ENVIRONMENTAL GEOLOGIC TRAVERSE

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GENERAL CONCEPT

Initially, this trip was going to include a number of stops in the Appalachian Fold Belt, the Highlands, the Newark Basin, the Coastal Plain and right down to New Jersey's barrier beaches. As the detailed plans began to take form, there appeared to be no way to sample in one day, all the varieties of geology that New Jersey has to offer unless one did it from a speeding helicopter. Thus, the route shown on Figure 1 attempts to sample as many different geological environments and concurrent geologic problems as can be "shoved" into a single field trip.

A total of 10 stops are planned (as shown on Figure 1). These are:

1. Route 280 West Orange, road cuts in the First and Second Watchungs;
2. Ridgedale Avenue, Morristown, terminal moraine—semi-abandoned quarry;
3. Route 202 South of Morristown, Ramapo Fault, hospital across "active" fault;
4. Great Swamp, problems of managing 6,000 acres of wildlife preserve in a suburban environment and how the refuge affects its surroundings;
5. Millington Gorge—faulted (or erosional) cut through Second Watchung, flooding concerns;
6. Millington Quarry—blasting and transportation of trap rock in a middle class suburban environment;
7. Bridgewater Township—Route 78 road "cuts" in Second Watchung Mountain, compare with Stop 1;
8. Far Hills—Where does the Ramapo go?
9. Bernards Township/Bedminster, proposed 1,500 acre development, variable soil and rock, mostly impermeable soils, mostly shallow rock —how do you build a new "town"?;
10. Berkeley Heights—Whither goest Route 78?

GENERAL GEOLOGY

Introduction

The first portion of this trip crosses the same geologic conditions that are discussed in Trip No. A-1 and will not be repeated here (we will make one "stop" on Route 280 as subsequently discussed under Stop 1). We will leave the Trip A-1 route at the intersection of Routes 80 and 287 and head south along Route 287 into Morristown (Figure 1). At this point, we are just within the Newark Basin with the fault-bordered New Jersey Highlands to the west.

NEW JERSEY HIGHLANDS (READING PRONG)

The Highlands are a belt of primarily Precambrian rocks some 20 miles wide in this area. The Precambrian igneous and metamorphic rocks are generally in parallel northeast trending ridges. Paleozoic sediments occur in a number of the intermontane valleys. The principal Precambrian rocks are granite, gneiss and schist. Locally, there is significant variation in mineral composition (Smith, 1969). The principal Paleozoic rocks are quartzites, limestones, dolomites and shales.

The Highlands are variously interpreted to be part of a large nappe structure, with the Precambrian rocks lying atop Paleozoic formations or alternately deep rooted and true basement (Smith, 1969). It is generally accepted that the Highland Rocks in the northern part of the state (near the Hudson River) are true basement. Well to the South, the analogous Blue Ridge Mountains are allochthonous. Drake (1969) summarizes the information leading to an allochthonous conclusion for at least the Delaware River area and south, for the Highlands. Thus, there apparently is some possibility that both assumptions hold true in New Jersey.

The northeasterly-trending ridges and valleys are principally the result of folding along the ancient continental margin and stream erosion. Jointing is well developed, with northwest striking joints the most abundant, followed in number by N 45° E joints (paralleling the strike of the Highlands).

BORDER FAULT

A prominent border fault is found along the southeastern edge of the Highlands (Figure 1) in the

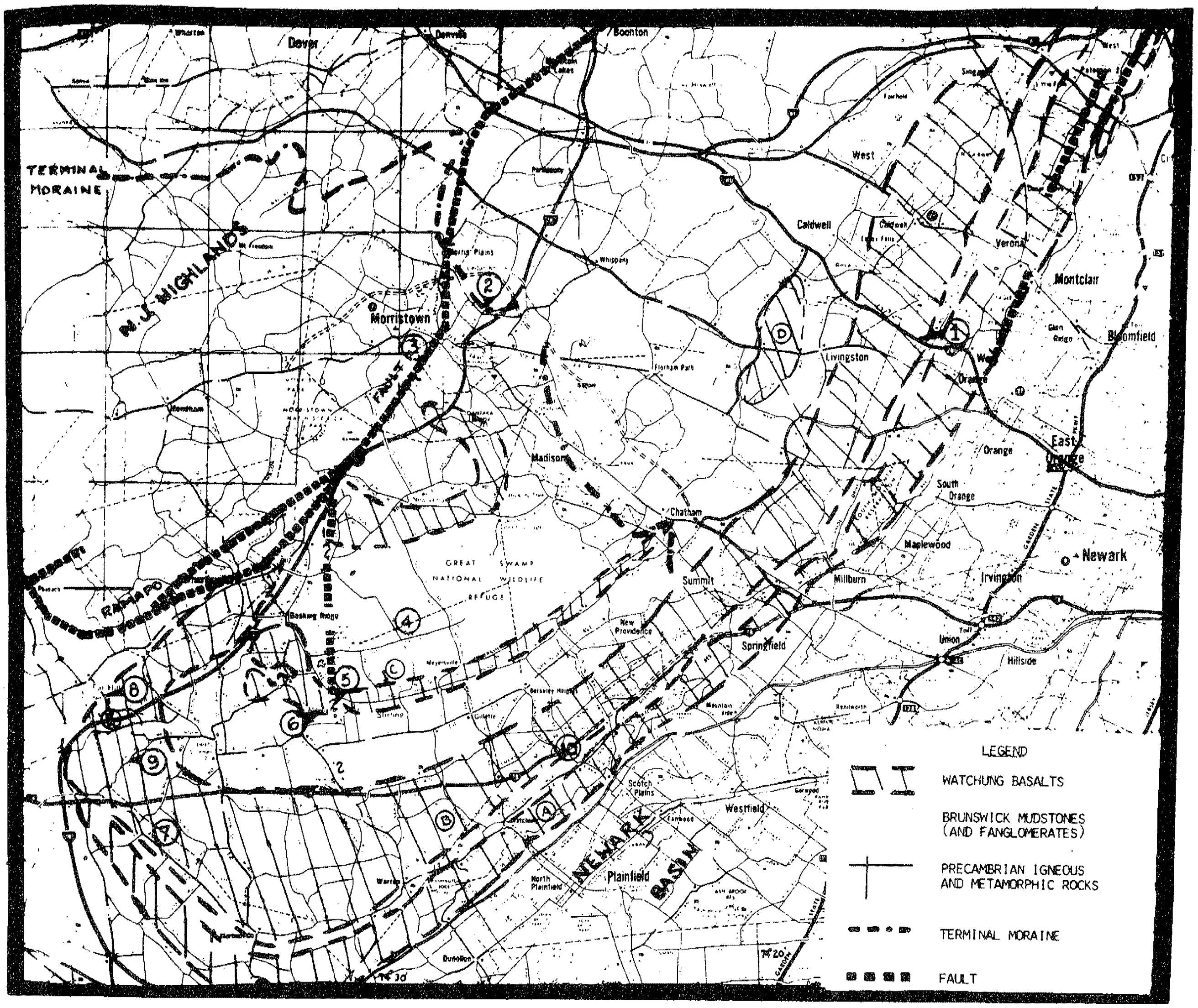

Fig. 1 Location map showing geology and field stops

field trip area. This fault system, the Ramapo, has been the subject of a great deal of recent controversy (also see Stop 2 discussion), concerning its relationship to current seismicity. What is generally accepted at present is the overall tectonic development of the fault system.

Two separate Precambrian episodes of faulting have been recognized. Initially, it is likely that ductile deformation was experienced during the Grenville Orogeny. Subsequently, Late Precambrian rifting along an ancient continental margin reutilized the older Grenvillian zone of weakness.

During Middle Ordovician, it is likely that block faulting, with attendant uplift resulted in further movements along the Ramapo System. The next recognizable phase of deformation, still in the Paleozoic, was characterized by a predominance of crustal shortening in the area and the suggestion of the Ramapo participation as a reverse fault. This phase of deformation is thought to have resulted in both syn- and post-regional metamorphism.

This reverse faulting was followed by regional right-lateral transcurrent faulting, at least along the northern portion of the Ramapo, and its northeasterly extension, the Canopus Fault System. The northeast trending systems, east of the Hudson River, were linked by several ENE-to-EW-trending fault zones to a second en-echelon system further to the east, the Croton Falls Fault System.

Transcurrent fault movements along these systems re-utilized and in some instances, crosscut the earlier reverse faults.

During the Mesozoic, the major northeast trending zones (including the Croton Falls System) were reactivated with dip-slip and left-lateral movement. The sinistral episode of movement probably represents the response to ongoing rifting in the central portion of the Appalachian Orogeny.

The wrench faulting may have occurred during, and did occur after, the sedimentation and lithification of Newark Basin strata and the emplacement and cooling of Triassic-Jurassic basalt and diabase (the Watchung Mountains and the Palisades).

The Palisades and Watchung igneous events appear to have occurred in the transition from dip-slip to strike-slip faulting. The drastic decrease in the rate of sediment accumulation after the First Watchung flow may reflect the change from predominantly dip-slip to strike-slip motion along the Ramapo Fault. Both igneous activity and sedimentation in the Basin slowed and eventually stopped prior to the complete cessation of left-lateral movement on the Ramapo.

By Middle to Upper Cretaceous time, fault movements ceased. Thus, in summary, the tectonic function of the Ramapo System during late Triassic is interpreted to be primarily as a normal fault with an active role in the development and filling of the Newark Basin. From late Triassic to late Jurassic, the Ramapo and associated faults to the northeast were left-lateral strike-slip features. Thus, we would expect smaller faults which exist in the Basin would have experienced Mesozoic-aged movements related to left-lateral movement on the main fault system.

NEWARK BASIN

The Newark Basin in this general area developed and was deformed during the Mesozoic Era. The initial subsidence of the basin was syn-sedimentary although this early period of normal faulting was gradually replaced by a period of pervasive left-lateral faulting.

The rocks in the Newark Basin in the area of this field trip consist of the Brunswick Formation and the Watchung Basalt. The Brunswick is a relatively soft (compared with the Watchung Basalts and the Highland rocks) reddish-brown shale and sandstone, which generally (but not always) is rippable with conventional construction equipment. Close to the edge of the Highlands, beds of border conglomerate and pebble-bearing sandstone are reported (Lucey, 1972). These beds interfinger with the finer grained Brunswick.

Interlayered with the later Brunswick Formation sediments are three extrusive flows. These sheet basalts were more resistant to erosion than the overlying more recent sediments and presently occur in three main series of ridges known as the First Watchung Mountain (A-Figure 1), the Second Watchung Mountain (B-Figure 1) and the Long Hill (C-Figure 1), Riker Hill (D-Figure 1), Hook Mountain, Packanack Mountain alignment. Generally, at least two flows are observed in the First Watchung basalt. The lower is markedly jointed, the overlying one ropey and pillow lava (Van Houten, 1969). The Palisades, to the northeast of the field trip area, are of the same age as the Watchung extrusives but are generally considered to be an intrusive (diabase) although having a similar mineral composition.

Both the Watchung basalts and the Brunswick Formation are found in outcrop throughout this area of the Basin. From an environmental/engineering geologic standpoint, however, the relatively thin soil cover is also of importance.

UNCONSOLIDATED QUATERNARY DEPOSITS

The predominant soil covers in the area are:

1. Glacial drift;
2. Residual soils (both from the basalts and the sandstones/shales);
3. Glacio-lacustrine sediments;
4. Alluvial sediments.

The general location of the terminal moraine of the Wisconsin Glaciation traverses the area approximately as shown on Figure 1. Thus, any glacially derived materials south of the moraine should be Pre-Wisconsin.

The terminal moraine is breached at two locations, one just north of Morristown, and the other in Chatham Borough and Summit Township, along the Passaic. South of the Passaic, the moraine is irregularly noted from Baltusrol Country Club to south of Scotch Plains. North and east of the terminal moraine, the surface is covered by some 5 to 12 feet of ground moraine (Gill, 1965). The drift within and behind the terminal moraine is generally poorly sorted with low permeability.

To the south and west of the terminal moraine, the glacial deposits can be subdivided into three categories: (1) drift from earlier glaciations; (2) stratified Wisconsin glacio-fluvial deposits; and (3) glacio-lacustrine deposits.

The scattered deposits of earlier drift are reported to be generally thin, typically highly oxidized, deeply colored, stony materials (Gill, 1965). The glacio-fluvial outwash deposits generally have coarse-grained layers of sufficient size and permeability to be sources of ground water for domestic use. Thickness of outwash deposits of the order of 100 feet are reported along the Passaic River (Gill, 1965).

The glacio-lacustrine deposits generally consist of relatively impermeable silts and clays deposited in Lake Passaic. Glacial Lake Passaic first filled the natural basin south of the Wisconsin glacier terminal and southern boundary and the Highlands its northwestern border. An outlet through the southwestern corner of the Second Watchung Mountain, near Far Hills allowed drainage into a tributary of the Raritan and thence to the sea. The outlet elevation is about at 330 feet above sea level and is know as Moggy Hollow (E-Figure 1).

Thus, once the lake formed, its level rose to the lowest point at Moggy Hollow. With the northward retreat of the glacier, lake water followed the ice front to about Pompton Plains. At this time, Lake Passaic was about 30 miles long, eight to ten miles wide and had a maximum depth of about 240 feet (Schuberth, 1968).

As the ice retreated, an outlet was exposed first at Great Notch, (Figure 1) at elevation about 300 ft. and the overflow at Moggy Hollow stopped. When the ice freed an outlet at Little Falls, Paterson (just to the north of Great Notch) and the lake drained to the level of that outlet (today at 185 feet above sea level), Lake Passaic ceased to exist. However, today much of the area formerly covered by Glacial Lake Passaic is subject to flooding from the Passaic River (almost a regular occurrence). Great Piece Meadows, Hatfield Swamp, Troy Meadows, Black Meadows, Duck Swamp and Great Swamp (Stop 3) are all areas of regular and extensive flooding.

The lacustrine deposits of Lake Passaic vary in thickness over the field trip area but primarily have low to very low permeabilities. Overlying and/or cutting through portions of these lacustrine deposits are relatively minor deposits of alluvial soils along a number of the small streams presently feeding the Passaic River (see Figure 1). In most instances, the alluvial soils are relatively fine-grained as the source material are oft-time silts and clays. These alluvial soils in the area cannot be considered either a prime source of ground water supply or have high suitability for septic system use in home construction.

The residual soils vary in thickness as one would expect. The basalt cover is thin; 10-15 feet is considered quite deep. The exact extent of "weathering" over the Brunswick is generally difficult to define as the change from soil to firm rock is gradual and subject to interpretation. However, thicknesses of 10-20 feet is not unusual except in "baked" areas adjacent to the basalt flows. Permeability of the residual Brunswick soils is generally low while the residual basalts weather to anything from sands to clay and permeability is laterally variable.

ECONOMIC GEOLOGY

It may be somewhat surprising to many but the general area was once a principal source of New Jersey iron ore. Over 200 mines existed at one time in Morris County (Lucey, 1972). The ore body is magnetite, found in the gneisses of the Highlands. Copper was mined in the First Watchung in the mid- and late 1800's. Legend has it that the mines were originally opened during the revolution by George Washington's forces (Tobiassen, 1978).

The basalts of the Watchung and Long Hill flows are quarried in a number of locations in the field trip area (See Stop 5 discussion). The basalt is utilized as aggregate, road metal, roofing materials, railroad ballast and rip rap.

The clays derived from weathering of the Brunswick Formation have been used to make bricks and for impermeable liner construction in areas to the south of the field trip area. There is no economic use of the Brunswick Formation in any form in the field trip area to the author's knowledge.

Several sand and gravel pits of commercial size (Stop 2) have been worked in the area for a number of years (Kruckick, 1969). Despite the impetus of burgeoning population growth in recent years, the expansion of a sand and gravel industry does not seem to have occurred.

WATER RESOURCES

As previously indicated, flooding along the Passaic and a number of its tributaries in the valley between the Second Watchung Mountain and Long Hill is a relatively common occurrence. Surface water storage is presently inadequate, both as a means of reducing flood potential and as a source of water supply. Discussion and studies relating to flood control along the Passaic River, which wanders through the field trip area, have been underway for decades.

Existing surface water storage facilities are as follows:

1. Osborn Pond in Bernards Township;
2. Two offstream (Passaic River) impoundments at Canoe Brook north of Summit;
3. Clyde Potts Reservoir (upper reaches of the Whippany River);
4. Cedar Hill Reservoir (east of Florham Park);
5. Boonton Reservoir.

Good quality ground water is found primarily in two aquifers in the region: the stratified drift, and the Brunswick.

The glacio-fluvial deposits are significant water sources where their thickness exceeds 50 feet (and thus are not abundant). Yields of from 60 to 1200 gpm have been recorded (Gill, 1962) in wells into these deposits.

The other source is within joints and fractures of the Brunswick. Although the depth of significant fracturing is variable, highly fractured and saturated zones have been found to depths as great as 500 feet (Gill, 1965). Yields range from 4 to 650 gpm.

Low yielding aquifers also exist in the basalt and the Highlands gneisses and granites. Well yields range from less than 5 gpm to several hundred gpm (Gill, 1956).

ROAD LOG

Mileage	Route Description
	Route 280W from Newark (Newark Basin)
0	Route 280 and Garden State Parkway
3	**STOP 1A** Route 280W (First Watchung) — SEE STOP 1 discussion
5	**STOP 1B** Route 280W (Second Watchung) — note Riker Hill to the west as 280W descends to the area of Glacial Lake Passaic
11.5	Follow signs for Route 287 — Morristown/Boonton, will actually be in local lanes of Route 80W (Glacial Lake Passaic)
14	Exit onto Route 287 S/Morristown — (New Jersey Highlands to the west, traversing glacial deposits overlying Brunswick Formation)
20	Exit at Ridgedale Avenue, go to stop sign and turn north (right) on Ridgedale Avenue
20.5	North on Ridgedale Avenue to County Concrete Corp. Quarry (Terminal Moraine) **STOP 2** (see discussion) Abandoned Quarry South on Ridgedale Avenue (go through Morristown to Route 202 S) to Morris Avenue
21	Turn west (right) on Morris Avenue (Route 510) to Center of Morristown and Route 202 S signs
21.7	South on Route 202 (Mt. Kemble Avenue)
22.5	**STOP 3** Route 202 S, Morristown Memorial Hospital, Mt. Kemble Division, (on Ramapo Fault — Highlands immediately west of road) — SEE STOP 3 discussion
	Continue on Route 202S to North Maple Avenue. Notice new construction, homes, apartments, office buildings. Some are on septic systems; some are on Morristown sewage treatment plant system. Route 202 generally lies along Ramapo Fault
27.5	Turn southeast (left) on North Maple Avenue (traffic light) to Basking Ridge
28.5	Turn east (left) on Madisonville Road (blinker light) — descend to Glacial Lake Passaic terrain — outlier of Third Watchung basalt flow to the north and Long Hill (third flow) to south
29	Turn southeast (right) on Pleasant Plains Road (Glacial Lake Passaic)
31	**STOP 4** Great Swamp Refuge — SEE STOP 4 discussion Continue on Pleasant Plains Road
33.5	Turn south (left) on Lupine Way (second intersection of Pleasant Plains Road with Lupine Way) (rise from Glacial Lake to Long Hill basalts)
33.6	Turn west on Long Hill Road, through blinker light (bearing right) as Long Hill Road changes to Basking Ridge Road

35.2 Turn south (left) on Pond Hill Road (basalts)

35.5 **STOP 5** Millington Gorge at intersection with Erie Lackawanna (Conrail) (gorge in basalt) SEE STOP 5 discussion

35.5 **STOP 6** Millington Quarry (quarry in basalt) SEE STOP 6 discussion

Continue on Pond Hill Road to Haas Road

36 Turn west (right) on Haas Road to Stone House Road (shallow Brunswick)

36.8 Turn south (left) on Stone House Road to Valley Road (Route 510) (shallow Brunswick)

36.9 Turn west (right) on Valley Road to Martinsville Road (Route 525) (shallow Brunswick)

39.5 Turn south (left) on Martinsville Road to Route 78W (shallow Brunswick to basalts, Second Watchung)

42 Turn west (right) on Route 78 to Exit for Scenic View.

42.2 **STOP 7** Scenic View Parking Area on Second Watchung, can view road cut best from east end of Parking Area — SEE STOP 7 discussion — view to the west is across Newark Basin to New Jersey Highlands
Return to Route 78W and continue to Route 287N exit (Morristown) (descend from Second Watchung)

43.5 Turn north (right) on Route 287 to Route 202, 206N (first exit)

45 Turn on to Route 202N to Bedminster and Far Hills (probably Brunswick mudstone with perhaps some more conglomeratic facies toward Highlands to the west)

47.8 Turn south (right) on Far Hills Road (Route 512)

47.9 **STOP 8** Far Hills Road (N.J. Highlands to West, known Ramapo Fault bends to west) — SEE STOP 8 discussion

Continue on Far Hills Road to unnamed road with sign to Leonard J. Buck Gardens

48.7 Turn right to Buck Gardens — the proposed (Spring 1980) arboreteum is at Moggy Hollow

48.8 Return to Far Hills Road

49 Turn east (right) on Far Hills Road (becomes Liberty Corner Road) to Mt. Prospect Road

50.5 Turn south (right) on Mt. Prospect Road (Second Watchung basalts)

51.4 **STOP 9** Continue on Mt. Prospect Road to central portion of Johns Manville Properties site — SEE STOP 9 discussion

Return on Mt. Prospect Road to Liberty Corner Road

52.3 Turn east (right) on Liberty Corner Road (Route 512) to Valley Road (from basalt to Brunswick mudstone approximately where road crosses small stream)

53.8 Turn south on Valley Road (still Route 52 — continue to Martinsville Road (Route 525) where road bears right to Route 78

55 Turn east (left) on Route 78 and continue to temporary end at Berkeley Heights (Second Watchung basalt)

63 **STOP 10** SEE STOP 10 discussion.

Return to Newark

STOP #1
Rte 280 - West Orange

Rather than a stop, this will be a slow drive by (either by direction or limitations of the bus). As the elevation rises from the Northfield Road (State Route 508) intersection with Route 280, the first outcrops seen are of the Brunswick Formation (sandstones). Then Route 280 climbs into a major road cut within the Watchung basalts (First Watchung). The basalt cut is steep and the blocky, columnar structure of the lower basalt can be observed early. At higher elevations, the cut is in ropey and pillow lava. Along the cut in the Second Watchung, while it is still at a high angle, several failures can be observed along minor shear zones in columnar basalt. (see Manspeizer, and Olsen this fieldbook).

STOP 2
Ridgedale Avenue - Morristown

This is a semi-abandoned quarry. The main purpose is to observe the materials in the terminal moraine at this point. At this location, the embankment is primarily sand.

STOP 3
The Ramapo Fault, Morristown

Is it or isn't it an active fault? If it is active, how active?
Lamont-Doherty Geologic Observatory has indicated it is a capable* fault. The technical and judicial examiners on the recent (1977) Indian Point Nuclear Power Plant Appeal Board hearings declared it was not. The Nuclear Regulatory Commission and Consolidated Edison Co. consultants agree with the hearing board.

Controversy still rages with the planning of two water supply dams across the fault in southern Rockland County. Intervenor witnesses have quoted an April 1978 Science article (see References) concerning the Indian Point plants as their rationale for requesting a seismic factor even greater than that used in design of the nuclear plants across the Hudson River.

Yet here in New Jersey, there are hospitals and schools built across the fault in two towns we will pass through on this field trip — Morristown and Bernardsville. No controversy seems to exist in this area of the state concerning the activity of the Ramapo, despite experiencing a Mag. 3.1 earthquake in Bernardsville as recently as March 10, 1979.

At this stop we'll quickly look at the "fault" as it passes below a hospital. Is it disaster waiting to happen or is it a tempest-in-a-teapot? Look at the trace here in Morristown. The trip will pass over the Ramapo and related structures several times. The seismicity of the Ramapo will be discussed at Stop 4 (in greater comfort).

* 10CFR 100 Appendix A, Seismic and Geologic Siting Criteria for Nuclear Power Plants.

STOP 4
The Great Swamp (lunch)

The Great Swamp Refuge was established in 1960. It is only 26 miles west of New York City in the Boston-Washington metropolitan corridor. It is approximately 6,000 acres of swamp woodland, hardwood ridges, grass lands, old croplands, and water impoundments. As previously noted, it is within a portion of the area covered by ancient Lake Passaic.

Approximately two thirds of the refuge is designated as Wilderness Area and the remainder as Management Area. Man-made structures and motorized vehicles and equipment are prohibited by law from this area. In the Management Area, the habitat is controlled by cutting brush and timber, mowing, farming, planting shrubs, regulating water levels, and by providing nesting structures.

The problems of maintaining a wildlife refuge in an area where population and commerce are steadily growing will be discussed by members of the Refuge staff.

STOP 5
Millington Gorge, Millington

This steep-sided cut through Long Hill (the Third Watchung) is aligned with Osborne Pond in Basking Ridge and Mt. Kemble Lake in Harding Township as well as a valley through a ring of basalt in the New Vernon area. Is this an en-echelon fault of the main branch of the Ramapo or just differential erosion and coincidence?

Whatever the reason, during heavy storms the Gorge acts as a contraint to flow in the Passaic ponding water as far upstream as the Great Swamp and contributing to many flooded basements to the north (see Figure 1) along Black Brook and the Passaic River.

STOP 6
Millington Quarry, Millington

At the time of preparing this outline, it was not known whether we would be allowed within the Quarry or would have to walk from Millington Gorge to view the scope of the operation. The concern here is not the mere idea of quarrying the Watchung basalts, which are well exposed in the Gorge and many other locations for inspection, but in blasting rock and the resulting transportation in a middle-class, suburban environment. The quarry has continually been in litigation with the town because of the noise, dust and shaking caused by trucking and blasting operations.

Present New Jersey State law requires that a peak particle velocity of two inches per second should not be exceeded in critical areas away from any blasting. Whenever checked, the quarry has not exceeded these limits yet the complaints continue, not unexpected as the human body is an excellent vibration device. The present N.J. criteria were derived from work undertaken in the 1960's by the U.S. Bureau of Mines with subsequent confirmation (?) by others in Sweden, Canada and Great Britain. The presently proposed Bureau of Mines' criterion is a particle velocity of one inch per second. What will these criteria do to quarries like this and others in similar environment? The proposed criteria also establish air blast limitations.

We'll discuss all of the above.

STOP 7
Route 78 - Bridgewater Township

Two possibilities exist for the problems as encountered at this highway cut. One is that a fault zone cut through the basalt in this area; the other is that merely the broken columnar nature of the rock here made steep rock cuts impossible. The embankments at this location were cut originally at the same slopes as the remainder of the highway. Repairs kept the highway closed for over a year while the pavement was otherwise completed. After a long period of cogitation, the slopes were cut back to what you see at present. Rock falls were minimized and the ten miles of highway opened. The additional costs of time and excavating are not known but must have been considerable. Could a good site investigation have prevented this problem? — a discussion.

STOP 8
The Ramapo Fault - Far Hills

At Far Hills, we can compare the mapped location of the Ramapo (See Figure 1) with the local topography and discuss the effect of the fault upon local construction, both socially and from a general ground water viewpoint.

On the way to stop 9, we'll detour by Moggy Hollow. It will be at some future time, a Somerset County Arboreteum. A bit of New Jersey geologic history will be retained.

STOP 9
Development of New Town-Bernards Township/Bedminster

A new development comprised of housing and office buildings is planned for a 1,500 acre site. The site was in litigation for several years and the decisions in the two townships were totally different (and will be discussed). Some 400 acres (higher density — Bedminster) will be sewered while 1,100 acres (low density — Bernards Township) will be on individual or small combined septic systems.

The site has shallow basalts and shales, residual soils, lacustrine deposits, glacial till, high water table, protected streams, steep slopes and is adjacent to the Ramapo Fault. How do you develop this property (the largest single site planned for development in New Jersey)? We'll have a local geology map, test this pit data, percolation test data and some development concepts for discussion — a seminar.

STOP 10
Route 78 - Berkeley Heights

The highway has been completed to this location for some 5 to 10 years. The road *has* opened in 1978 from Millburn to Newark Airport (see Figure 1) but there has been extensive discussion concerning the most environmentally sound route (or non-route). We'll discuss it a little more, from primarily a geologic viewpoint.

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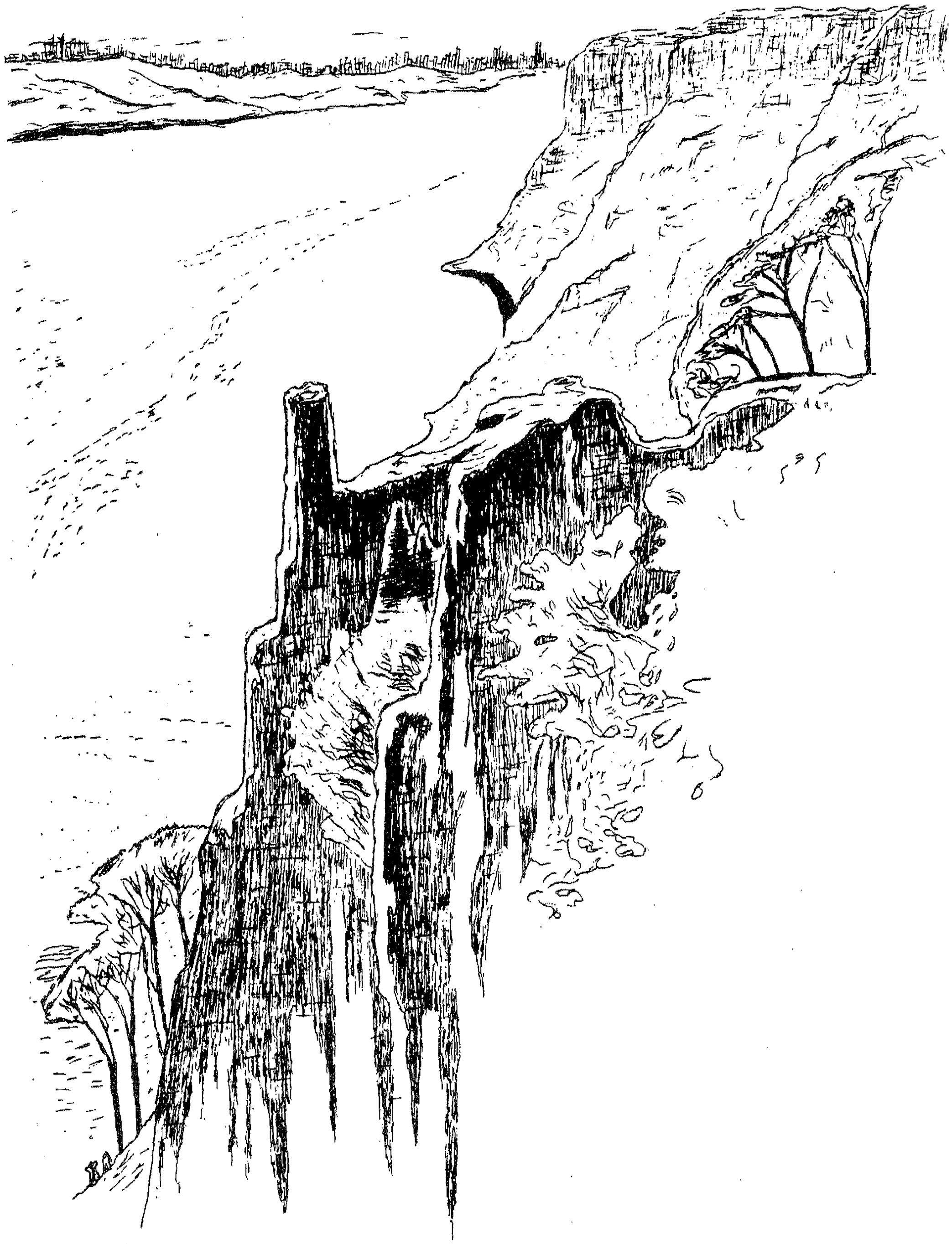

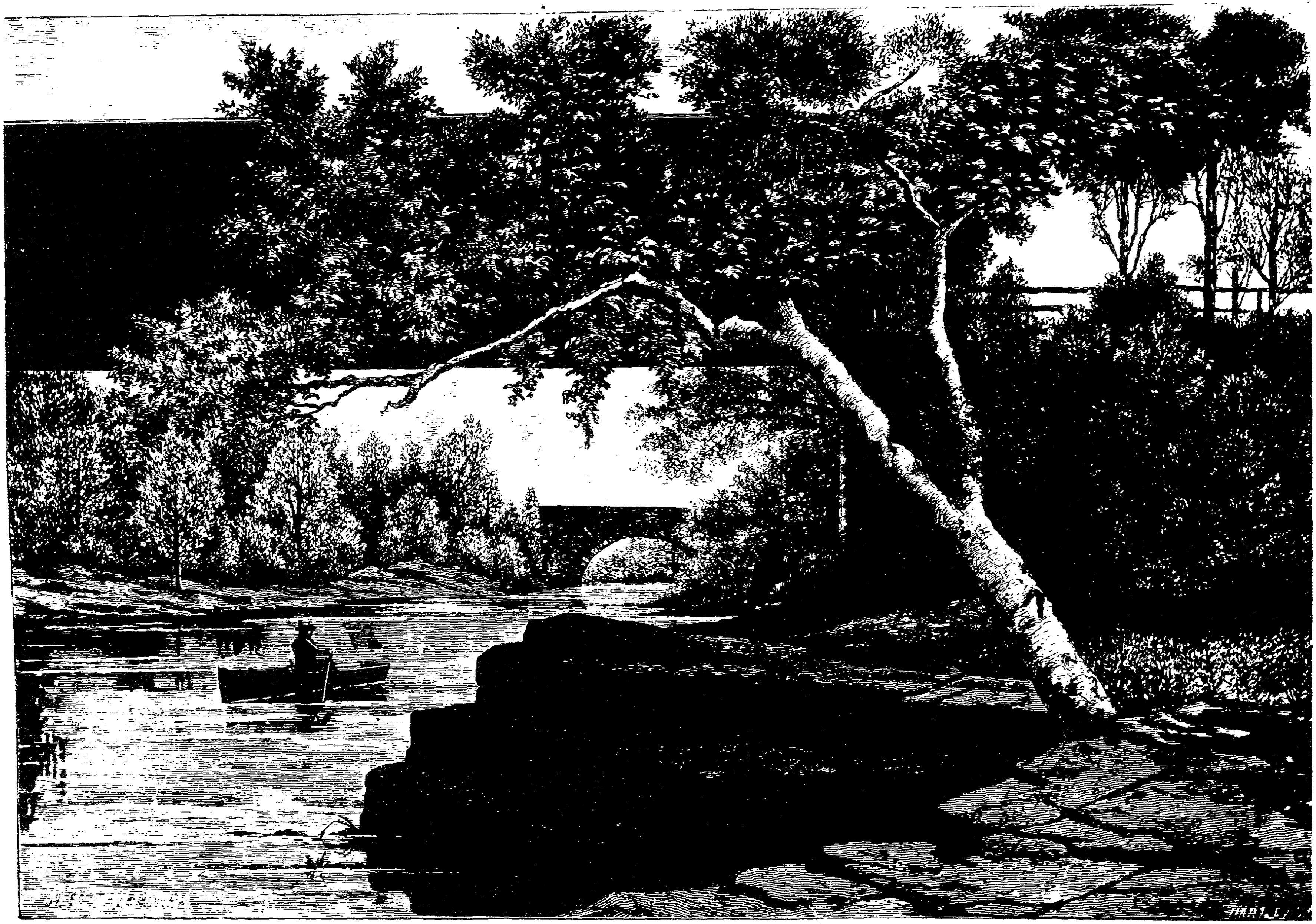

THE PASSAIC, BELOW LITTLE FALLS
by Jules Tavernier
from *Picturesque America,* Vol II, 1874