GEOLOGICAL ASPECTS OF STATEN ISLAND, NEW YORK

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INTRODUCTION

The purpose of this Staten Island field trip is to illustrate some of the major aspects of the island's geology. As shown in Figure 1, the geology of this area can be subdivided into four main units as follows:

1. A lower Paleozoic serpentine body that is exposed in the north central part of the island and which displays a northeast-southwest trend.

2. The late Triassic aged Stockton Formation of the Newark Group which overlays the serpentinite unconformably on the northwest. Its beds dip to the northwest and are generally arkosic in character. The southern extension of the Palisades diabasic sill is intrusive into the Stockton Formation.

3. The late Cretaceous aged Raritan Formation, which overlays the Triassic aged unit unconformably, is part of the Coastal Plain sedimentary deposits that outcrop on the southern and eastern part of Staten Island. It dips gently to the southeast and lithologically is composed of sand and clay interbeds.

4. Pleistocene deposits unconformably overlaying the older units almost everywhere on the island.

Figure 1 also shows the location of the four field trip stops that will be made and their relationship to the above mentioned geological units. Also shown are the locations of two geological cross-sections that will be discussed in this field trip. No stop will be made at a Triassic aged sedimentary outcrop.

GEOLOGY OF THE STATEN ISLAND SERPENTINITE

(By A. Ohan)

General Information

The Staten Island Serpentinite is a NE-SW trending oval shaped body located in the northeast portion of Staten Island and has an outcrop dimension of approximately 20 square miles. This ultramafic mass displays a sheared, conformable contact with metamorphic rocks of the lower Paleozoic New York City Group and is unconformably overlain by younger Triassic and Cretaceous sediments along the northwest and southeast borders, respectively.

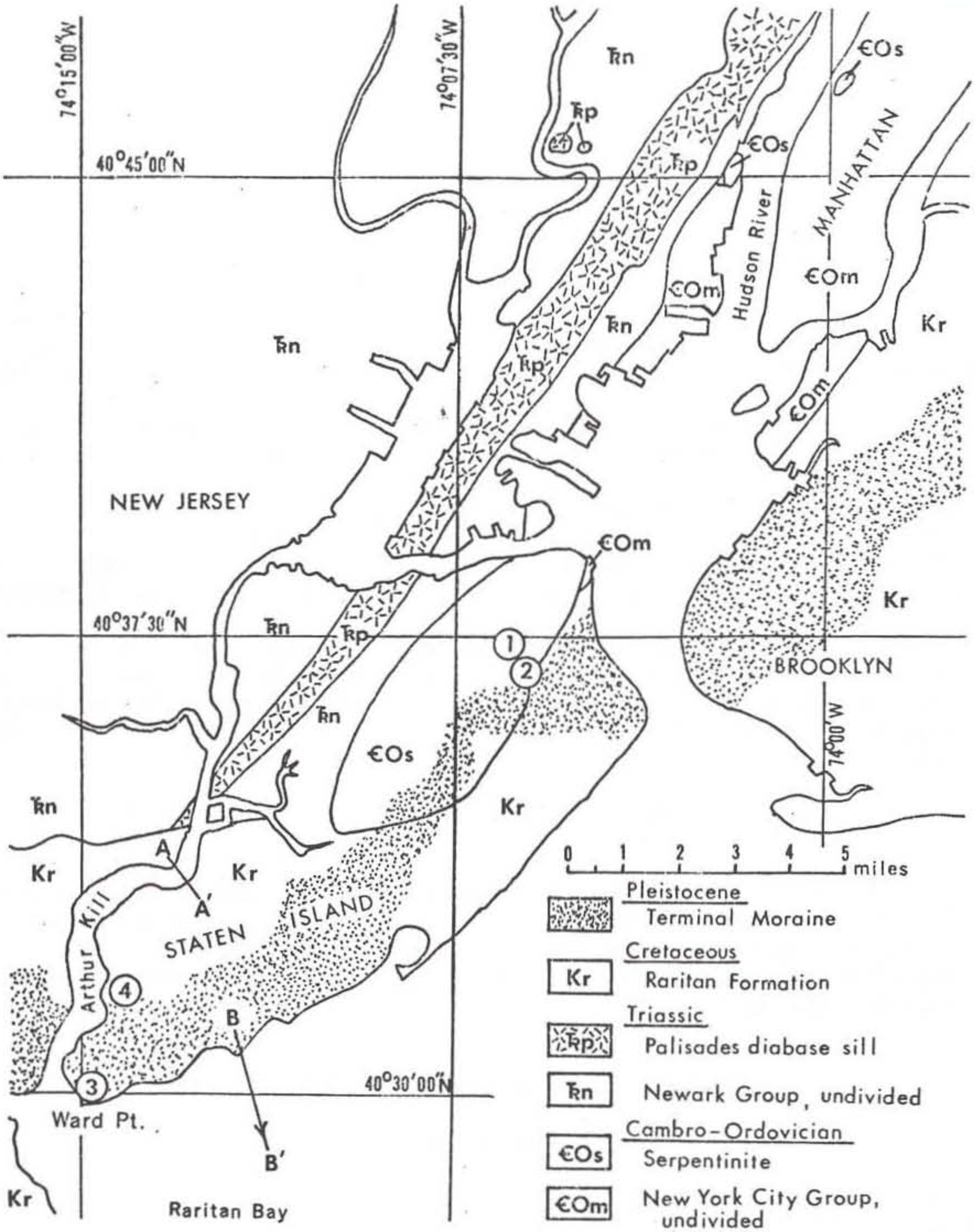


FIGURE 1 — REGIONAL GEOLOGY OF STATEN ISLAND
(Modified after Miller, 1970)

The long dimension of the Serpentinite is parallel to the structural trend of the New York City Group which evolved during the Ordovician Taconian Orogeny. As a result of extensive overlying Pleistocene deposits as well as urbanization, outcrops are few in number. Topographically, the Serpentinite is a ridge former, reaching an elevation of 413 feet above sea level.

Historical Summary of Investigations

The principal petrologic study of the Staten Island Serpentinite was accomplished by J. Behm (1954). His conclusions are outlined as follows:

1. The original ultramafic body was a harzburgite-type peridotite composed of olivine, orthopyroxene with accessory picotite.

2. As a result of serpentinization, the above minerals were altered to antigorite, bastite (serpentinized orthopyroxene), serpophite (glassy serpentine), chrysotile, talc, anthophyllite and magnetite.

3. Two major zones exist in the Serpentinite as shown in Figure 2. These are:

A Central Zone termed a massive porphyritic serpentinized peridotite, composed essentially of porphyritic enstatite-bastite and olivine in a matrix of antigorite, serpophite and olivine. Magnetite, picotite, anthophyllite, talc and chrysotile occur as accessory minerals. The rock is foliated with antigorite representing the essential foliation-producing mineral. The degree of serpentinization varies from one exposure to another.

A Border Zone termed a massive talcose serpentinized peridotite. This zone shows a more extensive degree of serpentinization when compared with the Central Zone and is characterized by a distinctive increase in talc, anthophyllite and magnetite. Talc and anthophyllite schists exist in a number of localities. In the northeast part of this zone, a dunite mass is present showing minor amounts of serpentinization. Throughout this zone, shearing is pronounced and veins of silica and carbonates are common.

Wasserman (1956) conducted a magnetic survey of the Serpentinite and recognized the presence of a high magnetic intensity area which corresponded with Behm's eastern Border Zone and a low intensity magnetic area which corresponded with his Central Zone (see Figure 3). Although several interpretations of the magnetic data are possible, Wasserman suggests that near vertical contacts and higher concentrations of magnetite within the eastern Border Zone are the controlling parameters. He concludes from the study of the magnetic patterns of the serpentinite body "that it might have the shape of a rectangular prism of limited cross sectional dimensions extending downward indefinitely."

The structural aspects of the Serpentinite were studied by Miller (1970), who recognized the presence of an affinity between the fault system and the tectonic axis of this body. He noted that the existing longitudinal, transverse and diagonal faults were extensively sheared, with near vertical

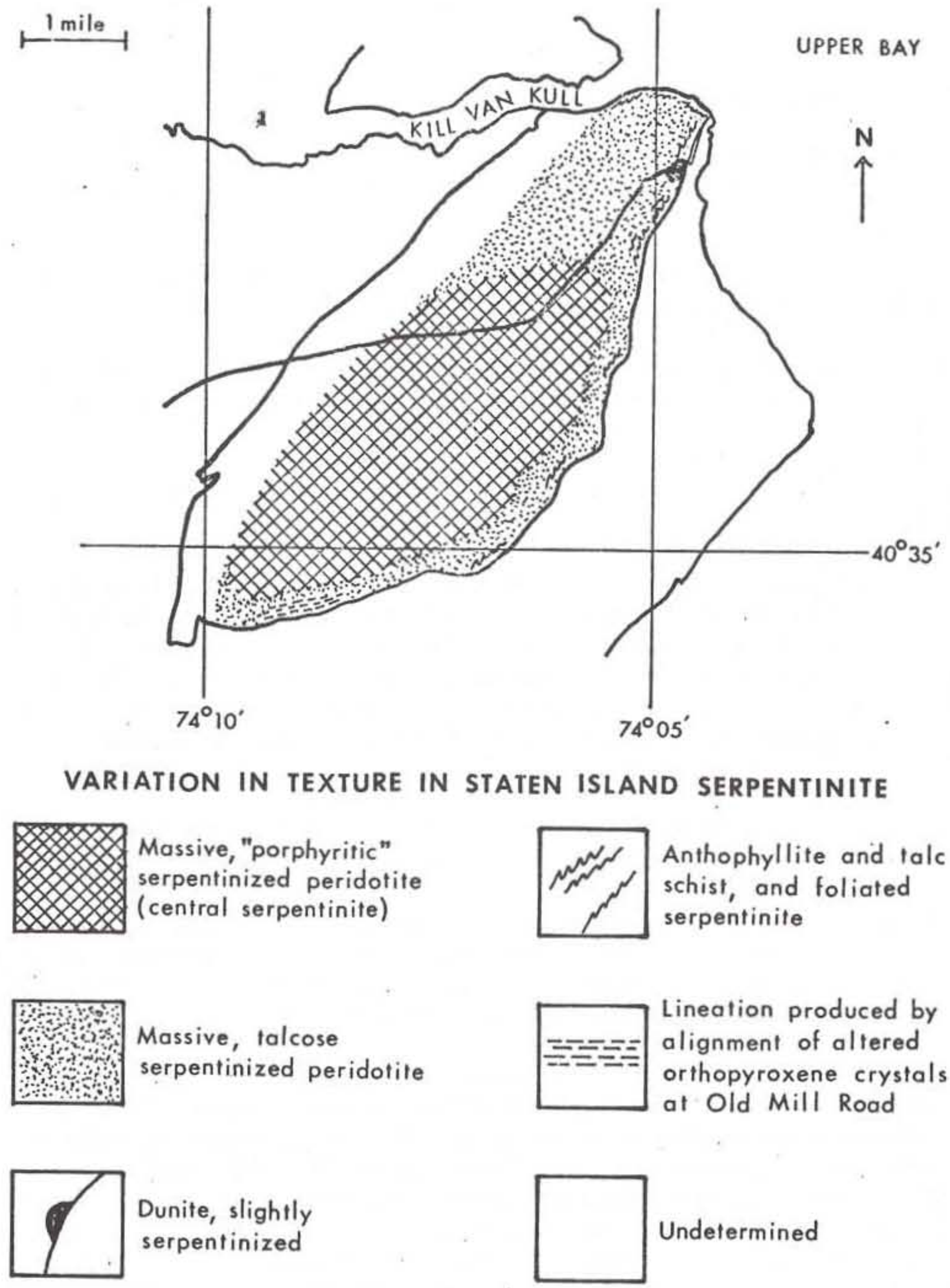
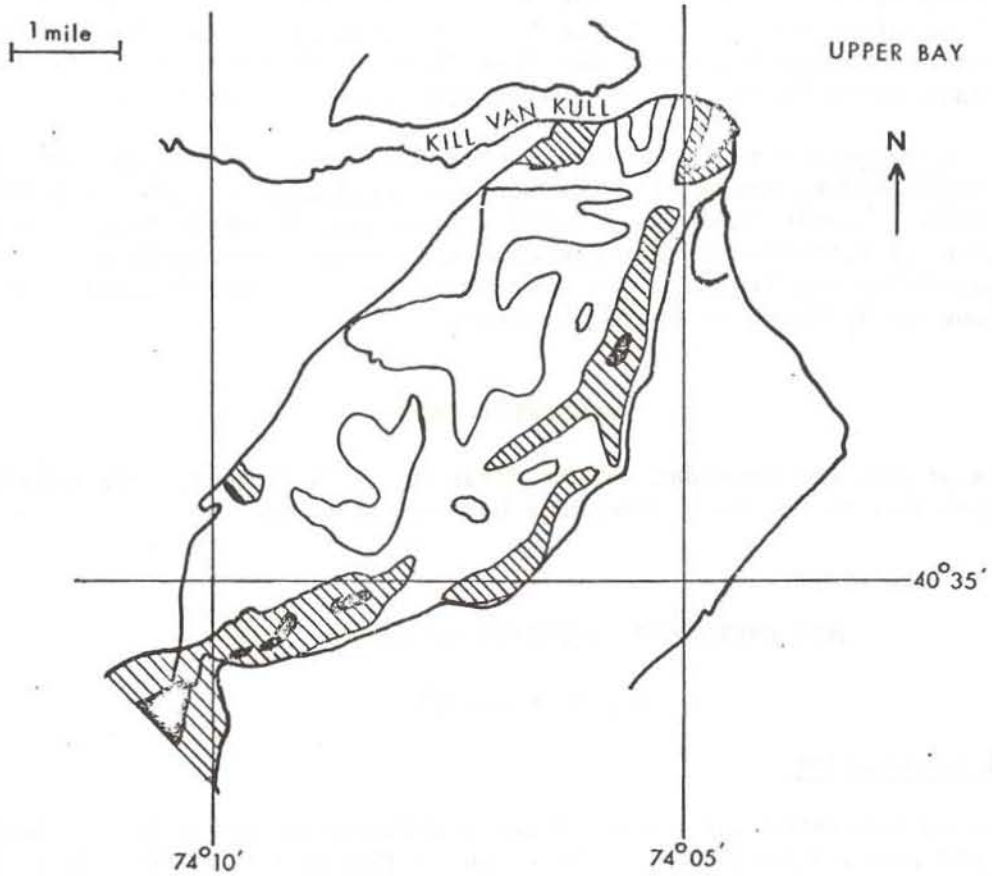


FIGURE 2 — FACIES MAP OF STATEN ISLAND SERPENTINITE
(after Behm, 1954)



CONTOURS OF VERTICAL MAGNETIC INTENSITY
contour interval – 500 gammas

Over 1500

Over 1000

500

FIGURE 3 — MAGNETIC INTENSITY MAP
(after Wasserman, 1956)

dips and fault movements that were essentially in a vertical direction. At a number of localities graben-like structures developed (e.g. Silver Lake) and the accumulations of Pleistocene and Recent sediments within these topographic lows may have controlled the low magnetic intensities found to be characteristic of the Central Zone of the Serpentinite body. Miller concludes that since the Serpentinite body is topographically higher than the more resistant lower Paleozoic New York City Group and also the Mesozoic sedimentary rocks it must be intrusive into the Mesozoic rocks.

It is suggested that the topographic expression of the Serpentinite may be explained by graben-like structures resulting through reactiviation of a number of early Paleozoic faults during late Triassic time. This conclusion is supported by the presence of a fault breccia with fragments of Serpentinite and Triassic sedimentary rocks in close proximity with a fault zone (Stop No. 2 at Spring Street).

ACKNOWLEDGEMENTS

Assistance was provided in the field by S. Okulewicz. Appreciation is also expressed to Dr. K. E. Lowe for his critical review.

LATE CRETACEOUS DEPOSITS OF STATEN ISLAND

(By A. Kureshy)

General Information

The consolidated and unconsolidated sedimentary sequences of Staten Island are comparatively thin. As shown in Figure 1 they consist of the Triassic aged Stockton Formation of the Newark Group in the northwestern part of the island and the Cretaceous aged Raritan Formation in the eastern and southern part where it overlies the Stockton. Throughout the area nearly all these strata are covered by either morainal or stratified drift of Pleistocene age. Both the upper and the lower boundaries of the Triassic and Cretaceous sequences are marked by pronounced unconformities.

Lithology of the Raritan Formation

The Raritan Formation is composed chiefly of sand and clay. Light colored sands are interbedded with dark variegated silty clays which show considerable variation in texture, composition and thickness. A thick bedded sequence of micaceous silt and clay containing a large amount of lignite and some sulphide minerals are also present. The sandy beds are extensively cross-stratified. In some places a different facies of the Raritan occurs which consists largely of thick intervals of light colored and massive to thick bedded variegated shale of red, white and light-green silty clay.

Nowhere on the island is a complete sequence of the members of the Raritan Formation exposed. However, Lovegreen (1974) reported the following stratigraphic succession in the Raritan from bore hole logs obtained along an E-W geological section extending from Perth Amboy, N.J. to Charleston, S.I. across the Arthur Kill:

(a) Gray consolidated varved clay
(b) Gray sand
(c) Gray and Red consolidated clay
(d) White sand
(e) Gray consolidated clay
(f) Red consolidated clay

This section is close to Stop No. 4 where the relationship of stratified and unstratified glacial deposits to older and younger sedimentary deposits can be seen in an exposure. The contacts and general interpretation of the bore hole data (Lovegreen, 1974) are recognized as only tentative.

Depositional Environments

The Atlantic Coastal Plain Sediments to which the Raritan Formation belongs consist of sediments deposited in a wide variety of continental, transitional and marine environments. The deposits of the Raritan are extensively cross-stratified which is characteristic of a non-marine origin. On the basis of its lithology and sedimentary structure, the Raritan deposits have been interpreted by Allen (1965) and by Owen et al. (1968), as having been deposited in a sub-aerial deltaic plain. However, a second view about their origin was proposed by Broughton (1966) which is that these deposits are partly marine and partly non-marine with much of the non-marine sediments being deposited in fluviatile or swampy lowland and estuarine environments along the coast.

Age and Fauna of the Raritan Formation

Since Broughton (1966) proposed that the Raritan Formation is composed of partly marine, partly non-marine Cretaceous deposits, corresponding kinds of fossil remains are required to establish these identities. In this connection the author examined samples of various local members of the Raritan Formation for such evidence. The washed residue of these deposit samples however proved to be barren, no macro or microfossils being recorded.

According to Hollick (1967) the Upper Cretaceous age of the Raritan Formation is delineated by characteristic fossils of plant leaves such as the following: *Liriodendropsis* simplex Newb., *Laurusplutonia* sp., *Thinufeldia* sp., *Sapindus* morrisoni Lesq., and *Moriconia cyclotoxon* Deb.

Occurrences

The Raritan Formation Cretaceous deposits apparently extend up to the southern border of the serpentinite ridge. Further to the west they apparently extend as far north as the Fresh Kills marshes. They are especially abundant in the morainal accumulations at Tottenville, Princess Bay and Arrochar. No strata of Cretaceous age have been found in the morainal deposits to the north and west of the serpentinite ridge. In the south much of the morainal material represents fragments which have been eroded from the Cretaceous deposits south of the serpentinite ridge and transported there by the advancing glacier or by streams from the melting glaciers.

Correlation of the Raritan Formation

The correlation of the Staten Island Cretaceous strata with those of other localities outside the island is difficult on account of the erosion and the disturbance to which they were subjected during the glacial epoch. Theoretically, according to Hollick (1967), if the Raritan Formation of New Jersey extended to Staten Island, then the lower members of this formation, represented by those at Woodridge, Perth and Amboy, would strike the western shore of Staten Island in the vicinity of Tottenville. The upper members of the Raritan in New Jersey, represented by the southern shore from Tottenville to Arrochar and a marl member, represented at Cliffwood, N.J., would be found in the vicinity of the Narrows. The correlation of the Raritan Formation of New Jersey with that of Staten Island is consequently quite arbitrary and it is not helped by the absence of any exposure on the island showing a complete sequence of this formation.

GLACIAL FEATURES AND DEPOSITS OF STATEN ISLAND AND ADJOINING AREAS

(By E. Kaarsberg)

Age and Distribution

Staten Island is covered almost entirely by glacial deposits, the most prominent of which is a terminal moraine extending along the south-east shore of the island from Long Island in the east to New Jersey in the west as shown in Figure 4. This moraine marks the most southerly advance along the Atlantic coastline of the last great continental ice sheet, the Wisconsinan, which Carbon 14 dating indicates began its retreat between 17,000 and 18,000 years ago (Bryson and Wendland, 1967 and Prest, 1969). An excellent cross sectional exposure of this moraine and in places nearby some of the associated stratified outwash material can be seen at the south end of the island at Stop No. 3. According to Prest's map the first recessional moraine along the Hudson River is found about 170 miles to the north of Staten Island and has a Carbon 14 date of 14,000 years B.P. However, other investigators find evidence of five or more other recessional moraine in the Wallkill Valley west of and parallel to the Hudson River in this same distance interval to the north.

Striations and groove patterns in the bedrock in the New York City area indicate, as also shown in Figure 4, that the movement of the ice was from north to south across Staten Island.

Some indication of a minor Wisconsin substage retreat and advance has also been found by Sanders (1975) in the Princess Bay area of Staten Island.

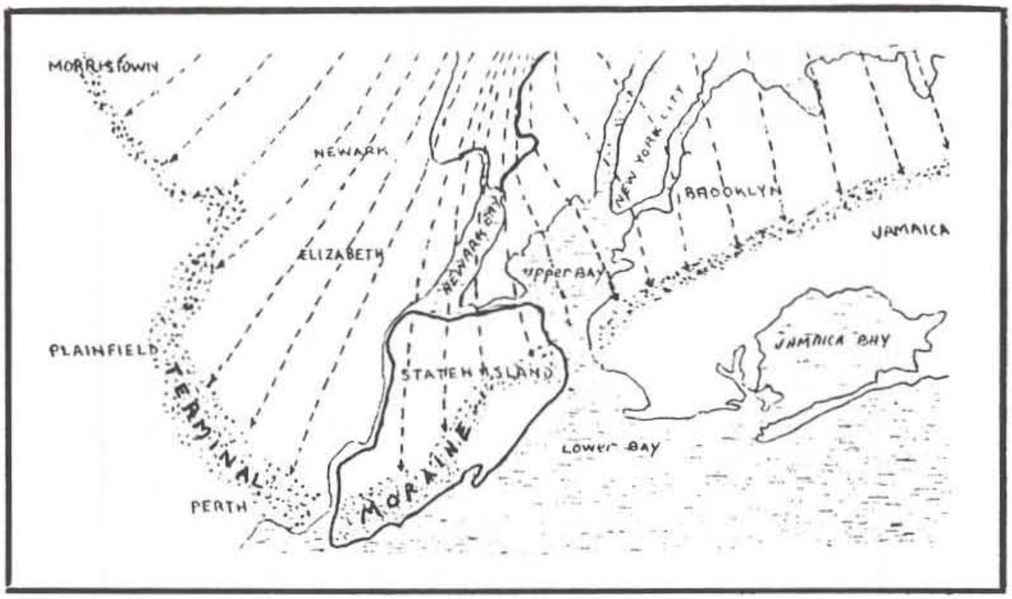


Figure 4. Sketch map of New York City and vicinity, showing position of the terminal moraine and the directions of the ice movement (indicated by arrows) during the last or Wisconsin Glaciation. (After Reeds, 1930 and the United States Geological Survey.)

At the peak of and during the early stages of retreat of the Wisconsin Ice sheet great quantities of sedimentary material were deposited on extensive outwash plains that then extended many miles off-shore eastward and which are now submerged. This was established by early investigators of off-shore seafloor deposits. From more recent investigations (Flint, 1971) it has been estimated that the lowest possible position of relative sea level during the peak of the Wisconsin ice age was about -100 meters. This would place the Atlantic shoreline at that time at about 50 miles east of its present position along the New York-New Jersey coast. The results of off-shore geological investigations of this kind, that are considered to be the most reliable and consequently the most discussed, are based on Carbon 14 dated fossil organisms of a kind that lived in very shallow littoral environments and that were collected from localities at which they are believed to have lived at known depths beneath the present sea level. With these it has been possible to construct Time-Depth Curves such as the one shown in Figure 5 of sea level changes associated with the retreat of the Wisconsin Ice Sheet.

Stratigraphic Relationships

Figure 6 is a generalized geological cross section between Seguine Point on Staten Island and Conaskonk, New Jersey (see line A-A' on map in Figure 1) prepared, by MacClintock and Richards (1936), from test hole borings that were made in 1930-31 for a proposed bridge between these two points. At Bore Hole No. 1 on Staten Island the glacial drift is gravelly and bouldery. Below this and extending far out under Raritan Bay is a deposit of reddish brown sand and gravel containing shell fragments in a few places which MacClintock and Richards identify as the Cape May Formation,

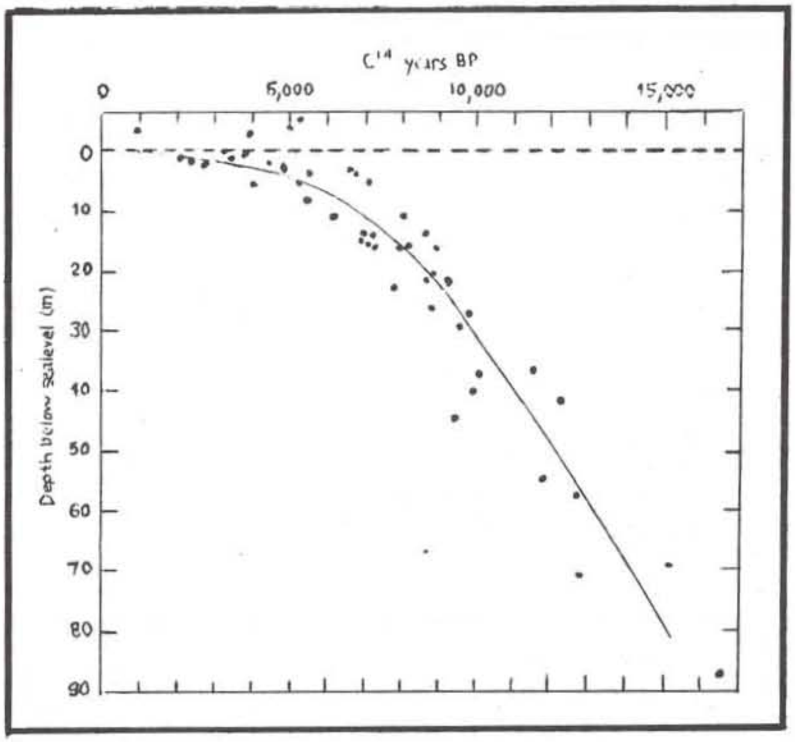


Figure 5. Submergence curve based on nearly 50 C_{14}-dated samples of organisms taken from growth positions judged to have been close to sea level. Samples are from various depths along or off several coasts thought to have been "relatively stable." C_{14} ages are plotted against depths. Curve reflects progressive submergence, believed to be chiefly eustatic. (After Shepard, 1963b.)

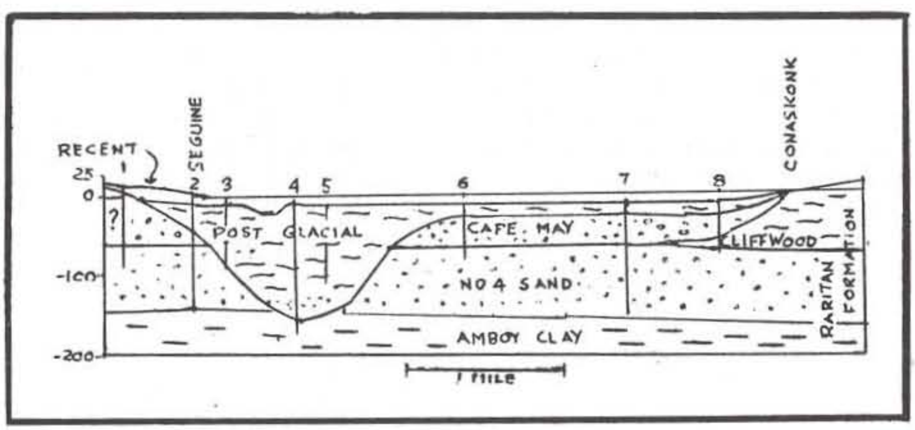


Figure 6. Generalized cross-section from Seguine Point, Staten Island, to Conaskonk Point, New Jersey, based on borings, as numbered, made by the Port of New York Authority. (After MacClintock and Richards, 1936.)

laid down during the Wisconsin glacial age. This depositional layer since that time was evidently deeply trenched as shown by the Raritan River to a depth of 170 feet into the underlying Raritan Formation (Cretaceous). This trench or channel was subsequently filled as shown with post-glacial material. Borings on the Staten Island shore, at locations No. 1 and 2, show a thin deposit of sand on top of the post-glacial "channel fill." This is interpreted to be beach material and post-glacial wash from the moraine to the north.

Figure 7 shows a northwest-southeast geological section from Carteret, New Jersey to Rossville, Staten Island, across Arthur Kill prepared by Lovegreen (1974) from bore hole logs (see Line B-B' on map in Figure 1). This section is the closest one that could be found to Stop No. 4. It is one of several Lovegreen prepared for the Staten Island and adjoining areas which show the relationships of the stratified and unstratified glacial deposits to the older and younger non-glacial deposits with which they are associated. The exposure at Stop No. 4 shows the contact between the Pleistocene glacial and the underlying Cretaceous deposits very clearly.

As indicated by the dashed boundary lines and the question marks on this geological cross section, the interpretation of the hole data presented by Lovegreen is regarded as being only tentative, a number of other interpretations being possible.

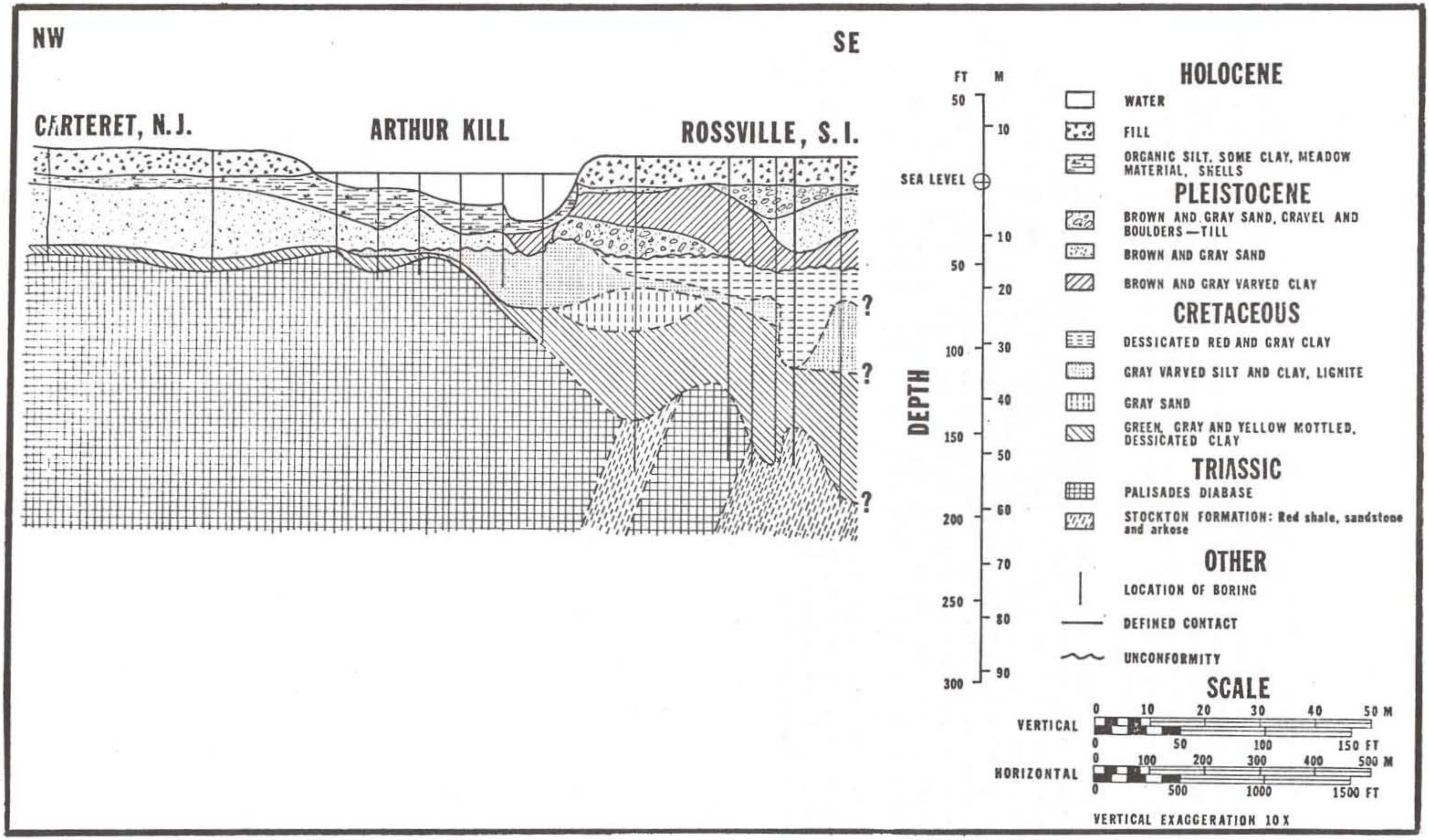


Figure 7. Geological cross section from Carteret, N.J. to Rossville, S.I. across Arthur Kill based on bore-hole logs (Interpretation after Lovegreen, 1974).

ROAD LOG

Cumulative Miles	Miles from last point	Description
0.0	0.0	Road log begins at the Verrazano-Narrows Bridge on Staten Island Expressway (Interstate 278) and goes west.
0.7	0.7	Exit from I-278 at Clove Road exit and follow Narrows Road, parallel to the expressway, to Richmond Road where the Narrows Road becomes Little Clove Road, which also parallels the expressway. Continue on Little Clove Road to Renwick Avenue.
2.0	1.3	Turn left onto Renwick Avenue, passing under the expressway, and reaching Milford Drive.
2.1	0.1	Turn right onto Milford Drive. This is a Dead End street and is used as an off campus parking lot at Staten Island Community College. Drive to the end of the street and park. Walk up the embankment there to an access road and turn left on the abandoned access road to the outcrop at I-278 and Slossen Avenue.

STOP NO. 1 - Serpentinite Outcrop

This outcrop represents the largest continuous exposure of the Central Zone Serpentinite on Staten Island. The rock is a foliated serpentinized peridotite. The dominant mineral is antigorite which has replaced in varying degrees the original olivine and enstatite. The minor constituents are magnetite, brucite, picotite (chrome spinel), picrolite (sheared antigorite) and graphite. Numerous veins are filled with talc, chrysotile or carbonates. Note:

1. The foliation has been deformed into small folds displaying axial planes which are almost vertical and trending in a general northeast-southwest direction.

2. A number of folds are cut by an axial plane oriented slip cleavage.

3. Several small, high angle, northeast-southwest trending faults and associated fault zones.

Return to bus. Follow Milford Drive back to Richmond Road (second traffic light).

3.4	1.3	Turn right on Richmond Road and continue on to Spring Street (first traffic light).
3.8	0.4	Turn right on Spring Street. Bear right at Y intersection and continue to outcrop ahead on right.

STOP NO. 2 - Serpentinite Outcrop**

This exposure is located within the Border Zone of the Serpentinite body and is in close proximity to the near vertical Spring Street Fault. The rock is essentially fine grained, foliated and extensively sheared. The principal mineral is antigorite with small amounts of magnetite and brucite. Some porphyritic serpentinite is present with phenocrysts of olivine and magnetite in a matrix of antigorite. Talc, hydromagnesite, aragonite and artinite exist in veins or along shear planes. Note:

1. Topographic expression of the northeast-southwest trending Spring Street Fault Zone.

2. Small folds with axial planes oriented in a northeast-southwest direction.

3. Fault breccia with fragments of serpentinite and Triassic sedimentary rocks.

4. Near-source glacial erratics with fragments of serpentinite, Triassic sedimentary rocks and gneisses (possibly fanglomerates?).

** This outcrop is in the locality for a housing development and may be eliminated in the near future. If this occurs an alternative exposure will be visited.

4.7	0.4	Return to bus. Turn right on Richmond Road. This road follows the almost vertical contact of the Serpentinite body and outcrops of this rock can be seen on the right in many places. Continue on Richmond Road to New Dorp Lane (Gulf Station on left).
7.2	2.5	Turn left on New Dorp Lane and continue on to Hylan Boulevard.
7.9	0.7	Turn right onto Hylan Boulevard and continue to the end of this thoroughfare.
14.5	6.6	Seguine Avenue which leads to Princess Bay and Seguine Point on the left.

14.9	0.4	Woodvale Avenue. Open areas here begin to show hummocky terrain with poorly developed drainage so typical of glaciated areas to the north.
17.7	2.8	STOP NO. 3 - Terminal Moraine Glacial Deposit Along the beach at the south end of Hylan Boulevard a Wisconsin aged terminal moraine has been clearly exposed by beach erosion. It shows the typical unsorted nature of this kind of glacial deposit with large boulders intermingled with finer rock debris. On the beach itself these boulders are left stranded after wave action and near-shore currents have removed the finer material. The great variety of composition that these boulders show bespeaks the great variety and far flung distribution of their source areas. For example the dark diabase boulders probably came from the Palisades Sill structure only a few miles to the north whereas many sedimentary boulders found on Staten Island often contain marine fossils which indicate that they probably came from rock exposures in east-central New York or northwest New Jersey. In places further along the beach remnants of stratified glacial outwash deposits may be found. Return to bus. Continue on back north on Hylan Boulevard to Page Avenue (first traffic light).
19.1	1.4	Turn left on Page Avenue and proceed along this road through the first traffic light at Amboy Road and across Mill Creek Bridge to Richmond Valley Road.
20.1	1.0	Turn left on Richmond Valley Road and continue to Arthur Kill Road.
20.3	0.2	Turn right on Arthur Kill Road and continue along this road underneath the Outerbridge Crossing to area of quarry operations.
21.0	0.7	STOP NO. 4 - Raritan Formation Outcrop The outcrops in the quarries in this area represent largest continuous exposures of Cretaceous sedimentary deposits found on Staten Island. Two members of the Raritan Formation belonging to the Gray consolidated clays and the Red consolidated clays are represented at these exposures. The Gray colored clay deposits are characterized by the presence of lignite fragments and pyrite. The Red

colored clays apparently do not contain any of these materials. These deposits are also characterized by various sedimentary structures of which cross stratification in the sands is one. Samples of these deposits were processed for the study of any microfossil fauna, but none were recorded. Neither were any plant fossil remains found.

Return to bus. Continue on Arthur Kill Road to Richmond Avenue.

25.6	4.6	Turn left onto Richmond Avenue and continue north to expressway (I-278).
30.4	4.8	Turn right onto expressway. Continue east toward Verrazano Narrows Bridge.
33.0	2.6	Staten Island Community College on right.
36.1	3.1	Entrance to Verrazano-Narrows Bridge.

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NOTES