SUBSURFACE GEOLOGY AND PALEOGEOGRAPHY OF QUEENS COUNTY, LONG ISLAND, NEW YORK

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FACTORS FOR CONVERTING ENGLISH UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

Multiply English Units	By	To obtain SI units
	Length	
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
	Flow	
gallons per minute (gal/min)	.06309	liters per second (L/s)
million gallons per day (Mgal/d)		cubic meters per second (m^3/s)
	Slope	
feet per mile (ft/mi)	.1894	meters per kilometer (m/km)

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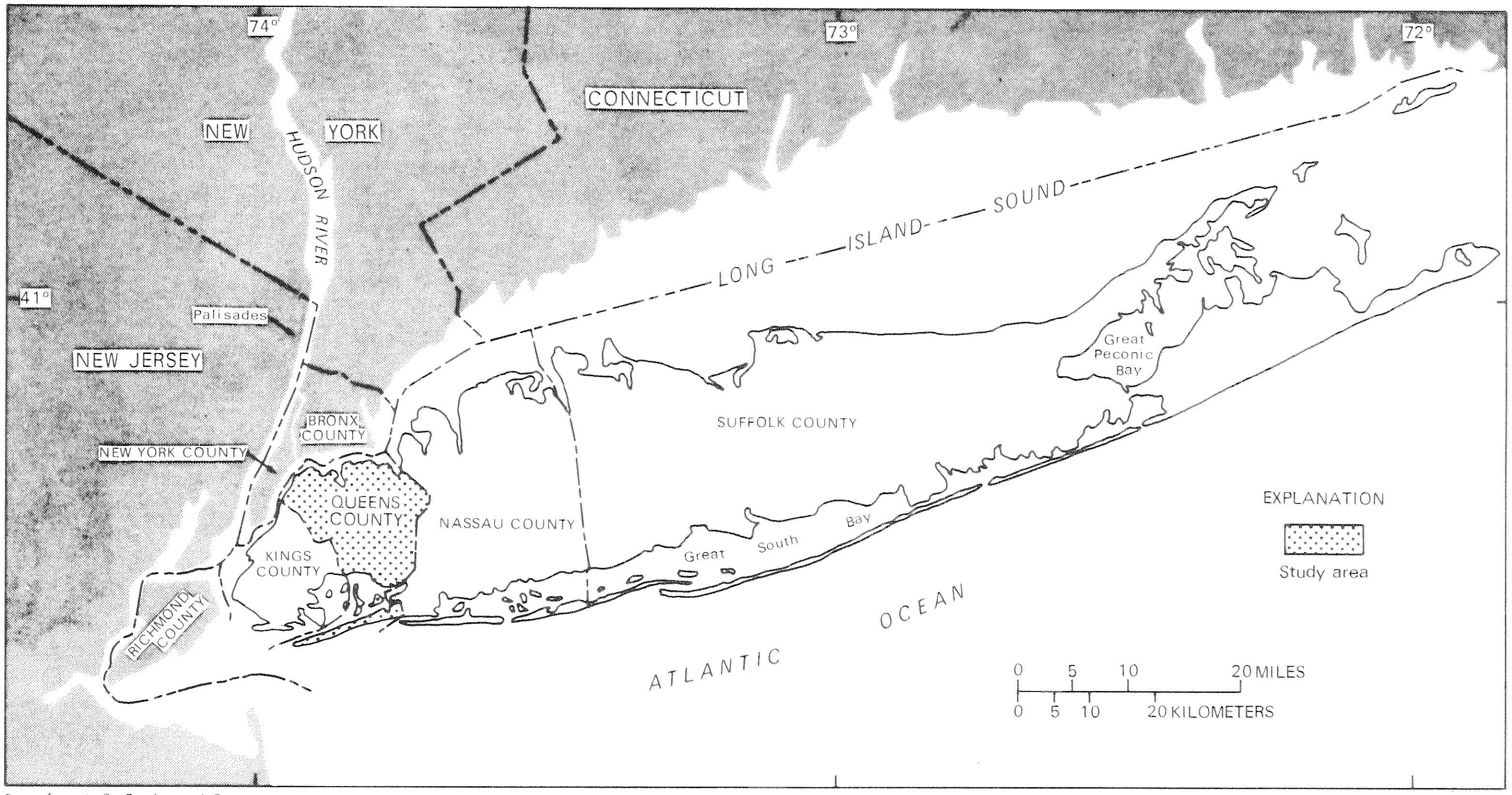
ABSTRACT

Unconsolidated strata of clay, silt, sand, and gravel of Late Cretaceous and pre-Wisconsin Pleistocene ages lie between crystalline basement rocks (bedrock) of Precambrian(?) age and unconsolidated deposits of late Pleistocene (Wisconsin) and Holocene ages in Queens County, Long Island, N.Y., a borough of New York City. Data collected during a recent study of the hydrogeology of the county and updated records of earlier studies have been used to prepare contour maps that delineate the surfaces of the bedrock and the Upper Cretaceous and pre-Wisconsin Pleistocene deposits. The presence of diabase fragments, apparently from the Hudson Palisades, in a buried valley through the county suggests that the ancestral Hudson River was diverted into Queens County in Pleistocene time.



Base from U.S. Geological Survey
State base map, 1:500,000, 1974

Figure 1.--Location of Queens County, N.Y. and general regional geography.

INTRODUCTION

Queens County, one of the five boroughs of the City of New York, is situated at the west end of Long Island (fig. 1). The County had a population of 1,962,900 in 1974 (I. L. Kundzins, Librarian, U.S. Department of Commerce, oral commun., Dec. 16, 1975) in a land area of 113 mi^2. Communities in the county are a mixture of urban and suburban developments; the west half of the county is mostly urban. The principal geographic and cultural features are described in Soren (1971, p. 3-6). Plate 1A shows the locations of communities and other geographic features.

Mapping of subsurface geologic units is important to ground-water-supply managers, well drillers, geologists, hydrologists, engineers, and others concerned with subsurface work and studies. Subsurface mapping is especially important in Queens County because ground water supplies the needs of about 3/4 million people there. This report provides maps showing contours on the surfaces of geologic units underlying Pleistocene deposits of Wisconsin age (pl. 2A-F) and shows stratigraphic relationships of the units in geologic sections (pl. 1B). Before this report, the only available subsurface geologic mapping of the County was given in Suter, deLaguna, and Perlmutter (1949), which provided formation-surface contour maps, geologic sections, geologic history, and lithologic descriptions. However, the maps in Suter and others (1949), at approximately 1:185,000, are at a smaller scale than those in this report, the formation-surface contours are not easily referenced to surficial geography, and the maps contain many inaccuracies owing to the quality of reported subsurface data available at that time. The remapping of the geologic units also indicates that the Hudson River was diverted into Queens County in the Pleistocene Epoch--an addition to the knowledge of the regional geomorphology.

The maps and geologic sections in this report supersede those in Suter and others (1949). Much of the well data used therein have been reinterpreted, and additional well and core data were collected and examined as part of a general investigation of geology and ground water in the county between 1958 and 1975. The location of wells and test borings used to prepare this report are shown in plate 1A. A report on ground water and geohydrologic conditions in the county is given in Soren (1971). The work in the County was done by the U.S. Geological Survey under a cooperative agreement with the New York State Department of Environmental Conservation.

Acknowledgments

Drill cuttings, core samples, and well logs were made unreservedly available to the author by Abe Kreitman of The Lauman Co., Inc., Bethpage, N.Y.; and by George Tibbe of the Layne-New York Co., Inc., Hauppauge, N.Y., during the course of the investigation. Robert N. Oldale and Francis A. Kohout, U.S. Geological Survey, provided valuable assistance in the preparation of the report manuscript.

GEOLOGY

The subsurface geologic units in Queens County described in this report consist of sequences of unconsolidated sediments of Late Cretaceous and Pleistocene pre-Sangamon and Sangamon ages that are underlain by crystalline bedrock of Precambrian(?) age and overlain mostly by glacial upper Pleistocene deposits of Wisconsin age but also, to a lesser extent, by Holocene deposits. These units, from bedrock upward, are the Raritan Formation, of Late Cretaceous age, consisting of the Lloyd Sand Member and an overlying clay member (unnamed); the Magothy Formation-Matawan Group undifferentiated, of Lake Cretaceous age; the Jameco Gravel, of pre-Sangamon age; and the Gardiners Clay, of Sangamon age. The Cretaceous formations are part of the Atlantic Coastal Plain. The overlying upper Pleistocene deposits extend to the land surface in more than three-fourths of the County; Holocene deposits mantle the remainder.

Erosion of the subsurface units developed a valley system, now buried, which traverses Queens County from north to south. The valleys are filled with Pleistocene deposits.

The unconsolidated deposits have been intensively developed, mostly for public-water supply, since before 1900; recorded pumpage from 1904 through the 1960's averaged 60 Mgal/d (Soren, 1971, p. 23). In the mid-1970's, pumpage increased to an average of 70 Mgal/d (New York State Department of Environmental Conservation, Stony Brook, N.Y. office, written commun., May 1, 1973, and R. J. O'Reilly, oral commun., Aug. 5, 1974).

Subsurface Geology

Precambrian(?) Rocks

Bedrock

The Precambrian(?) bedrock consists chiefly of complexly folded and faulted gneisses and schists that were eroded to a peneplain before deposition of the overlying Upper Cretaceous units.

The position of the bedrock surface is shown by contours in plate 2A. The strike of the bedrock surface in Queens County is about N 50° E, and the surface dips to the southeast at approximately 80 ft/mi, an angle of about 52 minutes. Small bedrock outcrops occur in the northwestern part of the County near the East River (Soren, 1971, pl. 1), and bedrock lies 1,100 ft below sea level at Far Rockaway, in the southeastern part of the County.

In most of Queens County, the bedrock surface was weathered to clay prior to deposition of the Upper Cretaceous strata. Perlmutter (in Suter and others, 1949, p. 13) states that the weathered bedrock-surface clay is 5 to 100 ft thick and can be identified and differentiated from younger clay units by examination of samples for indications of original bedrock minerals, such as ragged quartz grains, garnet fragments, biotite, amphibole, pyroxene, feldspar, or altered products of these minerals.

Information about the position of bedrock in Queens County is of interest to designers of subsurface structures, excavators, and water-well drillers, especially where bedrock is near the land surface in northwestern and northern Queens, because the bedrock surface is, for practical definition, the bottom of the ground-water reservoir on Long Island. Bedrock does not usually yield more than a few gallons per minute to wells and, except at a few wells in the extreme western part of the county, bedrock is not used for water supply because larger yields are usually available at shallower depths.

Upper Cretaceous Deposits

Raritan Formation

Lloyd Sand Member.--This unit is of continental origin and overlies the bedrock surface with angular unconformity. The Lloyd consists of very fine to very coarse quartzose sand, granule to medium-pebble gravel, and interbedded clay and clayey and silty sand; sand and gravel beds commonly contain much interstitial clay and silt. The sand and gravel are generally grayish white and light yellow; clays are grayish white, light to dark gray, pink, and reddish. Disseminated lignite and pyrite are common in Lloyd beds, and laminae and thin beds of these substances occur within the clayey beds. Other minerals are stable types such as muscovite, rutile, and garnet.

Thickness of the Lloyd Sand Member in Queens County increases southeastward and ranges from 0 to 300 ft. Strike and dip of the member are approximately the same as those of the bedrock surface.

The position of the Lloyd surface is shown by contours in plate 2B. The unit was not deposited in western and northwestern Queens County but tapers out along a line from the Ridgewood vicinity of the County to Jackson Heights. The Lloyd is missing in buried valleys between the New York Municipal airport and College Point, between College Point and Whitestone, and in the Flushing Meadows Park area (pl. 1B, section C-C') as a result of erosion mainly in post-Cretaceous time. The valleys were probably cut by the ancestral Hudson River and associated tributary and distributary streams. The valley system is discussed in the section "The Buried Valley of the Ancestral Hudson River(?) in Queens County."

Lloyd beds do not crop out in Queens County; the surface of the member lies 100 ft below mean sea level in the northern part of the county and descends to 800 ft below sea level at Far Rockaway.

The importance of the Lloyd Sand Member in Queens County is that it is a moderately developed aquifer (Lloyd aquifer). As much as 10 Mgal/d of freshwater was pumped from the Lloyd in the 1930's and 1940's, and an average of 5 Mgal/d was pumped from the unit in the 1960's (Soren, 1971, p. 26). Lloyd pumpage in the mid-1970's averaged 6 Mgal/d (New York State Department of Environmental Conservation, written commun., May 1, 1973 and R. J. O'Reilly, oral commun., Aug. 5, 1974). Individual wells screened in Lloyd strata have been pumped at sustained rates of more than 1,000 gal/min during their developmental stages.

Water in the Lloyd is under artesian conditions; it is confined by the overlying clay member of the Raritan Formation and the underlying bedrock. The Lloyd is the only large supply of fresh ground water on the Rockaway Peninsula, and since it lies below sea level everywhere on Long Island, its freshwater recharge can only be from above. Recharge is mostly at very slow rates through the clay member over large areas, but locally, in the buried valleys, the aquifer can be more easily recharged through adjacent Pleistocene deposits that extend from bedrock to land surface (pl. 1B, section C-C').

Clay member.--This unit, of continental origin, has not been formally named as a stratigraphic unit but is commonly referred to on Long Island as the Raritan clay; it has also been named "Raritan clay" as a hydrogeologic unit (Cohen and others, 1968, p. 18). The clay member overlies the Lloyd Sand Member with apparent conformity. In western Queens County, the clay member overlaps the Lloyd and lies on bedrock with angular unconformity (pl. 1B, sections A-A' and C-C').

Deposits of the clay member include clay, silty clay, and clayey and silty fine sand. Lignite and pyrite occur in the clay member as in the Lloyd Sand Member. Sandy beds are commonly found in the clay member, and thin gravelly beds have been found locally in the unit. The clays are mostly light to dark gray; others are brownish red, pink, red, and grayish white. The reddish hues are attributed to oxidation of iron minerals in the sediments where they crop out (or cropped out prior to burial), or where they are (or were) near enough to land surface for oxidation to occur.

The author observed one outcrop of the clay member in Queens County in a small bluff near the shore of the East River in Whitestone (Soren, 1971, pl. 1) and penetrated the unit with a hand auger 4 ft below beach deposits just north of the outcrop (the outcrop was covered by a few feet of earth at some time in the late 1960's). Elsewhere in the County, the clay member lies below land surface and almost entirely below sea level. The unit dips southeastward and is about 600 ft below sea level at Far Rockaway; strike and dip of the clay member's surface are approximately the same as the Lloyd's. Thickness of the clay member increases southward and ranges from 0 to 200 ft. However, where the unit is less than 100 ft thick, the thinning is generally a result of erosion.

The position of the surface of the clay member is shown by contours in plate 2C. The map of the unit's surface indicates that the clay member overlaps the Lloyd in western and northwestern Queens County. The unit is missing in the westernmost part of Queens and in the buried valleys, where the Lloyd is also missing. The clay member terminates generally as a low escarpment, probably because it is more resistant to erosion than the Lloyd Sand Member or overlying beds.

On Long Island, the major significance of the clay member is that it confines water in the Lloyd Sand Member (Lloyd aquifer).

Magothy Formation-Matawan Group Undifferentiated

This unit includes the remainder of the Upper Cretaceous strata above the Raritan Formation in Queens County. It apparently is of continental origin and disconformably overlies the clay member of the Raritan Formation. The Magothy-Matawan unit is unconformably overlain by formations of Pleistocene age, which are described in the following paragraphs. In older reports, such as Suter and others (1949), the unit was called the "Magothy(?) Formation"; the name change to Magothy Formation-Matawan Group undifferentiated was made by Perlmutter and Todd (1965, p. 9).

The Magothy-Matawan deposits consist of strata similar to those in the Lloyd Sand Member of the Raritan Formation; however, sand and gravel (up to large pebbles) generally occur only in the basal 50 to 100 ft of the Magothy-Matawan deposits. This basal sand and gravel bed indicates probable disconformity between the unit and the underlying clay member of the Raritan Formation. Thickness of Magothy-Matawan strata in Queens County ranges from 0 to 450 ft; the thickest section is in the Far Rockaway area. Thickness of the deposits varies greatly because of erosion near the end of and after Late Cretaceous time. Magothy-Matawan strata are missing in northern and northwestern Queens County and also in the buried valley trending southward from the Flushing Meadow Park area.

The position of the surface of the Magothy-Matawan unit is shown by contours in plate 2D. The intensity of erosion of the unit can be seen from the contour pattern, which shows a well-developed, ancient topographic relief. Magothy-Matawan beds do not crop out in Queens County. The surface of the unit is above sea level only in an area of approximately 4 mi^2 in the northeastern part of the county, in the vicinities of Bellerose, Floral Park, and Douglaston. The highest part of the Magothy-Matawan surface is approximately 50 ft above sea level in Douglaston. Its surface is deepest in the buried valley, from John F. Kennedy International Airport to Belle Harbor, where it is more than 400 ft below sea level. Only the basal Magothy-Matawan beds occur in the unit's northernmost extent in the county, and the thickest section of the unit, at Far Rockaway, is probably only one-third to one-half its original thickness. The greatest known thickness of Magothy-Matawan strata on Long Island, 1,059 ft, was determined by the author in 1975 at a deep observation-well installation at Smith Point, Fire Island, in Suffolk County, 47 mi east of Far Rockaway (well S52162, not shown in this report). In the Fire Island vicinity, the Magothy-Matawan unit is inferred to be unconformably overlain by the Upper Cretaceous Monmouth Group of marine origin (Jensen and Soren, 1974, sheet 1) because some erosion of uppermost Magothy-Matawan beds prior to deposition of the Monmouth seems to have occurred there.

The Magothy-Matawan unit is an important aquifer (Magothy aquifer) in Queens County. Intensive development of the aquifer started in the 1950's. About one-third of the 60 Mgal/d of water that was pumped mostly for public supply in the County in the 1960's came from this unit (Soren, 1971, p. 26). In the mid-1970's, pumpage from all the County's aquifers had risen to 70 Mgal/d (New York State Department of Environmental Conservation, written commun., May 1, 1973, and R. J. O'Reilly, oral commun., Aug. 5, 1975). Although a breakdown of pumpage by aquifer is not available for the years 1972 to 1975, pumpage from the Magothy-Matawan unit is estimated to have increased to more than half of the ground-water pumpage in the County during this period. Individual wells screened in the Magothy-Matawan strata have commonly been pumped at sustained rates of 1,500 gal/min during their developmental stages.

The Magothy-Matawan unit is poorly confined in the northern part of Queens County; in the southern part, where it is overlain by the Gardiners Clay, it is well confined (Soren, 1971, p. 10). In the extreme southern part, at and near The Rockaway Peninsula, water in the unit is salty (Soren, 1971, pl. 1).

Pleistocene Deposits

Pre-Sangamon deposits

Jameco Gravel.--The Jameco Gravel seems to have been deposited by streams in Queens County. The unit is found only in buried valleys, where it unconformably overlies older formations. It is unconformably overlain by the Gardiners Clay, of Sangamon age, except in the Glendale-Woodhaven-Ozone Park areas, where the Gardiners is missing. Here the Jameco is unconformably overlain by upper Pleistocene deposits (pl. 1B, section D-D').

Jameco deposits are the oldest Pleistocene sediments on Long Island. The Jameco is pre-Sangamon; otherwise its age is uncertain. The unit has been believed to be of Kansan or Illinoian ages; however, the most recent estimate of the formation's age is that it is Illinoian (Williams, 1976, p. 22).

Jameco deposits are mostly of coarse sand and granule to cobble gravel; boulders are commonly reported by well drillers. Larger rock fragments are composed mainly of granite, diabase, gneiss, schist, sandstone, and shale; smaller particles contain much of the same rock types and small to significant amounts of quartzose sand. The deposits become finer grained southward; the coarsest materials are in and near the thalweg of the buried valley from the Flushing Meadow Park area southward. Jameco deposits are generally dark brown and dark gray. Thickness of the Jameco ranges from 0 to 250 ft.

The stream that carried the Jameco materials into the County probably originated as melting glacial ice north of the County (deLaguna, in Suter and others, 1949, p. 41). Numerous diabase fragments in the Jameco indicate that the transporting stream had contact with the Palisades, a sill composed predominantly of diabase, at the west side of the Hudson River in New Jersey (fig. 1).

The position of the surface of the Jameco Gravel is shown in plate 2E. The unit occurs only in the central and southern parts of Queens County and in a small area of about 0.25 mi^2 near Maspeth, in western Queens. The formation is not believed by the author to be present in the buried valley from Flushing Meadow Park northward; the northernmost limit of the unit seems to be where the Harbor Hill moraine crosses the valley. Well logs do not show clearly definable Jameco deposits in the northern part of the buried valley, and it is probable that any Jameco deposits there were excavated and redeposited during Wisconsin glaciation. The Harbor Hill glacial advance terminated between sections C-C' and D-D' (pl. 1B), about 1.5 mi north of D-D'. Erosion of Jameco deposits does not seem to be significant in other parts of the county.

Jameco beds do not crop out in Queens County. Altitude of the Jameco surface ranges from approximately 80 ft below sea level in the Glendale and Laurelton areas to more than 200 feet below sea level in the Belle Harbor area of the Rockaway Peninsula.

The Jameco Gravel is a source of water in Queens County (Jameco aquifer). Individual wells screened in the Jameco strata have commonly been pumped at sustained rates of 1,500 gal/min during their developmental stages. In the 1960's, the Jameco was moderately developed for water supply at about 4.5 Mgal/d and about 2.5 Mgal/d in the mid-1970's (New York State Department of Environmental Conservation, written commun., May 1, 1973, and R. J. O'Reilly, oral commun., Aug. 5, 1974).

Water in the Jameco is well confined by the overlying Gardiners Clay, except where the Gardiners is missing in the Glendale-Woodhave-Ozone Park areas of the County (pl. 1B, section D-D'); in these areas water can readily move vertically between the Jameco and overlying glacial sand and gravel of Wisconsin age. Because the Jameco lies in a valley cut into the Magothy Formation-Matawan Group undifferentiated, ground water can readily move laterally between these units. At and near the Rockaway Peninsula, water in the Jameco is salty (Soren, 1971, pl. 1).

Sangamon deposits

Gardiners Clay.--The Gardiners Clay is an interglacial deposit of marine origin and contains fossil foraminifers, pelecypods, and gastropods. The formation unconformably overlies the Jameco Gravel and older formations in different parts of Queens County and is unconformably overlain by upper Pleistocene deposits.

Gardiners strata are mostly clay with some intercalated thin sandy and gravelly beds. The clays in the unit are mostly grayish green and, less commonly, dark gray. (The unit is generally described as "blue clay" by well drillers.) Minerals commonly found in the clays are muscovite, biotite, chlorite, quartz, pyroxene, glauconite, and amphibole; disseminated lignite is common in the unit.

Gardiners Clay beds do not crop out anywhere in the County. The formation is found only in the central and southern parts of Queens, and its surface lies mostly from 50 ft to 200 ft below sea level, descending southward. The position of the Gardiners surface is shown in plate 2F. Thickness of the Gardiners ranges from 0 to 150 ft; thickest deposits are where the unit overlies the Jameco Gravel in the buried valley. The Gardiners is missing in the Glendale-Woodhaven-Ozone Park area. It is not certain whether the formation was not deposited there or was eroded.

The surface of undisturbed Gardiners Clay has not been found higher than 40 ft below sea level anywhere on Long Island, and this altitude is probably at or near the maximum sea level in Sangamon time.

Gardiners Clay deposits have not been positively identified in northern Queens County. It is probable that during Wisconsin glaciation the unit was excavated and redeposited, as seems to have been the case with the underlying Jameco Gravel in the area.

The importance of the Gardiners Clay in Queens County is that it confines water in the underlying Jameco Gravel and Magothy Formation-Matawan Group undifferentiated.

Upper Pleistocene deposits

The name "upper Pleistocene deposits" was used by deLaguna (1948, p. 8 and 16) to include strata of Wisconsin age between the Gardiners Clay and Holocene deposits. Upper Pleistocene deposits range in thickness from 0 to 300 ft and are chiefly composed of glacial-drift material such as till, lacustrine deposits, and outwash sand and gravel. The upper Pleistocene deposits usually contain many unstable individual-mineral grains such as biotite, chlorite, feldspar, and hornblende as well as many compound-mineral grains containing these minerals; coarse-grained deposits and till often contain easily recognizable fragments of igneous, metamorphic, and sedimentary rocks. The deposits also contain fossil plant material, disseminated in coarse-grained deposits and both disseminated and bedded in fine-grained deposits, in stages from fairly fresh in appearance to peat. Upper Pleistocene deposits unconformably overlie the older formations in Queens County. Areal distribution of glacial drift in the county is shown in Fuller (1914, pl. 1) and, in modified form, in Soren (1971, pl. 1).

In the Far Rockaway area, a clay unit of marine origin known as the "20-foot clay" occurs within upper Pleistocene deposits of outwash (Perlmutter and Geraghty, 1963, p. 36-37, and pl. 7, section X-X', also shown in this report in pl. 1B, section B-B'). The 20-foot clay was first described by Perlmutter and others (1959, p. 422) in the southwestern part of Nassau County, adjacent to Queens County, and was named for the fact that it was discovered 20 ft below sea level. The lithology and fauna of the 20-foot clay are similar to those of the Gardiners Clay (Perlmutter and Geraghty, 1963, p. 37); Weiss (1954, p. 143) states that the most abundant species of Foraminifera found in the Gardiners are still living locally and therefore are not restricted to the Pleistocene. Thickness of the 20-foot clay ranges from 0 to 40 ft.

The 20-foot clay is probably an interstadial deposit. Two ice-sheet advances seem to have occurred in late Wisconsin time; their terminal positions on Long Island are marked in Nassau and Suffolk Counties east of Queens County by the Ronkonkoma Terminal Moraine and the younger Harbor Hill Terminal Moraine. Only the Harbor Hill is visible in Queens County. The 20-foot clay probably was deposited during a period of rising sea level between the glacial advances. Glacial deposits below the 20-foot clay were probably deposited by the Ronkonkoma ice-sheet advance and retreat.

From earliest times of development through the 1950's, most pumping in Queens County was from outwash in upper Pleistocene deposits (upper glacial aquifer). By the 1960's, pumpage from this aquifer in Queens County constituted approximately one-half the total and, by the mid-1970's, only about one-third of the total (New York State Department of Environmental Conservation, written commun., May 1, 1973, and R. J. O'Reilly, oral commun., Aug. 5, 1974). Individual wells screened in outwash have commonly been pumped at sustained rates of 1,500 gal/min during their developmental stages.

Water in the upper Pleistocene deposits is mostly unconfined (under water-table conditions); in the northern part of Queens County, however, local confining conditions are created by complex interbedding of layers of sand and gravel and clayey and silty ground moraine (Soren, 1971, p. 8).

Upper Pleistocene deposits are shown but not differentiated in geologic sections A-A' through D-D', except for the 20-foot clay shown in section B-B' (pl. 1B).

Surficial Geology

The surficial glacial deposits in Queens County consist mainly of ground moraine in the northern part and outwash in the southern part. The areas are separated by the Harbor Hill moraine, which traverses the County from Glendale to Floral Park. Holocene surficial deposits consist of shore and salt-marsh deposits in the southern part of the County; artificial fill has been used in many places to extend and reinforce shorelines and to eliminate swampy areas. Surficial geology is described and illustrated in Soren (1971, p. 6-7 and pl. 1). A few small outcrops of preglacial formations occur in the western and north-central parts of the County.

PALEOGEOGRAPHY

Buried Valley of Ancestral Hudson River(?) in Queens County

A major buried valley stream traverses all of Queens County from north to south. The valley was cut through the Cretaceous formations into bedrock as far as the southern end of the Flushing Meadow Park area (pl. 2A-2D). From the park area southward, the valley was cut deeply into the Magothy Formation-Matawan Group undifferentiated to more than 400 ft below sea level (pl. 2D). The valley cutting was done by a stream system that apparently started late in the Late Cretaceous Epoch and probably continued into the Pleistocene Epoch to Jameco time. From Jameco time through the end of Pleistocene time, the valley system was buried by the Jameco Gravel, Gardiners Clay, and upper Pleistocene deposits. Evidence given in the following paragraphs indicates that the ancestral Hudson River(?) flowed through the main channel of this valley system.

Two tributary streams are indicated to have entered the ancestral Hudson course in the College Point vicinity (pl. 2A). One of these streams, probably an ancestral Bronx River, entered between the New York Municipal Airport and College Point; the second stream entered from between College Point and Whitestone. The second stream, which was in alinement with today's Westchester Creek in Bronx County, was probably associated with an ancestral Hutchinson River, also in Bronx County. These tributaries eroded to bedrock (pl. 2A) and left an isolated body of the Raritan Formation between them in the College Point area (pl. 2B, 2C).

The buried valley in Queens County was depicted by Veatch (1906, pl. 6) as having been cut in Tertiary time by a stream named the Sound River, which he showed to flow into Queens from Connecticut. Veatch also indicated that the main feeders into the Sound River were the ancestral Housatonic and Connecticut Rivers, 40 mi and 80 mi east of Queens, respectively. Veatch (1906, pl. 6) depicts the ancestral Hudson River as having flowed across the west end of Kings County, where it joined the Sound River south of Queens County. DeLaguna (1948, p. 14) gives evidence that precludes the

Sound River's having flowed into Queens County; furthermore, no indications of a major eastward drainage in the Long Island Sound area are known. Recent geophysical surveying of the Long Island Sound area (Grim and others, 1970, p. 661) does not indicate a buried channel of the Connecticut streams leading into Queens County, and McMaster and Ashraf (1973a, p. 374) show that ancient, prominent streamflow in the Connecticut River area developed a south, rather than east-trending, pattern and found thalwegs of these valleys cut into coastal-plain deposits to depths between 256 ft and 938 ft below sea level (1973b, p. 374). Major buried south-trending paleodrainage channels in the vicinity of Queens County and in Nassau and Suffolk Counties, east of Queens, are discussed and shown by Williams (1976, p. 39-50). Jensen and Soren (1974, pl. 1) show contours of the buried channels in Suffolk County.

DeLaguna (1948, p. 15) suggests that the diabase fragments in the Jameco deposits in the buried valleys of Queens and Kings Counties came from the nearby Palisades (fig. 1) and (in Suter and others, 1949, p. 42) states the possibility of the Hudson River's deflection across Kings and Queens Counties.

The thalweg of the buried valley in Queens County is as deep or deeper than the known bedrock surface in the Hudson River estuary between New York and New Jersey and between Kings and Richmond Counties, New York (fig. 1); therefore, the most likely explanation for the diabase in the buried valley in Queens is that the ancestral Hudson River(?) flowed through the buried valley. A capture of the Hudson could have been effected through the channel of the Harlem River between New York and Bronx Counties, or the river may have been diverted through the Harlem River's channel by an ice or moraine blockage. The change in course occurred prior to the deposition of the Jameco Gravel and probably during an interval that could range in age from Kansan to Illinoian. Dating of events in the Pleistocene Epoch earlier than the beginning of the Sangamon Interglaciation, about 125,000 years ago, is uncertain (Meyer Rubin, oral commun., July 21, 1976); the only certainty is that the course change occurred more than about 125,000 years ago. Braiding of the river was probably effected by distributaries branching through channels of the East River into Queens and Kings Counties; such a drainage pattern also accounts for the Jameco deposits in buried valleys in Kings County.

Mapping of the Hudson Channel in the continental shelf seaward from New York to the Hudson Canyon in the continental slope by Uchupi (in Schlee, 1973, p. 3-4) shows the north end of the channel curving into alinement with the buried valley in Queens County rather than with the present Hudson estuary (The Narrows) between Kings and Richmond Counties (figs. 1 and 2).

A paleotopographic map of the approximate pre-Jameco surface of Queens County is shown in plate 2G; the map is a composite of plates 2A-2D,

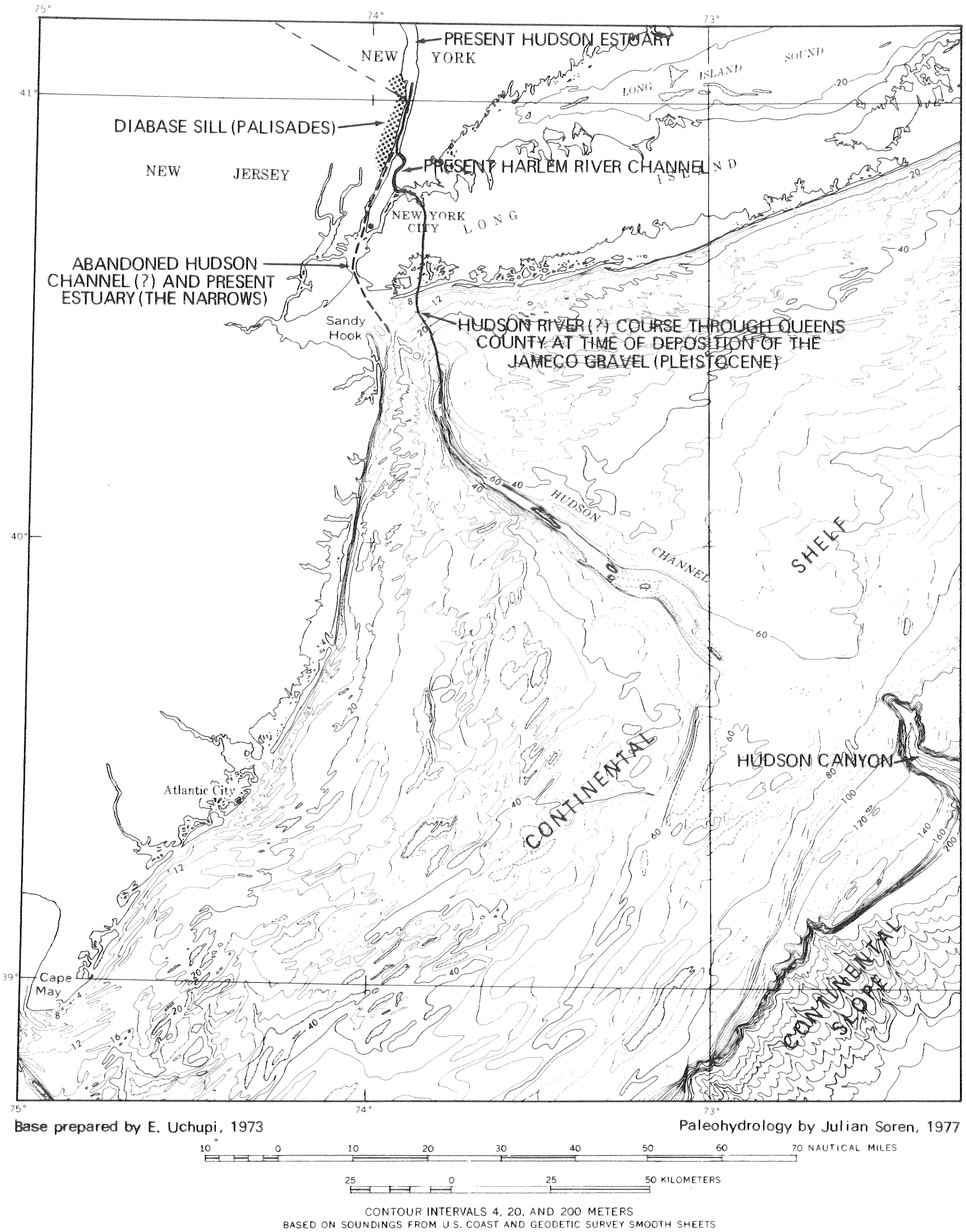


Figure 2.--Hudson River(?) diversion through Queens County and course alinement with Hudson Channel and Canyon in the continental shelf.

inclusive. The pre-Jameco surface in the northern part of the County was altered by erosion during late Wisconsin glaciation. This eroded surface seems to be particularly evident in the Little Neck Bay area, as depicted by the broad valley cut into the Cretaceous deposits (pl. 2G), and in the Flushing Creek area where the Jameco Gravel and Gardiners Clay are absent in the valley cut through the Cretaceous deposits into bedrock (pls. 2E, 2F).

CONTOUR MAPS OF FORMATION SURFACES

Contour lines are drawn on formation surfaces in plate 2A-2G to show the surface positions and configurations. On uneroded formation tops, the lines show structure contours; on eroded former land surfaces, they are paleotopographic contours. For example, a contour line on the clay member of the Raritan Formation where it is covered by the Magothy Formation-Matawan Group undifferentiated is a structure contour. Where such a contour runs into a buried valley, it ceases to be structure contour; it makes a sharp, angular bend "upstream" and becomes a topographic contour traversing the valley wall to reach the bottom of the unit and continues onto the eroded surface of the underlying unit.

Contour lines on the bedrock and Magothy-Matawan surfaces (pl. 2A and 2D) depict former topography. Contours on the surfaces of the Lloyd and clay members (pl. 2B, 2C) are structure contours where the units are uneroded, but show former topographic contours where the units were eroded in a buried valley. The contours on the Jameco and Gardiners surfaces (pl. 2E, 2F) are most likely structural and topographic, but data on the histories of these units are insufficient to permit precise distinctions. However, where the units' surfaces are fairly even, the contours are probably structural. All the contours shown in plate 2G are paleotopographic contours.

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