the basal contact of the Palisades Sill a small stream has eroded through the Stockton formation which consists of arkosic sandstone and black and green shales. The alternating sandstone and shale beds attest to the changing environmental conditions during the deposition of the Stockton formation. Continuing up the trolley track right of way the concordant basal contact between the Palisades Sill and the arkosic sandstone of the Stockton formation can be observed. The contact metamorphic zone at this outcrop can be observed by noting that the shale has been metamorphosed into a hornfels and the sandstone has developed

TOTAL MILES	MILES BETWEEM POINTS	REMARKS
		quartzitic characteristics. Columnar jointing has developed perpendicular to the basal contact at this outcrop. Further up the right of way a xenolith of shale plucked from the floor of the intrusion can be seen near the basal chilled zone. At the bend in the trolley route the Mg-Olivine layer comes into full view. The base of this layer is approximately 40 feet above the chilled diabase. The layer outcrops as a highly weathered zone due to differential weathering of the cliff face. It is believed that the Mg-Olivine layer formed at the junction between two magma phases (Walker, 1969). Columnar jointing is pronounced directly above this layer.
		Make a right turn from the trailer parking lot onto route 5 West.
42.05	1.4	Bear right onto route 67 going towards Fort Lee, New Jersey and the George Washington Bridge.
43.45	1.4	Left turn onto Cross Street, just beyond the George Washington Bridge underpass.
43.85	0.4	Left turn at sign for Interstate 80 West.
44.80	0.95	Just beyond viaduct park on the right shoulder of Interstate 80.
		STOP 3: Upper contact of the Palisades Sill: This exposure of the upper contact of the Palisades sill is concordant with the rocks of the Stockton formation (Fig. 4).

TOTAL MILES	MILES BETWEEN POINTS	REMARKS
		The chilled diabase is fine-grained here as compared to the course-grained diabase to the east of this outcrop. Although the metamorphism is less pronounced at the upper contact than the lower contact the shale has been metamorphosed into a hornfels and the sandstone has developed quartzitic characteristics. Both the contact and strata dip gently to the west.

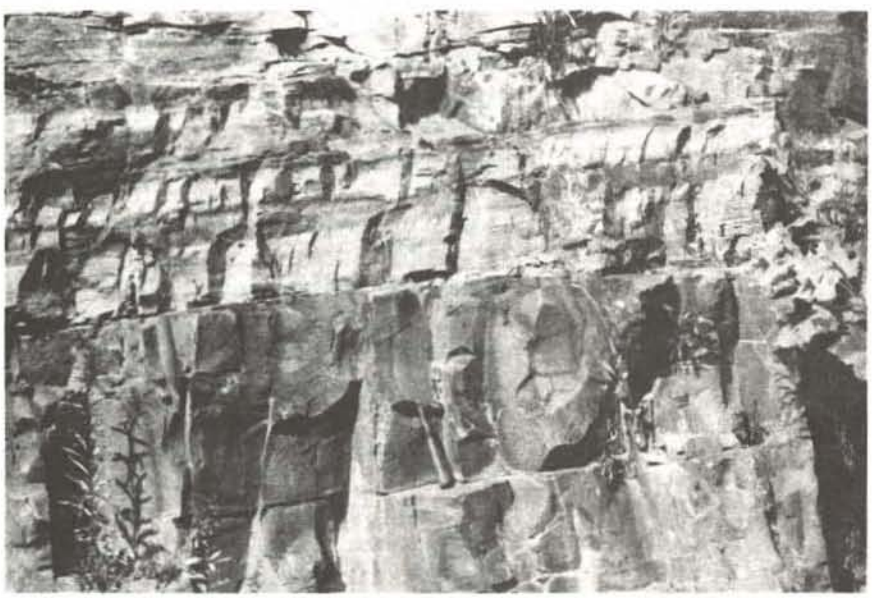

Figure 4. The upper contact of the Palisades Sill and the Stockton formation.

		Continue on Interstate 80 West towards Paterson, New Jersey.
57.75	12.95	Exit at Squirrelwood Road. Left turn at the stop sign onto Squirrelwood Road.

TOTAL MILES	MILES BETWEEN POINTS	REMARKS
57.95	0.2	Left turn into the Mobil Station parking lot. Walk for 200 yards on entrance ramp to Interstate 80 East. Outcrop on the right shoulder.

STOP 4: Pillow lava of 1st Watchung Lava:
The pillow lava of the 1st Watchung Mountain at this exposure represents the uppermost flow unit of a two unit system (Van Houten, 1969). Nichols (1936) defines a "flow unit" as a tongue shaped structure within a flow. The individual pillows are somewhat ellipsoidal in outline and have long dimensions of approximately 0.5 meters in length (Fig. 5). Adjacent pillows have adjusted their shape to fit together quite well. Some individual pillows exhibit vesicularity and radial jointing. The pillows lie in a matrix of tuffaceous material and weathered basalt. It appears that pillow lavas must generally form by a combination of the process of bulbous budding underwater and by the generation of an emulsion (Lewis, 1915; Fuller, 1940) in which the disperse phase consists of rounded "drops" of fluid lava and the disperse medium is water, very watery sediment, or water-saturated hyaloclastic debris (MacDonald, 1967).

TOTAL MILES	MILES BETWEEN POINTS	REMARKS

Figure 5. The pillow lava of the 1st Watchung Mountain.

58.40	0.45	Continue on Squirrelwood Road to New Street. Left turn at New Street.
58.50	0.10	Left turn onto Rifle Camp Road.
58.80	0.30	Left turn at sign for Garret Mountain Reservation.
59.10	0.3	Right turn and then a left turn onto Benson Drive.
59.55	0.45	Proceed on Benson Drive to the overlook on Garret Mountain Reservation.
		STOP 5A: Upper Surface of 1st Watchung Lava Flow at Garret Mountain Reservation: The Garret Mountain overlook

TOTAL MILES	MILES BETWEEN POINTS	REMARKS
		allows for a spectacular view of the Triassic Lowlands of northern New Jersey. From this vantage point the more resistant Watchung lava flows are seen topographically as ridges. To the northeast beyond the Paterson water gap, which is occupied by the Passaic River, the 1st Watchung flow is easily observed. To the northwest the 2nd Watchung mountain can be seen. On the walkway at the overlook evidence for glacial movement in this area is in the form of glacial polish, striations and erratics. The hackly appearance of the unglaciated portions of the lava flow are due to the differential weathering of the tops of columns which comprise a major section of the lower flow unit of the 1st Watchung mountain.
		Leaving the overlook, make a left turn onto Benson Drive.
60.65	1.0	Left turn onto Mountain Park Road.
61.10	0.45	Left turn onto Valley Road.
61.30	0.20	Left turn to Administration Building and Main Entrance to Garret Mountain Reservation.
61.75	0.45	Proceed to parking lot of Garret Mountain Administration Building. Walk along dirt road approximately 350 yards to the Northeast.
		STOP 5B: Lower Contact of the

TOTAL MILES	MILES BETWEEN POINTS	REMARKS
		1st Watchung Mountain: At this exposure the lower chilled contact of the 1st Watchung mountain lies directly over the red shales and sandstones of the Brunswick formation. In this lower flow unit, the chilled zone is highly vesicular, above this zone the colonnade and entablature are clearly visible. In the talus slope below this outcrop representative samples of each zone of the basaltic lava flow can be found. At the stop sign to Garret Mountain Reservation make a right turn onto Valley Road.
61.90	.15	Left turn at the sign for Garden State Parkway.
62.25	.35	Right turn at traffic light and sign for entrance to the Garden State Parkway.
62.45	.20	Left turn onto Garden State Parkway.
72.55	10.10	Exit for Interstate 280 West.
76.75	4.20	Stop on right shoulder of Interstate 280 West at road cut. STOP 6: Lower part of the 1st Watchung mountain: In this exposure of the lower part of the 1st Watchung mountain one encounters a well-developed lower colonnade zone and a curvi-columnar zone with markedly radiating slender joints (Manspeizer, 1969).

TOTAL MILES	MILES BETWEEN POINTS	REMARKS
		The flow units of the Garret Mountain section cannot be seen at this outcrop (Fig. 6).

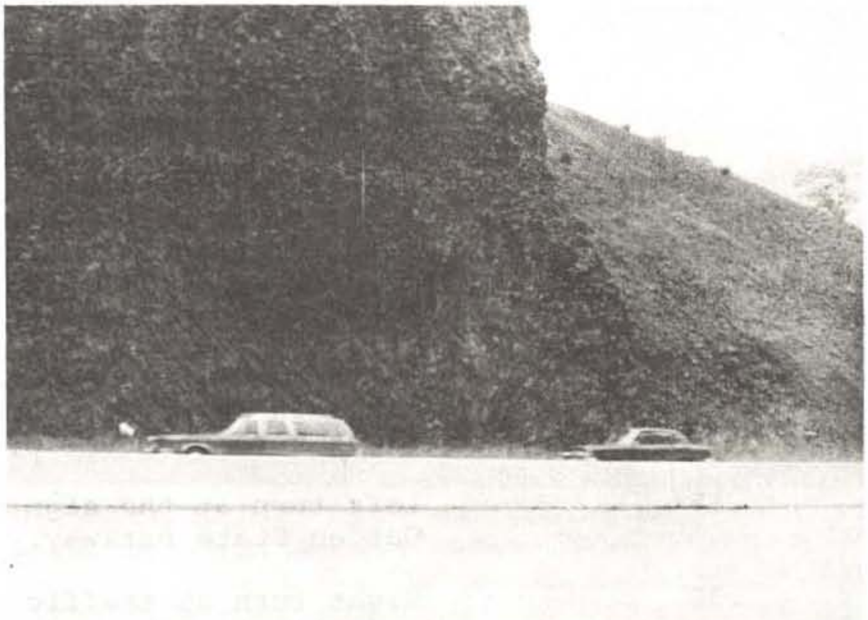

Figure 6. Radiating slender joints of the 1st Watchung mountain.

		End of trip. Proceed back to Hofstra University parking lot.

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