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EVIDENCE FOR PRE-WOODFORDIAN AGES OF LONG ISLAND'S TERMINAL MORAINES

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INTRODUCTION

Long Island's prominent terminal moraines (Figure 1), the southern and older Ronkonkoma, and the northern and younger Harbor Hill, are considered to have been deposited by the fluctuating margin of one and the same glacier, the latest Wisconsinan glacier, the Woodfordian (Table 1). A further corollary commonly attached to this age assignment is that the volume of the Woodfordian glacier exceeded that of any older glaciers. And, applying the principle that the larger the volume of ice, the colder the climate, the Woodfordian episode is ranked as the coldest of the glacial stages.

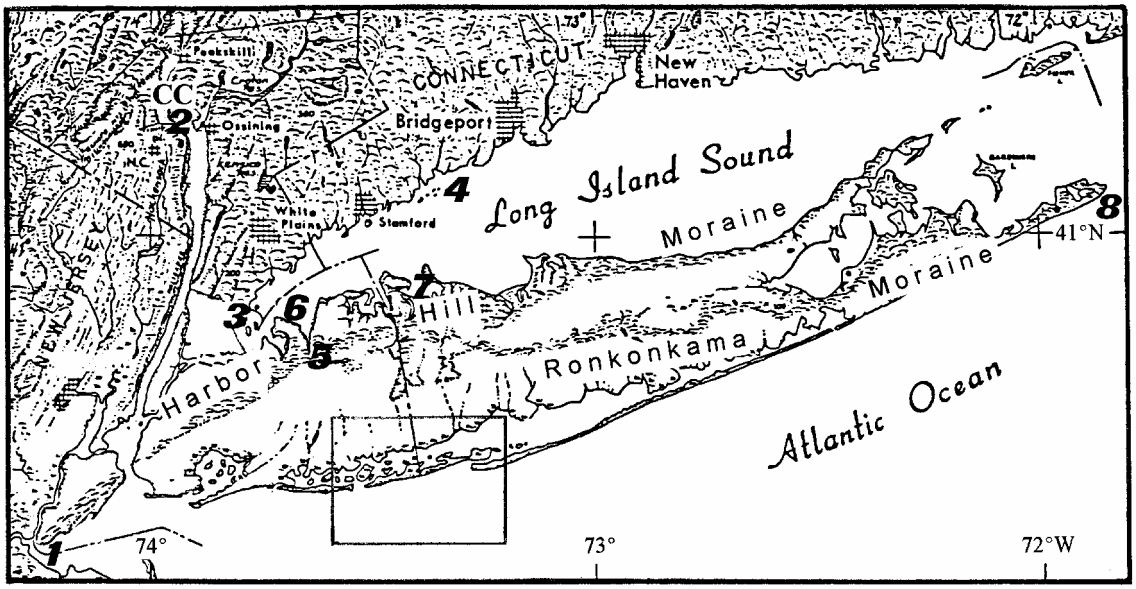

Figure 1 - Map of Long Island and vicinity showing Harbor Hill Moraine, Ronkonkama Moraine, and places mentioned in text. CC (S of Peekskill in upper left), Cortlandt Complex of coarse ultramafic rocks; 1, eroding cliff on shores of Princes Bay, Staten Island; 2, Croton Point; 3, Twin Islands, Pelham Bay Park; 4, Norwalk Islands; 5, Harbor Hill; 6, Sands Point; 7, Target Rock; 8, Montauk Point. Rectangle locates boring-index map, Figure 6a. (Modified from J. A. Bier, 1964.)

Stage	Fuller, 1914	Fleming, 1935	MacClintock and Richards, 1936
Wisconsin		Harbor Hill Moraine Ronkonkoma Moraine	Harbor Hill Moraine Ronkonkoma Moraine
		Hempstead Gravel	Manhasset Formation
		Montauk Till	
	Harbor Hill Moraine Ronkonkoma Moraine	Herod Gravel	
Sangamon	Vineyard erosion surface		Jacob Sand Gardiners Clay
Illinoian	Hempstead Gravel Montauk Till Herod Gravel } Manhasset Fm.		
Yarmouth	Jacob Sand Gardiners Clay	Jacob Sand Gardiners Clay	Gardiners Clay (in part)
Kansan	Jameco Gravel		
Pre-Kansan	Manetto Gravel		

Table 1 - Classification of Pleistocene formations of Long Island according to Fuller (1914); Fleming (1935); and MacClintock and Richards (1936). Woodfordian, the youngest subdivision of the Wisconsinan Stage, not shown. (Modified from S. W. Muller, 1965, table 2, p. 104.)

On the basis of new stratigraphic evidence uncovered in the north-shore cliffs by the coastal storm of December 1992, on our investigations of flow-directional features eroded by glaciers on bedrock surfaces and of provenance of the tills, and of directional interpretation of ice-thrust features on Staten Island, we challenge not only the Woodfordian age assignment but also the concept that these moraines were deposited by the fluctuating margin of a single glacier. In this paper, we review previous ideas about these two moraines and present the bases for our proposed new age assignments.

REGIONAL GEOLOGIC SETTING

The Harbor Hill Moraine is a prominent feature of the landscape of New York City and Long Island. (See Figure 1.) According to most classifications of the Quaternary deposits of the New York City region, not only the Harbor Hill Moraine but also the closely associated, but older, Ronkonkama Moraine, are assigned to the most-recent, Woodfordian, glacial episode. (See Table 1.)

PREVIOUS WORK

Not all geologists have classied these two famous moraines as Woodfordian. The first geologist who studied these moraines, Warren Upham (1879), inferred that they had been deposited by two different glaciers (from the "First" and "Second" glacial epochs). Based on the general uniformity of the state of stream dissection of the outwash plains lying south of each moraine, T. C. Chamberlin (1883) made a persuasive case for concluding that these two moraines had been deposited by the same glacier. Chamberlin argued that if each moraine and outwash plain had been deposited by a different glacier, then the older, southern deposits left by the first glacier would have been notably dissected by streams during the interglacial interval prior to the advance of the second glacier. Most geologists have accepted Chamberlin's same-glacier interpretation. Fuller (1914), correctly we think, assigned the Long Island terminal moraines to the Early Wisconsinan. (See Table 1.) Ever since the mid-1930's, however, these moraines have been assigned to the latest Wisconsinan (W. L. S. Fleming 1935; MacClintock and Richards 1936 and others).

Sirkin (1968, Table 1, p. 234) initially assigned the two moraines to a pre-Cary Wisconsinan age. At Harbor Hill, Roslyn, "...the type locality of the Harbor Hill Moraine and the Harbor Hill Till..." the till/outwash contact is visible (p. 250). The long axes of pebbles from the Harbor Hill till at Alley Pond Borrow Pit "point generally NNW" (p. 248). At the intersection of Lakeville Road and the Northern State Parkway, Sirkin found "about 5 feet of Harbor Hill till overlying 20 + feet of stratified lacustrine sands with thin clay partings (Plate 1, figures 2, 3, and 4)" (p. 249). Subsequently, Sirkin proposed the term Roslyn Till for the "Harbor Hill Till" at Harbor Hill, Roslyn.

At the intersection of Roslyn Road and the Northern State Parkway: "Another cut into the Ronkonkama Moraine, on the northeast side of the road, has exposed the lower till (cf. the Montauk Till). Approximately 10 to 15 feet of till are overlain by 25 to 30 feet of coarse cobbly, outwash (or Kame) deposits (Plate 2, figures 1 and 2)" (p. 249).

Fuller (1914) placed the Montauk Till in the Manhasset Formation (with Herod Gravel below and Hempstead Gravel, above). Sirkin rejected all this; he claims that the Hempstead Gravel is Woodfordian outwash (Sirkin and Mills, 1975; Sirkin and Stuckenrath, 1980).

From our studies of the Pleistocene deposits and of glacially sculpted features on bedrock surfaces in New York City and vicinity (Merguerian and Sanders 1990, 1991, 1992, 1994; Sanders and Merguerian, 1991a, 1992, 1994b), we re-emphasize the significance of Woodworth's generally neglected evidence that the reddish-brown materials forming the Harbor Hill Moraine in Queens were deposited by a glacier that flowed across the Newark basin and across the Hudson River on a path from the NNW to the SSE (Figure 2). Moreover, Woodworth found that these reddish-brown glacial sediments were overlain by non-reddish till. (A till younger than that forming the Harbor Hill Moraine has been reported by Walter Newman 1975; 1977; and Newman and Pike 1975. We do not know what, if any relationship exists between the post-Harbor-Hill till mentioned by Newman and Newman and Pike and Woodworth's non-reddish till.). Other examples of reddish-brown till resting on a glaciated bedrock surface with

striae oriented NNW-SSE, as near Long Island City, Queens, described by Woodworth (1901), are present at South Twin Island, Orchard Beach, Pelham Bay Park, The Bronx (Figure 3).

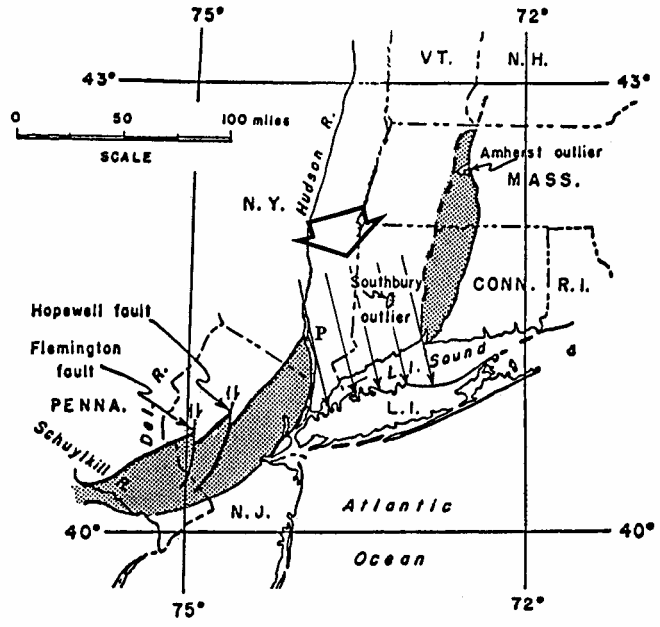

Figure 2 - Regional map of part of northeastern United States showing locations of preserved filling strata of Newark Basin (NJ and PA) and of Hartford Basin (CT and MA) (light gray tone). Parallel line segments in between show how glacial ice flowing from NNW to SSE across the "crystalline corridor" between these two basins would not deposit reddish-brown Newark-type erratics throughout a substantial stretch of the N shore of L.I. but would deposit reddish-brown erratics in extreme W and extreme E L.I.

Striae oriented NNW-SSE are parallel to the predominant direction of "diluvial scratches and furrows" found by L. D. Gale (1828; in Mather 1843) in Manhattan and by J. G. Percival (1842) in Connecticut. This direction of NNW-SSE is the same as the inferred flow direction of the Lake Chamberlain Till in south-central Connecticut (Flint 1961). The Lake Chamberlain Till underlies the Hamden Till, which was deposited by a glacier that flowed from NNE to SSW.

Additional evidence that the glacier responsible for the Harbor Hill Moraine flowed from NW to SE is found in the orientation of a well-exposed glacial-tectonic recumbent fold in the shore cliffs at Princes Bay, Staten Island (Sanders, Merguerian, and Okulewicz, 1995a, b). We regard this new evidence that the Harbor Hill Moraine was deposited by glacial ice flowing from NNW to SSE as a further compelling argument that this moraine was not deposited by the Woodfordian glacier, whose direction of flow was from NNE to SSW.

Figure 3 - View of striated bedrock overlain by reddish-brown till (black, beneath sod), South Twin Island, Pelham Bay Park, The Bronx. Handle of trenching tool is aligned N-S with blade on N end. Striae oriented NNW-SSE. (J. E. Sanders.)

DISCUSSION

One of our most-significant conclusions from our studies of features eroded on the bedrock in The Bronx and Westchester counties and vicinity and of the provenance of the associated till is that the ice sheet responsible for the Harbor Hill moraine flowed regionally from NNW to SSE, across the lower Hudson Valley (Fig. 4). This conclusion supports the results obtained by J. B. Woodworth (1901) in Queens and adjacent western Nassau County. Our results in the New York City region match those published from studies in the Boston area and in southeastern Massachusetts by the late C. A. Kaye, of the U. S. Geological Survey (Kaye, 1964a, b, c; 1982), who argued for Illinoisan and early Wisconsinan ages of the moraines on Martha's Vineyard, Massachusetts.

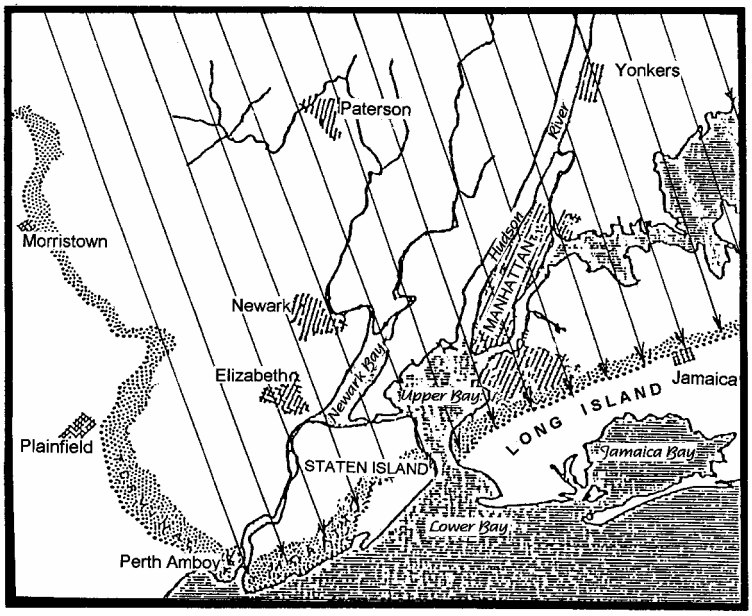

Figure 4 - Map of Metropolitan New York showing parallel flow lines trending NNW-SSE in glacier that deposited the Harbor Hill Moraine. (Based on Salisbury map, Fig. 7 of companion paper, this volume.)

For what it may be worth, here are some of the implications of our particular bias that the Pleistocene deposits in the New York City region were deposited by glaciers following the principle of one glacier, one flow direction.

(1) The youngest glacier (presumably the Woodfordian) flowed from NNE to SSW. This glacier did not spread so far south as some of its predecessors (Fig. 5). In fact, this glacier did not reach most of Long Island (but did cross parts of northern- and western Queens (Newman and Pike, 1975), Brooklyn, and Staten Island). This glacier spread large indicator boulders from the Cortlandt Complex near Peekskill to Croton Point, Westchester County. Part of the terminal moraine deposited by this glacier lies beneath western Long Island Sound, following the isobaths marked by Execution Rocks and Hen and Chick Shoals (Newman and Pike, 1975) and reappears along the S coast of Connecticut from Captain Islands and the Norwalk Islands eastward (Ellis, 1962; Newman and Pike, 1975; Flint and Gebert, 1974, 1976).

(2) A pre-Woodfordian glacier (exact age not known) crossed the region from NNW to SSE. (See Figure 4.) This glacier transported indicator stones from the Newark Basin and points to the NW into areas lying E of the Hudson River. The till deposited by this glacier, which includes that forming the Harbor Hill Moraine, undergoes a dramatic facies change controlled by the "crystalline corridor" in the bedrock that exists between NE end of the reddish-brown rocks filling the Newark Basin to the SW and the S end of the Hartford Basin to the E (Sanders and Merguerian, 1991b; 1994b). We have not found the exact line of separation along

the north shore of Long Island where the color of the till deposited by this glacier changes from reddish brown (downflow from the Newark Basin) to gray or even yellowish brown (downflow from the "crystalline corridor"). We have so far determined only that this line of separation lies between Sands Point and Target Rock. At Sands Point, a reddish-brown till fills valleys cut into the deltaic sands underlying the coastal cliffs (Sanders, Merguerian and Mills, 1993). At Target Rock, the youngest till present is gray and contains erratics derived from the NNW, including Inwood Marble and Cortlandt-Complex ultramafic igneous rocks (Sanders and Merguerian, 1991b; 1994b). The absence of reddish-brown till in the segment of Long Island lying SSW of the S end of the Hartford Basin strongly supports our interpretation that the Woodfordian glacier, which flowed from NNE to SSW, did not reach much of Long Island.

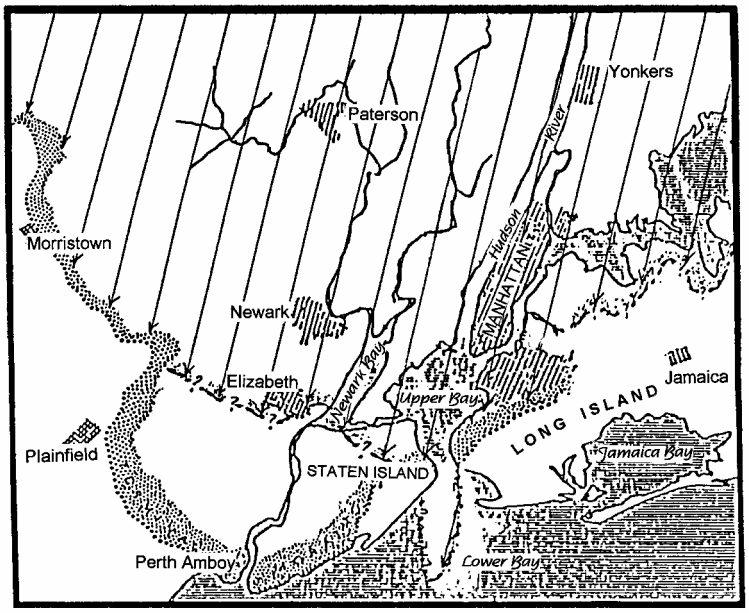

Figure 5 - Map of Metropolitan New York showing parallel flow lines trending NNE-SSW in Woodfordian glacier that for the most part did not reach to the Harbor Hill Moraine except in The Narrows, where it sent a tongue of ice out into the Lower Bay. (Based on Salisbury map, Fig. 7 of companion paper, this volume.)

(3) The flow pattern of the glacier responsible for the Ronkonkoma Moraine matched that of the glacier responsible for the Harbor Hill Moraine. If the correlations that have been made between the inferred outwash sediments in the subsurface near Jones Beach (Rampino, 1978 ms.; Rampino and Sanders, 1981b) and the two Long Island moraines are correct, then these two moraines could not have been deposited by the fluctuating margin of the same glacier. This statement is based on the subsurface relationships whereby conditions between deposition of the lower inferred outwash (Merrick Formation; correlated with the Ronkonkama Moraine) and the upper inferred outwash (Bellemore Formation; correlated with the Harbor Hill Moraine) were sufficiently "interglacial" to enable the marginal-marine Wantagh Formation to be deposited between these two inferred outwash formations (Figure 6).

(4) The extensive lake deposits including the Gilbert-type deltas, which underlie much of Long Island's north-shore cliffs (Sanders, Merguerian, and Mills, 1993) and also are present in the eroding coastal cliffs at Montauk Point, imply a large lake whose waters were held in on the south by a now-eroded terminal-moraine dam older than the Ronkonkama Moraine (Sanders and Merguerian 1994a, b). The glacier which deposited this pre-Ronkonkama Terminal Moraine was areally the most-extensive of the Quaternary ice sheets.

CONCLUSIONS

Many features made by the Pleistocene ice sheets that invaded the New York City region imply that two distinct flow patterns prevailed: (1) NNW to SSE and (2) NNW to SSE. Ice-flow features having these orientations have been observed for more than 150 years. They include features eroded on the bedrock (striae and grooves, crescentic marks, roches moutonn,es, roche-moutonn,e structures, and rock drumlins) and flow-directional characteristics of glacial sediments (orientations of long axes of drumlins and of axes of ice-push folds and provenance of till). The youngest glacier to reach the New York Metropolitan area flowed from NNE to SSW. Although this ice sheet crossed parts of northern- and western Queens, parts of Brooklyn, and Staten Island, its most-prominent terminal moraine was deposited along the S coast of Connecticut.

The glacier responsible for depositing the Harbor Hill Moraine flowed regionally on a rectilinear path from NNW to SSE. This flow direction was established by J. B. Woodworth (1901) in Long Island City, Queens, and is reinforced by abundant evidence (Sanders and Merguerian, 1991a, b; 1992; 1994b).

The glacier responsible for depositing the Ronkonkoma Moraine flowed regionally on a rectilinear path from NNW to SSE, the same pattern followed by the ice sheet that deposited the Harbor Hill Moraine. Evidence from the shallow subsurface near Jones Beach supports the view that two units of inferred outwash (a lower one correlated with the Ronkonkama Moraine and an upper one correlated with the Harbor Hill Moraine) are separated by marginal-marine sediments. If the correlations of the inferred outwashes with the Long Island moraines are correct, the intervening marginal-marine sediments imply that "interglacial" conditions reappeared between two glacial episodes. This relationship, in turn, implies that each terminal moraine was deposited by a separate glacier, not the fluctuating margin of a single glacier.

Extensive lake sediments, including those exposed in the eroding coastal cliff at Montauk Point, imply that in eastern Long Island, the lake waters were impounded on the south by a pre-Ronkonkama terminal-moraine dam, now eroded. If this is correct, then it suggests that the areally most-extensive of the Pleistocene ice sheets was not the youngest (a corollary of the Woodfordian age assignment of the Ronkonkama-Harbor Hill moraines). Indeed, the Pleistocene glacier that spread the farthest south probably was one of the earliest ones to reach the metropolitan New York area.

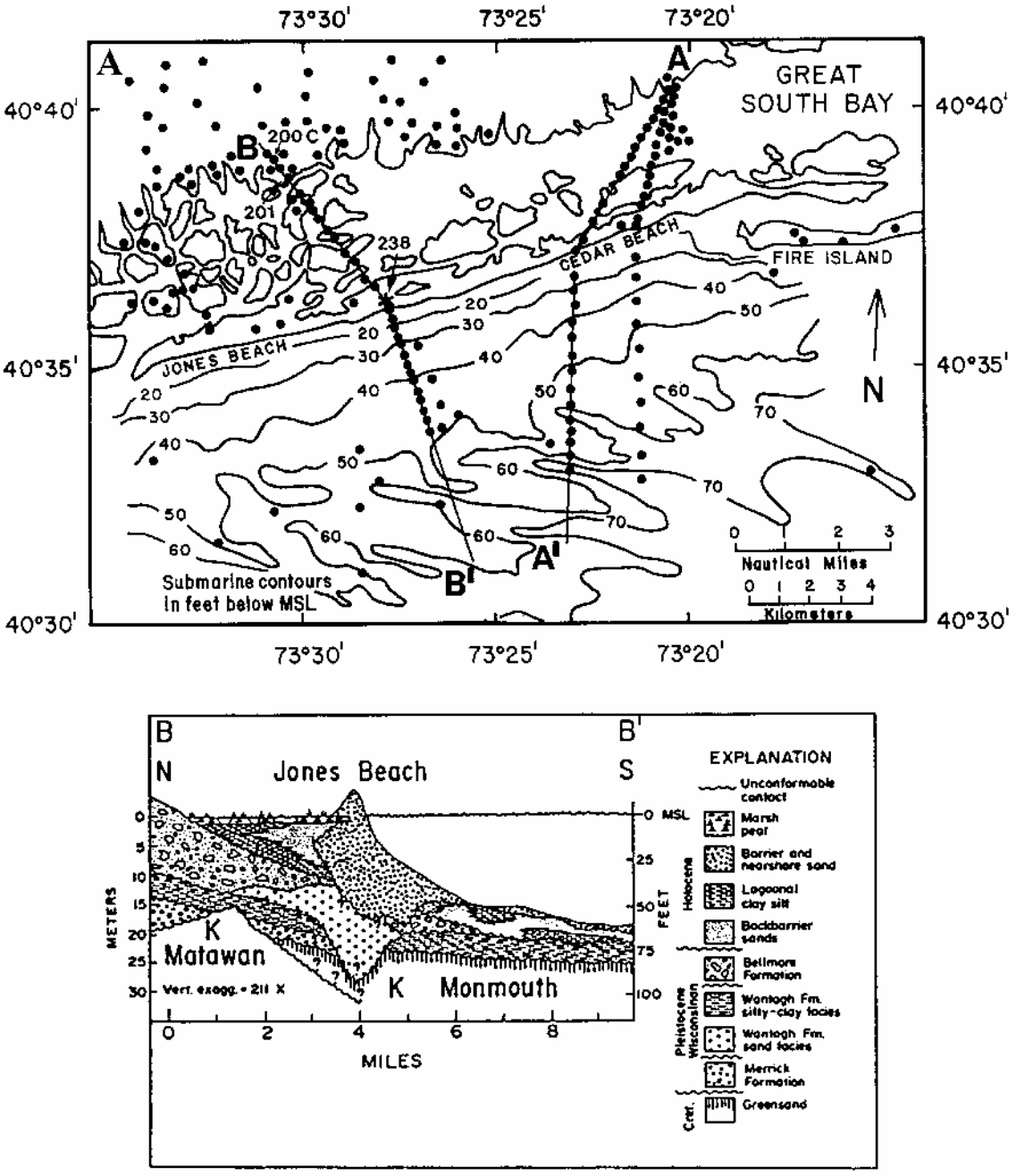

Figure 6 - Shallow subsurface relationships, Jones Beach and vicinity. (M. R. Rampino and J. E. Sanders, 1981b; a, fig. 3, p. 118; b, fig. 4, p. 119.)

a. Location map of lines of borings used to prepare stratigraphic profile-sections. Line B-B' locates Jones Beach section. Regional setting shown by rectangle, Fig. 1.

b. Jones Beach profile section showing tripartite Pleistocene succession consisting of Merrick Formation, Wantagh Formation, and Bellmore Formation. Further explanation in text.

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REFERENCES

Bier, J. A., 1964, Landforms of New York: Alpine Geographical Press, Illinois, Scale 1:1,000,000.

Cadwell, D. H., ed., 1986, The Wisconsinan Stage of the First Geological District, eastern New York: New York State Museum Bulletin 455, 191 p.

Cadwell, D. H., 1989, Surficial geology map of New York, Lower Hudson sheet: New York State Museum Map and Chart Series 40, scale 1:250,000.

Chamberlin, T. C., 1883, Preliminary paper on the terminal moraine of the second glacial epoch, p. 291-402 in United States Geological Survey Annual Report, 3rd (1881-1882), 564 p.

Connally, C. G., and Sirkin, L. A., 1973, The Wisconsinan history of the Hudson-Champlain lobe, p. 47-69 in Black, R. F., Goldthwait, R. P., and Willman, H. B., eds., The Wisconsinan Stage: Geological Society of America, Memoir 136, 334 p.

Ellis, C. W., 1962, Marine sedimentary environments in the vicinity of the Norwalk Islands, Connecticut: Connecticut Geological and Natural History Survey Bulletin 94, 89 p.

Fleming, W. L. S., 1935, Glacial geology of central Long Island: American Journal of Science, 5th series, v. 30, p. 216-238.

Flint, R. F., 1943, Growth of North American ice sheet during the Wisconsin Age: Geological Society of America Bulletin, v. 54, no. 3, p. 325-362.

Flint, R. F., 1945, Glacial map of North America: Geological Society of America Special Papers No. 60, 37 p.

Flint, R. F., 1961, Two tills in southern Connecticut: Geological Society of America Bulletin, v. 72, no. 11, p. 1687-1691.

Flint, R. F., and Gebert, J. A., 1974, End moraines on and off the Connecticut shore (abstract): Geological Society of America Abstracts with Programs, v. 6, no. 7, p. 738-739.

Flint, R. F., and Gebert, J. A., 1976, Latest Laurentide ice sheet: new evidence from southern New England: Geological Society of America Bulletin, v. 87, p. 182-188.

Friedman, G. M., and Sanders, J. E., 1978, Principles of sedimentology: New York, John Wiley and Sons, 792 p.

Friedman, G. M., Sanders, J. E., and Kopaska-Merkel, D. C., 1992, Principles of sedimentary deposits. Stratigraphy and sedimentology: New York, NY, Macmillan Publishing Company, 717 p.

Fuller, M. L., 1914, The geology of Long Island, New York: U. S. Geological Survey Professional Paper 82, 231 p.

Fuller, M. L., 1937, Comment on: "Correlation of Late (sic) Pleistocene marine (sic) and glacial deposits of New Jersey and New York:" Geological Society of America Bulletin, v. 47, p. 1982-1994.

Gale, L. D., 1843, Diary of a geological survey of the Island of New York, p. 581-604 in Mather, W. W., The geology of New York, Part I. Comprising (sic) the geology of the First Geological District: Albany, Carroll & Cook, Printers to the Assembly, 653 p., 46 pl.

Kaye, C. A., 1964a, Boulder train of silicified Paleozoic wood, southeastern Massachusetts: Geological Society of America Bulletin, v. 75, no. 3, p. 233-236.

Kaye, C. A., 1964b, Outline of Pleistocene geology of Martha's Vineyard, Massachusetts: United States Geological Survey Professional Paper 501-C, p. C134-C139.

Kaye, C. A., 1964c, Illinoisan and early Wisconsin moraines of Martha's Vineyard, Massachusetts: United States Geological Survey Professional Paper 501-C, p. C140-C143.

Kaye, C. A., 1982, Bedrock (sic) and Quaternary geology of the Boston area, Massachusetts, p. 25-40 in Legget, R. F., ed., Geology under cities: Boulder, Colorado, The Geological Society of America, Reviews in Engineering Geology, v. 5, 131 p.

Lyttle, P. T., and Epstein, J. B., 1987, Geologic map of the Newark 1ø by 2ø quadrangle, New Jersey, Pennsylvania, and New York: United States Geological Survey Miscellaneous Investigations Series Maps, Map I-1715 (2 sheets; scale 1:250,000).

MacClintock, Paul; and Richards, H. G., 1936, Correlation of the late (sic) Pleistocene marine (sic) and glacial deposits of New Jersey and New York: Geological Society of America Bulletin, v. 47, no. 3, p. 289-337.

Mather, W. W., 1843, Geology of New York. Part I. Comprising (sic) the geology of the First Geological District: Albany, NY, Carroll & Cook, Printers to the Assembly, 653 p., 46 pl. (Includes report of Prof. L. D. Gale on New York Island based on survey of 1828 and 1829.)

Merguerian, Charles; and Sanders, J. E., 1990, Trip 15, Glacial geology of Long Island, 17-18 November 1990: New York Academy of Sciences Section of Geological Sciences Trips on the Rocks Guidebook, 96 p.

Merguerian, Charles; and Sanders, J. E., 1991, Trip 19, Geology of Staten Island and vicinity, 29 September 1991 (revision of 1989 Trip 04, 15 April 1989): New York Academy of Sciences Section of Geological Sciences Trips on the Rocks Guidebook, 78 p.

Merguerian, Charles; and Sanders, J. E., 1992, Trip 25, Geology of Croton Point and Peekskill Hollow, 21 November 1992, (revision of Trip 10, May 1990): New York Academy of Sciences Section of Geological Sciences 1992 Trips on the Rocks Guidebook, 107 p.

Merguerian, Charles; and Sanders, J. E., 1994, Trip 33, Staten Island and vicinity, 16 October 1994: New York Academy of Sciences 1994 Trips on the Rocks Guidebook, 151 p.

Mueser Rutledge Consulting Engineers, 1990, Ground conditions encountered Oakwood Beach Water Pollution Control (sic) Project Contract 6B-3, East Heading, Staten Island, New York: Report submitted to New York City Department of Environmental Protection for Moretrench American Corporation, not paginated.

Muller, E. H., 1964, Quaternary geology of New York, p. 99-112 in Wright, H. E., and Frey, D. G., eds., The Quaternary of the United States: Princeton, NJ, Princeton University Press, 922 p.

Newman, W. S., 1973, A very late Wisconsin glacial advance to western Long Island (abstract): Geological Society of America Abstracts with Programs, v. 5, no. 2, p. 202 (only).

Newman, W. S., 1977, Late Quaternary paleoenvironmental reconstruction: some contradiction from northwestern Long Island New York: New York Academy of Sciences Annals, v. 288, no. 7, p. 545-570.

Newman, W. S., and Pike, T. J., 1975, Late Quaternary geology of northern Queens County, Long Island (abstract): Geological Society of America Abstracts with Programs, v. 7, no. 1, p. 99 (only).

Percival, J. G., 1842, Report on the geology of the state of Connecticut: New Haven, CT, Osborn and Baldwin, 495 p.

Perlmutter, N .M.; and Arnow, Theodore, 1953, Ground water in Bronx, New York, and Richmond counties with summary data on Kings and Queens counties, New York City, New York: New York State Water Power and Control Commission Bulletin GW-32, 86 p.

Perlmutter, N. M., and Geraghty, J. J., 1963, Geology and ground-water conditions in southern Nassau and southeastern Queens counties, Long Island, New York: U. S. Geological Survey Water-Supply Paper 1613-A, 205 p. (mention the 20-Foot Clay)

Rampino, M. R., 1978 ms., Quaternary history of south-central Long Island, New York: New York, New York, Columbia University, Department of Geological Sciences, Ph. D. Dissertation, 742 p.

Rampino, M. R., and Sanders, J. E., 1976, New stratigraphic evidence for major mid-Wisconsinan climatic oscillation and sea-level rise: "Interstadial" or "Interglacial"? (abstract): Geological Society of America Abstracts with Programs, v. 8, p. 1059-1060.

Rampino, M. R., and Sanders, J. E., 1980, Holocene transgression in south-central Long Island, New York: Journal of Sedimentary Petrology, v. 50, no. 4, p. 1063-1080.

Rampino, M. R., and Sanders, J. E., 1981, Episodic growth of Holocene tidal marshes in the northeastern United States: a possible indicator of eustatic sea-level fluctuations: Geology, v. 9, no. 2, p. 63-67.

Rampino, M. R., and Sanders, J. E., 1981a, Evolution of the barrier islands of southern Long Island, New York: Sedimentology, v. 28, no. 1, p. 37-47.

Rampino, M. R., and Sanders, J. E., 1981b, Upper Quaternary stratigraphy of southern Long Island, New York: Northeastern Geology, v. 3, no. 2, p. 116-128.

Ricketts, H. C., 1986, Examination in boreholes of the subsurface Gardiners Clay (Pleistocene), in the context of the Cretaceous-Quaternary section of Great Neck, Long Island, New York: Northeastern Geology, v. 8, nos. 1/2, p. 13-22.

Salisbury, R. D., assisted by H. B. K□mmel, C. E. Peet, and G. N. Knapp, 1902, The glacial geology of New Jersey: Geological Survey of New Jersey, Final Report of the State Geologist, v. 5: Trenton, New Jersey, MacCrellish and Quigley, Book and Job Printers, 802 p.

Sanders, J. E., and Merguerian, Charles, 1991a, Pleistocene tills in the New York City region: New evidence confirms multiple (three and possibly four) glaciations from two directions (NNE to SSE (sic) and NW to SE) (abstract): Geological Society of America Abstracts with Programs, v. 23, no. 1, p. 123.

Sanders, J. E.; and Merguerian, Charles, 1991b, Pleistocene geology of Long Island's north shore: Sands Point and Garvies Point to Target Rock: Long Island Geologists' Association Field Trip 29 June 1991 Guidebook: Hempstead, NY, Hofstra University Department of Geology, 40 p.

Sanders, J. E.; and Merguerian, Charles, 1992, Directional history of Pleistocene glaciers inferred from features eroded on bedrock, New York metropolitan area, SE NY (abstract): Geological Society of America Abstracts with Programs, v. 24, no. 1, p. 72 (only).

Sanders, J. E.; and Merguerian, Charles, 1994a, Fitting newly discovered north-shore Gilbert-type lacustrine deltas into a revised Pleistocene chronology of Long Island (extended abstract), p. 103-113 in Hanson, G. N., chm., Geology of Long Island and metropolitan New York, 23 April 1994, Stony Brook, NY: Stony Brook, NY, Long Island Geologists Program with Abstracts, 165 p.

Sanders, J. E.; and Merguerian, Charles, 1994b, Glacial geology of the New York City region, p. 93-200 Benimoff, Alan, ed., The Geology of Staten Island, New York: Geological Association of New Jersey Annual Meeting, 11th, Somerset, NJ, 14-15 October 1994, Field Guide and Proceedings, 296 p.

Sanders, J. E.; Merguerian, Charles; and Mills, H. C., 1993, "Port Washington deltas" of Woodworth (1901) revisited: pre-Woodfordian Gilbert-type deltas revealed in storm-eroded

coastal bluff, Sands Point, New York (abstract): Geological Society of America Abstracts with Programs, v. 25, no. 6, p. A-308 (only).

Sanders, J. E.; Merguerian, Charles; and Okulewicz, S. C., 1995a, Glacio-tectonic evidence for SE-directed glacial flow in displaced slab of Upper Cretaceous sediments exposed in the Harbor Hill Moraine, Princes Bay, Staten Island, New York (abstract): Geological Society of America Abstracts with Programs, v. 26, no. 1, p. 79-80.

Sanders, J. E.; Merguerian, Charles; and Okulewicz, S. C., 1995a, Recumbent fold in displaced slab of Upper Cretaceous sediments, Princes Bay, Staten Island, New York: further evidence that ice flowing southeastward deposited the Harbor Hill Moraine (extended abstract): This volume

Sanders, J. E., and Rampino, M. R., 1978, Wisconsinan stratigraphy, New York metropolitan area: interpretation of newly recognized units does not support modern concepts of the "Laurentide" ice sheet (abstract): Geological Society of America Abstracts with Programs, v. 10, no. 2, p. 84 (only).

Schuberth, C. J., 1968, The geology of New York City and environs: Garden City, NY, Natural History Press, 304 p.

Sirkin, L. A., 1968, Geology (sic), geomorphology (sic) and late glacial (sic) environments of western Long Island, New York or suburban Pleistocene geology: who built a parkway on my bog? p. 233-253 in Finks, R. M., ed., New York State Geological Association Annual Meeting, 40th, Queens College, Guidebook to field trips: Flushing, NY, Queens College of City University of New York Department of Geology, 253 p.

Sirkin, L. A., 1982, Wisconsinan glaciation of Long Island, New York, to Block Island, Rhode Island, p. 35-59 in Larson, G. L., and Stone, B. D., eds., Late Wisconsin glaciation of New England. A symposium: Dubuque, Iowa, Kendall/Hunt Publishing Company, 242 p.

Sirkin, L. A., 1986, Pleistocene stratigraphy of Long Island, New York, p. 6-21 in Cadwell, D. H., ed., The Wisconsinan Stage of the First Geological District, eastern New York: New York State Museum Bulletin 455, 191 p.

Sirkin, L. A., 1991, Stratigraphy of the Long Island platform, p. 217-227 in Gayes, P., Lewis, R. S., and Bokuniewicz, H. J., eds., Quaternary geology of Long Island Sound: Journal of Coastal Research, Walter Newman Memorial volume, Special Issue No. 11, 215 p.

Sirkin, L. A., 1994, Geology of the Long Island platform (extended abstract), p. 137-139 in Hanson, G. N., chm., Geology of Long Island and metropolitan New York, 23 April 1994, Stony Brook, NY: Stony Brook, NY, Long Island Geologists Program with Abstracts, 165 p.

Sirkin, L. A.; and Mills, Herb, 1975, Wisconsinan glacial stratigraphy and structure of northwestern Long Island, p. 299-327 in Wolff, M. P., ed., New York State Geological

Association, Annual Meeting, 47, Guidebook to Field Excursions: Hempstead, New York Hofstra University, Department of Geology, 327 p.

Sirkin, L. A.; and Stuckenrath, R., 1980, The Portwashingtonian warm interval in the northern Atlantic coastal plain: Geological Society of America Bulletin, v. 91, p. 332-336.

Upham, Warren, 1879, Terminal moraines of the North American ice sheet: American Journal of Science, 3rd series, v. 18, p. 81-92, 197-209.

Woodworth, J. B., 1901, Pleistocene geology of portions of Nassau County and Borough of Queens (N. Y.): New York State Museum Bulletin 48, p. 618-670 (includes geologic map).

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