DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
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NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION
WATER-RESOURCES INVESTIGATIONS REPORT 87-4159
PLATE 2--SURFICIAL GEOLOGY AND GEOLOGY AND GEOLOGIC SECTIONS

Late Glacial History of the Lower Hudson River Valley

The glacial deposits in the Croton-Ossining area are a product of the deglaciation process in the Lower Hudson valley. As the front of the Wisconsin ice sheet receded northward from the region, a large lake (glacial Lake Hudson) formed and extended southward from the retreating ice front in the Hudson River gorge to a dam formed by the Harbor Hill terminal moraine at the Narrows, approximately 40 miles south of Croton Point, (Neuman and others, 1969). The ice front retreated northward from its terminal position at the Narrows (and Long Island) to a point now marked by the Wallkill moraine, approximately 35 miles northwest of Croton Point, between 17,000 and 15,000 years B.P. (before present) (Weiss, 1974). Thus, by 15,000 years B.P., glacial Lake Hudson occupied the lower Hudson valley and was receiving sediment-charged glacial meltwater from tributary streams.

This lake occupied the lower Hudson valley until about 12,000 B.P., when a change to modern-day estuarine conditions began (Neuman and others, 1969). Tributary streams deposited the coarser fraction of their sediment loads (sand and gravel) as deltas, which then prograded out into the lake. The finer fraction of the sediment load (silt and clay) was carried out into the deeper water of Lake Hudson and settled out to become varved lake-bottom sediment. Cores from test borings in the Hudson River between Croton Point and Tarrytown (Weiss, 1974, p. 1564) show varved lacustrine silt and clay deposits (rhythmites) extending from 50 feet to as deep as 160 feet below present sea level. These varved silts and clays are lakebottom deposits of glacial Lake Hudson; in some areas they overlie an unknown thickness of Pleistocene sand and gravel.

In most reaches of the Hudson, the lacustrine silt and clay is overlain by a variable thickness of Holocene organic-rich silt up to 200 feet thick. This silt has been accumulating since Lake Hudson drained and estuarine conditions began. Interposed between the lake silt and clay and the Holocene organic silt in some areas are sand and gravel deposits. Neuman and others (1969) postulate that these fluvial deposits may represent the drainage episode of Lake Hudson and Lake Albany, which was possibly caused by the draining of Lake Iroquois in the Mohawk Valley.

During its retreat northward, the Hudson River ice tongue stopped temporarily in places, where it left a series of end and lateral moraines. Woodworth (1905, p. 103) discovered thick deposits of bouldery till that he considered to be an end moraine on the western edge of Croton Point; from this evidence he postulated a temporary ice-front position in the Hudson valley that he termed the Croton-Haverstraw stage. Later workers (Kindle, 1949; Markl, 1971) discovered that, at the outer edge of Croton Point, these end-moraine deposits were overlain by silt, clay, and fine sand, which suggests that the moraine became submerged by glacial Lake Hudson as the ice front retreated northward from this point. More recently, Markl (1971) postulated that this may actually be a lateral moraine and may be contemporaneous with another lateral moraine at Haverstraw, directly across the river.

Croton River Delta

The fine sand, silt, and clay that overlies the moraine at Croton Point's outer edge is part of the delta produced by the Croton River as it flowed into glacial Lake Hudson. Most of Croton Point consists of these deltaic deposits, which are typically coarse grained close to the mouth of the Croton River and fine grained farther out in the delta. As in a classic prograding deltaic sequence, the sediments on Croton Point also show a "fining-down" sequence of deposition (section C-C') where the uppermost deltaic deposits consist of medium to fine sand and grade into silt and clay at depth. Remnants of the Croton River delta are emplaced along the eastern bank of the Hudson River from Croton-on-Hudson to Ossining and also on Croton Point. This delta was deposited in a lake whose level ranged from at least 25 feet to as much as 100 feet above present-day sea level (Woodworth, 1905; Markl, 1971). With the ultimate breaching of the lake dam at the Narrows, the lake level dropped, causing a renewal of the drainage from the Croton River valley. This increased drainage caused dissection and channel erosion in the Croton Point delta (the area now occupied by a landfill) and the deposition of a layer of coarse gravel over the deltaic sand on Croton Point (Markl, 1971). Markl (1971) suggests that meltwater flowing through other drainage channels, notably the bedrock valley along Rt. 129 at Croton-on-Hudson, may have contributed to the formation of the part of the Croton River delta that is north of the present Croton River.

Bedrock Channels

Several buried bedrock channels that represent preglacial stream drainage traverse the area. Most of these channels have some surface expression and roughly coincide with present-day streams. They generally follow one or more bands of easily erodible Inwood Marble (pl. 3) or major fracture zones. These preglacial channels are filled with either sand and gravel or till or a combination of the two. Most of Markl's (1971) postulated auxiliary "Croton Delta" buried drainage channel, which would parallel Rt. 129 at Croton-on-Hudson, is in an area underlain by a wide band of Inwood Marble, which lends some credibility to the channel's existence. If present, this channel may be filled with sand and gravel.

The Furnace Brook stream valley between Oscawana and Woodybrook may contain significant quantities of saturated sand and gravel and probably is underlain by a preglacial bedrock drainage channel. This valley also is underlain by a band of Inwood Marble that is separated from the adjoining Fordham Gneiss by a reverse fault. Well 02-28 at Woodybrook (pl. 1), which is 8 inches in diameter and 100 feet deep, is finished in sand and gravel and produces 60 gal/min from more than 95 feet of saturated aquifer material.

Another preglacial channel, which runs from Crotonville to just south of Teatown Lake, may coincide with the narrow belt of Inwood Marble that runs northeast-southwest across the mapped area. This narrow valley is probably less than 50 feet deep, however, and is probably filled with till rather than sand and gravel.

Another bedrock channel may lie between Gannungs Hill and Catamount Hill, in the central part of the area. Two wells in this vicinity, 04-33 and 47-35, penetrate 118 and 104 feet of till, respectively. These two wells may mark the thalweg of a drainage channel that connects two parallel bands of Inwood Marble. The inferred thalwegs of these bedrock channels are indicated.

Croton River Aquifer

Outwash sand and gravel that was deposited in the Croton River valley during and after deposition of the Croton delta forms a small but productive aquifer. The aquifer extends approximately 3 miles from the base of New Croton Dam to the Hudson River and ranges in width from 100 to 1,500 feet. The lower third of the reach is tidal, however, and probably brackish; thus, wells installed near the head of tidewater may risk pumping brackish water through induced infiltration of saline surface water.

The bedrock valley below New Croton Dam is roughly U-shaped but has a narrow, deeply incised V-notch valley within it (section A-A'). Test borings drilled before construction of the dam show that the original bedrock surface at the dam is about 20 feet below sea level (section B-B'), whereas borings at a proposed site farther downstream near Quaker Bridge (section A-A') show the bedrock to be incised to 50 feet below sea level.

The stratified drift within the Croton valley generally consists of an upper zone of clean sand and gravel underlain by alternating beds of silt, sand and gravel, and silty sand and gravel. These, in turn, are underlain by another silty sand and gravel unit of variable thickness.

Test drilling in the vicinity of the Croton-on-Hudson supply wells near Quaker Bridge (Leggette and Jacob, 1938) shows that the valley fill there can be considered as two sand and gravel aquifers separated by a confining unit. The upper (water-table) aquifer consists of about 35 feet of saturated sand and gravel; the confining unit is composed of 8 to 10 feet of silt, and the confined aquifer consists of variably silty sand and gravel up to 40 feet thick. Section A-A' shows the stratigraphic relationship of these units.

Laboratory determinations of aquifer permeability and pumping tests by Leggette and Jacob (1938) indicated the average horizontal hydraulic conductivity of the upper (water-table) aquifer in the vicinity of the Croton-on-Hudson supply wells (section A-A' and inset map on pl. 1) to be 475 ft/d (feet per day) and that of the lower (confined) aquifer to be about 300 ft/d. These values are typical for valley outwash elsewhere in the glaciated northeast.

Recharge

The Croton Valley aquifer downstream of New Croton Dam is recharged primarily by direct precipitation, runoff from adjacent hillsides, and leakage under or through New Croton Dam. Leggette and Jacob (1938) estimated the average daily leakage through or under the dam to be about 0.65 Mgal/d (million gallons per day) and direct precipitation and runoff from adjacent hillsides to contribute an average of 1.08 Mgal/d. Thus, the total average daily recharge to the aquifer between New Croton Dam and Quaker Bridge is about 1.73 Mgal/d except during periods when the dam is overflowing. These recharge estimates are still considered valid because the direct drainage area to the Croton River has undergone little development since 1936.

Discharge

Water is discharged from the Croton Valley aquifer as groundwater pumpage (essentially by Croton-on-Hudson wells), ground-water underflow through the upper and lower aquifers, as streamflow, and through groundwater evapotranspiration. Leggette and Jacob (1938) estimated that the average ground-water underflow past the Quaker Bridge site (section A-A') was 90,000 gal/d in the surficial aquifer and 130,000 gal/d in the lower, confined aquifer. The average daily discharge of the Croton River at Quaker Bridge downstream from the Croton-on-Hudson well field during a 3-month period ending September 30, 1936, was 720,000 gal/d, and the average daily pumpage from Croton's public-supply wells was 790,000 gal/d. Ground-water evapotranspiration was not considered in that study but is probably small in comparison to the other discharges. Thus, the estimated average daily discharge in 1936 from the aquifer section studied was 1,730,000 gal/d.

Induced Infiltration

Leggette and Jacob (1938) concluded that virtually all water withdrawn by the Croton-on-Hudson supply wells comes from induced infiltration of surface water and by capture of ground water that would otherwise provide base flow to the river. They estimated that, if the Croton wells were not pumping, the increase in base flow between gaging stations at New Croton Dam and Quaker Bridge would be between 750,000 and 900,000 gal/d. Therefore, the Croton supply wells are essentially intercepting the increase in base flow that takes place in the reach upstream of the well field, and this water is being pumped, via induced infiltration, through the streambed in the immediate vicinity of the well field. The cone of depression produced by the Croton well field causes the water table in the vicinity of the well field to be below the river level virtually all the time, so that induced infiltration from the river is continuous (Leggette and Jacob, 1938). Leggette and Jacob further concluded that little, if any, ground water was being removed from storage (at 1936 pumping rates) and that the underflow through the valley fill was virtually unaffected. Because the average daily pumping rate has increased by 35 percent to 1,220,000 gal/d since 1936 (New York State Department of Health, written commun., 1984), either greater induced infiltration, a reduction in ground-water storage, or a combination of the two can be expected to make up for this pumpage increase.

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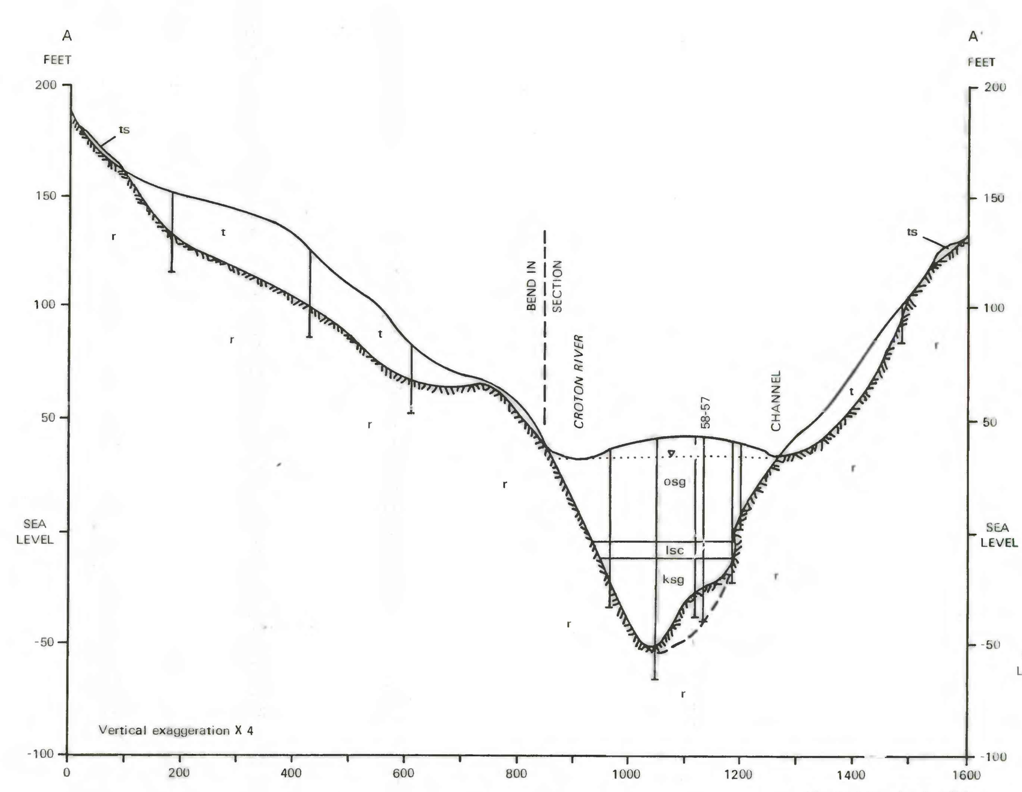

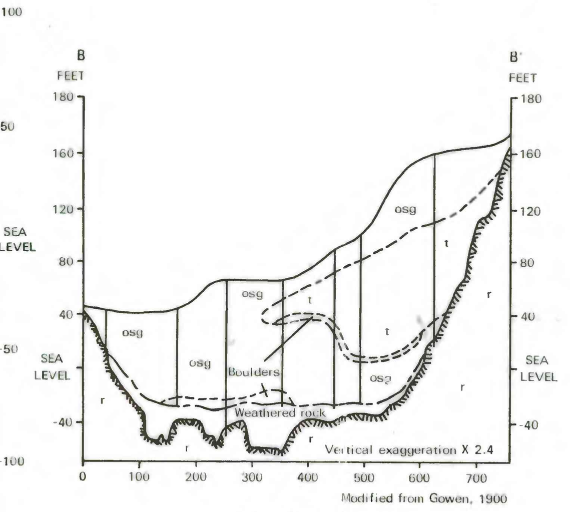

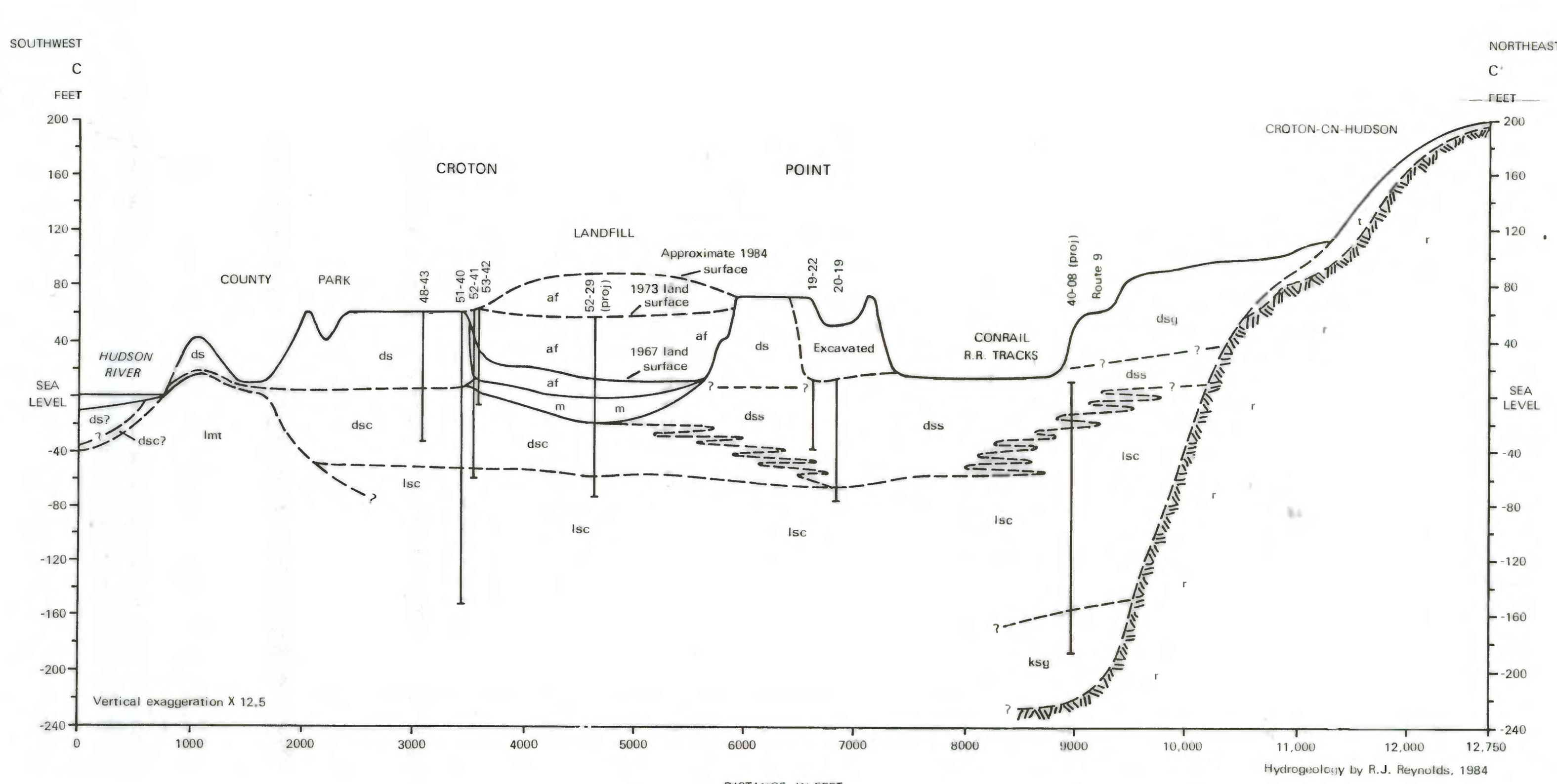

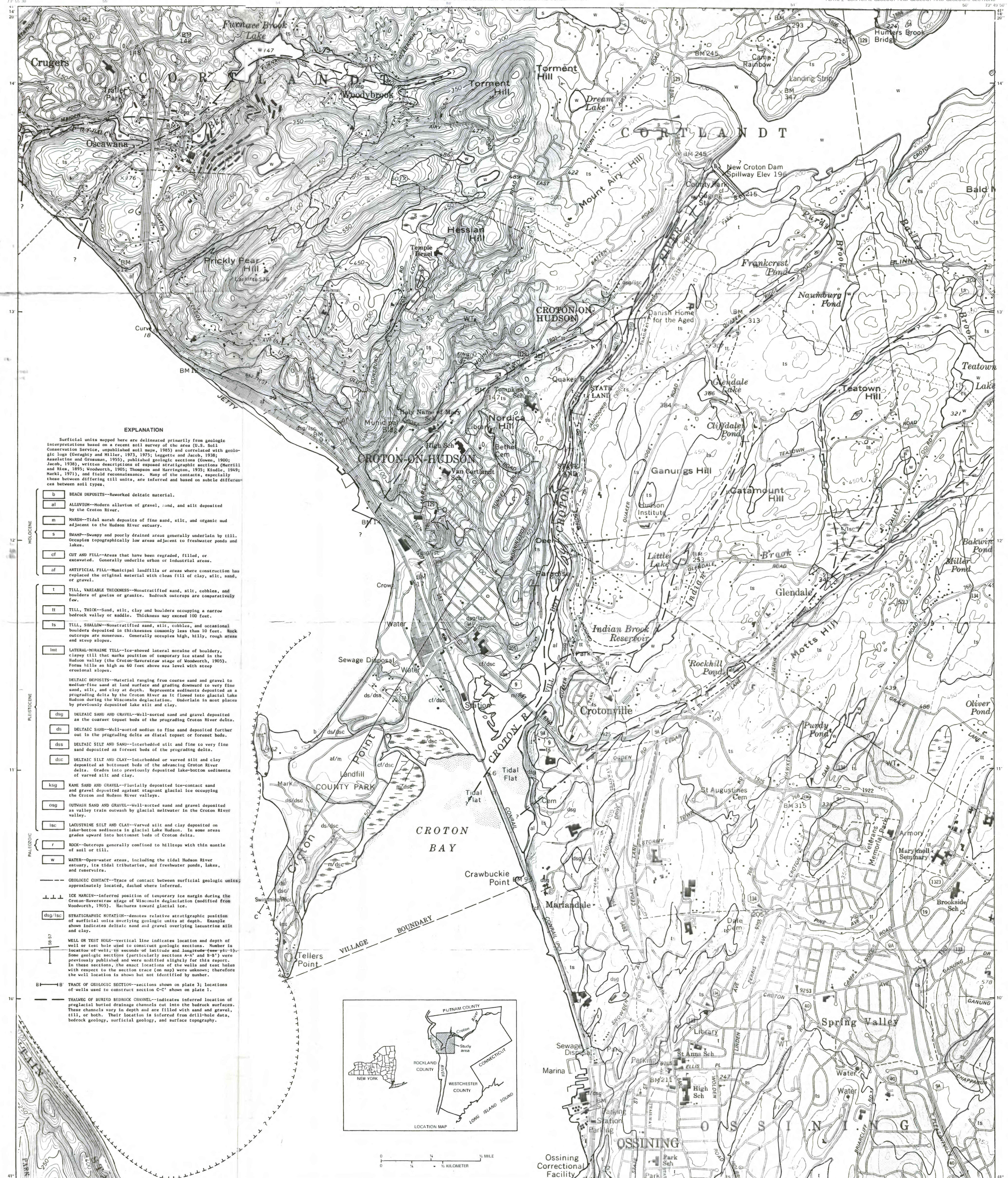

EXPLANATION

Surficial units mapped here are delineated primarily from geologic interpretations based on a recent soil survey of the area (U.S. Soil Conservation Service, unpublished soil maps, 1985) and correlated with geologic logs (Geraghty and Miller, 1973, 1975; Leggette and Jacob, 1938; Asselstine and Grossman, 1955), published geologic sections (Gowen, 1900; Jacob, 1938), written descriptions of exposed stratigraphic sections (Merrill and Ries, 1895; Woodworth, 1905; Thompson and Harrington, 1935; Kindle, 1949; Markl, 1971), and field reconnaissance. Many of the contacts, especially those between differing till units, are inferred and based on subtle differences between soil types.

HOLOCENE

b — BEACH DEPOSITS--Reworked deltaic material.

al — ALLUVIUM--Modern alluvium of gravel, sand, and silt deposited by the Croton River.

m — MARSH--Tidal marsh deposits of fine sand, silt, and organic mud adjacent to the Hudson River estuary.

s — SWAMP--Swampy and poorly drained areas generally underlain by till. Occupies topographically low areas adjacent to freshwater ponds and lakes.

cf — CUT AND FILL--Areas that have been regraded, filled, or excavated. Generally underlie urban or industrial areas.

af — ARTIFICIAL FILL--Municipal landfills or areas where construction has replaced the original material with clean fill of clay, silt, sand, or gravel.

PLEISTOCENE

t — TILL, VARIABLE THICKNESS--Nonstratified sand, silt, cobbles, and boulders of gneiss or granite. Bedrock outcrops are comparatively few.

tt — TILL, THICK--Sand, silt, clay and boulders occupying a narrow bedrock valley or saddle. Thickness may exceed 100 feet.

ts — TILL, SHALLOW--Nonstratified sand, silt, cobbles, and occasional boulders deposited in thicknesses commonly less than 10 feet. Rock outcrops are numerous. Generally occupies high, hilly, rough areas and steep slopes.

lmt — LATERAL-MORAINE TILL--Ice-shoved lateral moraine of bouldery, clayey till that marks position of temporary ice stand in the Hudson valley (the Croton-Haverstraw stage of Woodworth, 1905). Forms hills as high as 60 feet above sea level with steep erosional slopes.

DELTAIC DEPOSITS--Material ranging from coarse sand and gravel to medium-fine sand at land surface and grading downward to very fine sand, silt, and clay at depth. Represents sediments deposited as a prograding delta by the Croton River as it flowed into glacial Lake Hudson during the Wisconsin deglaciation. Underlain in most places by previously deposited lake silt and clay.

dsg — DELTAIC SAND AND GRAVEL--Well-sorted sand and gravel deposited as the coarser topset beds of the prograding Croton River delta.

ds — DELTAIC SAND--Well-sorted medium to fine sand deposited further out in the prograding delta as distal topset or foreset beds.

dss — DELTAIC SILT AND SAND--Interbedded silt and fine to very fine sand deposited as foreset beds of the prograding delta.

dsc — DELTAIC SILT AND CLAY--Interbedded or varved silt and clay deposited as bottomset beds of the advancing Croton River delta. Grades into previously deposited lake-bottom sediments of varved silt and clay.

ksg — KAME SAND AND GRAVEL--Fluvially deposited ice-contact sand and gravel deposited against stagnant glacial ice occupying the Croton and Hudson River valleys.

osg — OUTWASH SAND AND GRAVEL--Well-sorted sand and gravel deposited as valley train outwash by glacial meltwater in the Croton River valley.

lsc — LACUSTRINE SILT AND CLAY--Varved silt and clay deposited on lake-bottom sediments in glacial Lake Hudson. In some areas grades upward into bottomset beds of Croton delta.

PALEOZOIC

r — ROCK--Outcrops generally confined to hilltops with thin mantle of soil or till.

w — WATER--Open-water areas, including the tidal Hudson River estuary, its tidal tributaries, and freshwater ponds, lakes, and reservoirs.

GEOLOGIC CONTACT--Trace of contact between surficial geologic units; approximately located, dashed where inferred.

ICE MARGIN--Inferred position of temporary ice margin during the Croton-Haverstraw stage of Wisconsin deglaciation (modified from Woodworth, 1905). Hachures toward glacial ice.

dsg/lsc — STRATIGRAPHIC NOTATION--denotes relative stratigraphic position of surficial units overlying geologic units at depth. Example shown indicates deltaic sand and gravel overlying lacustrine silt and clay.

58-57 — WELL OR TEST HOLE--vertical line indicates location and depth of well or test hole used to construct geologic sections. Number is location of well, in seconds of latitude and longitude (see pl. 1). Some geologic sections (particularly sections A-A' and B-B') were previously published and were modified slightly for this report. In these sections, the exact locations of the wells and test holes with respect to the section trace (on map) were unknown; therefore the well location is shown but not identified by number.

B—B' — TRACE OF GEOLOGIC SECTION--sections shown on plate 3; locations of wells used to construct section C-C' shown on plate 1.

THALWEG OF BURIED BEDROCK CHANNEL--indicates inferred location of preglacial buried drainage channels cut into the bedrock surfaces. These channels vary in depth and are filled with sand and gravel, till, or both. Their location is inferred from drill-hole data, bedrock geology, surficial geology, and surface topography.

HYDROGEOLOGY OF THE CROTON-OSSINING AREA, WESTCHESTER COUNTY, NEW YORK

By
Richard J. Reynolds
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Plate 2. Surficial Geology and Geologic Sections