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Surficial Geology of the Old Orchard Beach 7.5-minute Quadrangle, Cumberland and York Counties, Maine

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INTRODUCTION

The Old Orchard Beach 7.5 minute quadrangle was mapped during 1987 to 1989 as part of the COGEOMAP program of the Maine Geological Survey and the U.S. Geological Survey in the coastal zone of southwestern Maine. Two maps are associated with this report consists of two maps: a surficial geologic map (Retelle, 1999) which shows landforms and geologic map units interpreted from the underlying surficial materials and a surface materials map (Retelle, 1998) which shows thickness and textural composition of surface sediments in the map area.

Location

The Old Orchard Beach 7.5' quadrangle (43°30' to 43°37'30" north latitude and 70°22'30" to 70°30' west longitude) is located in the coastal zone of southwestern Maine in York and Cumberland Counties. The map area includes the larger towns of Old Orchard Beach, Saco, and Scarborough, and smaller, rural portions of the towns of Buxton and Gorham. A small (approximately 1 mile-long) strip of the southeastern corner of the quadrangle borders Saco Bay of the Atlantic Ocean. The land use of the area is variable. Much of the map area is rural to rural residential, especially north of the Maine Turnpike, which cuts northeast to southwest through the quadrangle, A smaller portion of the quadrangle includes the town of Old Orchard Beach, with its developed sandy beach, which has long been noted as a regional recreation center.

The topography in the southern and eastern sectors of the quadrangle is generally low-lying and gently rolling with average elevation between 80 to 140 feet above sea level. The gentle topography is basically dominated by the blanket of surficial deposits which are, in places, incised by postglacial streams. The drainage systems of the Nonesuch River and other smaller streams, such as Finnard and Dunstan Brooks, are superimposed on the surficial sediment blanket. In general, the streams and rivers form a dendritic pattern that drains to the east and northeast into the Atlantic Ocean. The narrow eastern coastal section of the quadrangle in Old Orchard Beach is dominated by a sandy beach-dune system. The beach provides a barrier for a small saltmarsh in the Ocean Park area. A more extensive saltmarsh is found north and east of the village of West Scarborough in the east-central zone of the quadrangle.

The northern third of the quadrangle is slightly hilly with small rolling bedrock hills with elevations slightly over 215 to 228 feet. Surficial materials, including sand, silt, clay, and till commonly blanket the bedrock topography; elsewhere the surficial blanket is thin and bedrock outcrops are more common.

Previous Research in the Field Area

Prior to mapping conducted in association with the COGEOMAP program, little detailed surficial geologic mapping was done in the southwestern coastal zone although numerous topical studies on the history of ice retreat, moraine development, and the nature of the marine sequence are summarized in such papers as Bloom (1963), Stuiver and Borns (1975), Borns (1985), Thompson et al. (1989), Smith (1982, 1985).

Specific research on the surficial geology of the Old Orchard Beach quadrangle has been preliminary in nature. Prescott and Thompson (1976) published a reconnaissance map of the Cumberland County portion of the quadrangle. Smith (1977) also produced a preliminary map which showed the location of major landforms and numerous end moraines in the York County portion of the Portland 15-minute quadrangle (of which the Old Orchard Beach quadrangle constitutes the southwestern quarter). Sand dune mapping in the quadrangle has been conducted by the coastal geology division of the Maine Geological Survey (Dickson, 1990).

Bedrock Geology

Bedrock in the quadrangle can be classified into two basic groups separated by the northeast to southwest-trending Nonesuch River fault. The fault displays right-lateral strike-slip motion and extends through the Nonesuch River valley in the north and northwest sector of the quadrangle (Hussey, 1981). Foliation and bedding structures are visible in outcrop and display this general northeast-southwest structural grain in the metasedimentary rocks.

Rock units northwest of the fault include Silurian to Ordovician metasediments of the Vassalboro Formation and a thin slice of a felsic volcanic member of the Vassalboro Formation (Hussey, 1981). Southeast of the fault, the exposed metasediments of the Casco Bay Group include rocks of the Cape Elizabeth (phyllite, schist, and gneiss ranging from chlorite to sillimanite grade metamorphism) and Scarborough Formations (gray phyllite to green-gray chlorite-phyllite) and a thinner folded intervening layer of metasediments and mafic and felsic metavolcanics of the Spring Point and Diamond Island Formations (Hussey, 1981; Hussey et al., 1986).

Methods Used in this Study

Various methods were employed in the geologic investigation. Preliminary analysis of topography and landforms was made using vertical aerial photography. Information obtained from airphoto analysis was correlated with topography expressed on the 1:24,000 scale base map and then field-checked by foot and automobile traverse.

The primary data was obtained by field investigation of natural and artificial exposures. Natural exposures of surficial materials were limited to a few small exposures such as stream and river cuts. More extensive artificial exposures in active borrow pits provided the best picture of surface and subsurface materials. Numerous inactive pits are also located within the quadrangle and provided a limited view of the materials. In addition, temporary exposures such as building excavations, holes for telephone poles, and trenches along water and sewage lines were often utilized. Many hand auger holes and small shovel holes were dug in the surface sediments.

Well and boring logs provided valuable subsurface data, although this data is sparse in some areas and concentrated in other locations (see materials map for locations and Appendixes 1 and 2). Boring logs were made available from several sources. Borings were made along underpasses and bridge crossings of the Maine Turnpike (Appendix 2). A detailed network of borings was made for the town of Scarborough during expansion of water and sewer service for the town (Appendix 1).

SURFICIAL DEPOSITS

The following is a descriptive list of map units and their principal identifying characteristics that were employed during the mapping of the field area.

Till

In this study, the term till is defined as poorly sorted sediment deposited directly by the action of glacial ice. Till includes a generally fine-grained matrix consisting of a mixture of sand, silt and clay, and clasts of varying composition (metamorphic and igneous) and size, ranging from pebble to boulders. The till in the field area is generally compact and ranges in color from dark olive gray to dark olive brown.

Till occurs in several stratigraphic and morphologic associations in the field area. Most till mapped in the field area is in the slightly hilly areas in the northern third of the quadrangle, where a veneer of till of varying thickness overlies bedrock. Where the till veneer is thin, the surface topography reflects that of the underlying bedrock and bedrock outcrops may be common. In this case a horizontally ruled pattern is shown on the surficial geologic map.

Where till occurs at the surface and masks the underlying bedrock, a gently rolling topography with bouldery surface is common. Along with an assortment of stratified materials, till also occurs in some end moraines in the coastal zone (Smith, 1985; Retelle and Bither, 1989).

Till also occurs beneath a variable thickness of glaciomarine and glaciofluvial deposits. In rare instances, thin layers and pods of till may occur within stratified sediments. This sediment, deposited by mass flow, is sometimes referred to as flowtill (Hartshorn, 1958; Boulton, 1971).

The definitive age of till in the field area is unknown. It is assumed that the till was most likely deposited during the last advance and retreat of the Laurentide Ice Sheet through the area during the late Wisconsinan period. It is possible, however, that some till exposed at depth may be older, deposited during a pre-late Wisconsinan glaciation (cf. Thompson and Borns, 1985; Weddle et al., 1989), however no stratigraphic evidence exists at this time to confirm any age correlation.

End Moraines

End moraines of various sizes have been mapped in the field area. End moraines are linear ridges of varying composition interpreted as having been deposited parallel to, and along, the former front of the retreating ice margin. In this study, end moraines were identified by air photograph analysis (cf. Smith, 1981) followed by field checking. The moraines vary in height, length, and spatial distribution across the quadrangle and the region. Small end moraines may be as small as several feet across and several tens of feet in length, whereas larger moraines may be over 20 feet high and with individual segments over 1/4 mile long. When exposed in borrow pits, moraines contain a wide range of materials including slabs of till, folded and faulted sand and gravel, and fine-grained marine sediments (Smith, 1982; Smith and Hunter, 1989; Retelle and Bither, 1989).

A series of small moraines was mapped in the area north of Boothbay Park, north of "The Heath" in the central portion of the field area. These moraines are short crested with a low relief, generally less than 2 to 3 feet. A larger end moraine was mapped south of Goosefare Brook in the south-central area of the quadrangle. This discontinuous ridge extends over 20 feet above the surrounding marine sediments and forms a discontinuous ridge over 3000 feet long. Unfortunately, no exposures exist in either of these deposits.

Esker-Submarine Fan Complexes

Several morphologically and stratigraphically complex features, designated as submarine fans, were mapped in the field area. Large quantities of sediment derived from subglacial and englacial drainage was delivered to the marine environment through the esker-submarine fan system. In modern tidewater glacier settings, fans occur at the glacier grounding lines where meltwater streams enter the sea. Depending on the rate of retreat of the glacier and the number of meltwater conduits, or switching of the meltwater conduit along the ice margin, fans commonly overlap both parallel and perpendicular to the direction of ice retreat. Deposits in the Pleistocene record have also been referred to as subaqueous outwash (Rust and Romanelli, 1975; Rust, 1987).

Eskers. Linear ridges of poorly sorted sand and gravel, oriented roughly parallel to former ice flow and perpendicular to end moraines, were mapped in close association with submarine fan deposits. Esker ridges commonly form a coarse bouldery gravel core in the fan complexes. Eskers may be found directly overlying bedrock or till. Sharpe (1987) refers to deposits in a similar glaciomarine setting in the Ottawa, Canada area as "conduit deposits," formed by englacial or subglacial streams that delivered sediments to the submarine fans. A small, but distinct esker forms the core of a small submarine fan in the west-central area of the quadrangle and is exposed in a borrow pit (Fielding Sand and Gravel) located between Grant Road and McKenney Road, due north of "The Heath". At this site, several exposures offer various views of the esker. Along an east-west pit wall at the south end of the pit approximately 10 feet of sediment is exposed. In this transverse section of the esker, a core of coarse cobble to boulder-gravel contains crude arched bedding that dips away from the central crest of the ridge. The gravel is draped by finer horizontally laminated medium to coarse block-faulted sand. The uppermost sediment in the exposure is fine-grained marine silty clay that drapes the entire esker.

Submarine Fans. These deposits are seaward-dipping and wedge-shaped, and consist principally of sand and gravel delivered to the sea floor at the glacier margin by sub- or englacial streams. Other sediments such as till and fine-grained marine sediments may be associated with the submarine fan deposits. The size of the fans depends on the supply of sediment and rate of retreat of the glacier margin. Commonly, fans contain horizontal to dipping beds of gravel and gravelly sand. Current structures, such as ripple-drift lamination, are common in some sand units. The direction of dip of the bedding is variable, however most current indicators demonstrate paleocurrent flow ranging from east through south to west, with the predominant flow direction in the southeasterly to southwesterly directions, away from the ice front. Larger fans (such as those exposed in the series of large borrow pits between Route 5 and the Maine Turnpike in the southwest corner of the quadrangle) may be over 50 feet thick and consist of overlapping fan lobes and successive ice marginal positions. A smaller discrete fan deposit was mapped in the Saco Industrial Park approximately 2000 feet due north of Phillips Spring. In this small deposit, steep southward-dipping cobble gravel beds grade distally (approximately 500 feet) to structureless gravelly matrix-supported mud interbedded with rhythmically laminated sand-silt couplets.

Presumpscot Formation and Marine Regressive Sand Deposits

These deposits were originally defined by Bloom (1963) as glaciomarine clay. However, the fine-grained unit that blankets the coastal lowland commonly consists of a fining-upward sequence of sand, silt, and clay with fossil marine molluscs and dropstones common. The deposit forms a continuum with the esker-submarine fan system that delivers glacial sediments to the sea floor, hence complex relations within fan deposits often juxtapose coarse esker-fan sand and gravel and the finer sand, silt, and clay deposited predominantly by suspension settling distal to, or adjacent to, meltwater point sources.

In this study, two extensive marine sediment facies are mapped. On the geologic map, fine-grained ocean-bottom silt and clay (with minor amounts of fine sand) is denoted by the symbol Pp, whereas the coarse-grained sandy sediments are designated by the symbol Pmrs. The latter unit was most likely deposited in the sea by reworking of nearshore deposits and other sand sources such as marine fans as relative sea level was falling. A vast area of the Old Orchard Beach quadrangle is covered by this deposit, which is common throughout the southwestern Maine coastal zone. The sandy facies commonly overlies the fine-grained facies of the classic Presumpscot Formation (as defined by Bloom, 1963). The fine-grained unit is found in varying shades of gray to olive gray when weathered. In some cases the clay has been referred to as "the blue clay" from its bright bluish-gray unweathered appearance. Grain-size analysis of the fine unit commonly indicates that the "clay" contains a high proportion of silt and a smaller percentage of fine sand.

Large vertical exposures of the fine-grained unit are noticeably absent in the field area although smaller surface exposures in stream banks and road cuts are common. Noteworthy exceptions in the area include the Douville Pit (located in the southwest corner of the quadrangle west of the Turnpike, south of Route 5, and north of the Saco River). In this site, approximately 5 feet (1.5 meters) of fine-grained laminated silt and silty clay is overlain by coarse sand, gravel, and interlaminated mud and overlies approximately 2 meters of thick horizontally layered beds of medium to coarse sand. In borings from the adjacent turnpike crossing of the Saco River the fine-grained unit comprises 18.5 feet (approximately 5.8 meters). At the Beech Ridge Road crossing of the turnpike (in the adjacent Prouts Neck Quadrangle) the fine-grained silty clay reaches a thickness of 87 feet (approximately 27 m) (Maine Turnpike Authority, written communication, 1990).

Nearshore Deposits

Generally coarse-grained deposits were formed by nearshore processes (predominantly wave reworking) during the late phases of marine submergence of the coastal zone. Gravel and sand deposited in submarine fans were reworked as sea level fell during glacio-isostatic emergence of the coastal zone. Distinctive nearshore deposits, such as spits, can be found in the field area. The most obvious deposit is found in the southeastern corner of the quadrangle extending from the Milliken Mills area to the town of Old Orchard Beach. The extensive sandy deposit links together two bedrock topographic highs at the north and south end of the deposit and intervening sandy hillocks that were possibly remnants of submarine fans. The sand unit ranges in elevation from near 130 feet in the hill south of Milliken Mills to 100 feet in the hilly area in the town of Old Orchard Beach. The deposit stands topographically above the plain of the adjacent sea floor deposits (Pmrs and Pp) which are at an elevation of 60 to 80 feet. The best exposure in the feature occurs in the Old Orchard Beach town pit east of U-Turn Road. In this pit, approximately 20 feet of steeply dipping cross-bedded sands, resembling delta foreset beds, is exposed. The beds dip to the southeast (140^{o}) and show a slight coarsening trend to the north into the apex of a former fan deposit. Along the north flank of the deposit, paleocurrents in coarse cross-bedded sand trend in a westerly direction and indicate sediment transport parallel to the former shoreline by longshore drift.

Modern or Holocene nearshore deposits are mapped along the present coastline.

Alluvium and Stream Terraces

Alluvium and stream terraces, presumably of Holocene age, are mapped along numerous present-day stream courses in the field area. The most extensive deposit occurs along the Nonesuch River which flows from southwest to northeast across the northern portion of the map area. Poorly sorted silty sand and debris such as tree limbs and other vegetation are commonly deposited on terraces and low-lying areas bordering the modern stream during periods of high water. Where a distinctive terrace morphology is preserved due to stream downcutting in the surface materials, a stream terrace (Hst or Qst) is mapped. Terraces were mapped along the south bank of the Nonesuch River and also along the small portion of the Saco River in the extreme southwestern corner of the quadrangle.

Wetlands

Several extensive and numerous small wetlands were mapped in the quadrangle. The largest deposit mapped in the area is referred to as The Heath, located in a low-relief, poorly drained west-central area of the quadrangle. This deposit includes a central zone of heath (Hwhp, Hwht) fringed by swamp deposits (Hwst, Hws). The Scarborough marsh is an extensive marine wetland in the east central area of the quadrangle. This deposit ranges from broad salt marsh deposit (Hwsmt) into narrower linear deposits that extend inland up the stream valleys of Cascade, Dunstan, and Finnard Brooks and grade into freshwater marsh deposits (Hwfmt) in these locations.

GLACIAL AND POSTGLACIAL HISTORY

Although numerous authors have demonstrated that northern New England (cf. Koteff and Pessl, 1985) and specifically Maine (Borns and Calkin, 1977; Thompson and Borns, 1985) have been subjected to multiple glaciation, primary evidence for multiple glaciation (multiple drift sheets and crossing striation sets) were not found in the field area. The present evidence in the Old Orchard Beach quadrangle suggests that the area has been only subjected to the latest, or late Wisconsinan, advance and retreat of the Laurentide Ice Sheet through the coastal zone. The limited exposures of till in the area do not show advanced weathering typical of older ice advances (Weddle et al., 1989) and hence are assigned a late Wisconsinan age. Till was probably deposited subglacially during late stages of ice advance or during the retreat phase of the late Wisconsinan ice. Ice flowed through the Old Orchard Beach quadrangle from north-northwest to south-southeast (striation directions range from 160^{o} to 178^{o}).

During the maximum of the last glaciation, the Laurentide Ice Sheet extended beyond the present Maine coastline onto the continental shelf and probably began to recede from that position around 17,000 to 15,000 years ago (Tucholke and Hollister, 1973). Stuiver and Borns (1975) estimate that the ice margin reached the present coastline around 13,500 yr B.P. During the retreat, the ice margin was in contact with the sea, forming a tidewater margin. Marine submergence of the coastal zone occurred from the time of deglaciation until the ice margin had receded to the interior and isostatic rebound caused sea level to retreat to the continental shelf (Schnitker, 1974).

Based on sea level features such as ice-contact deltas (with surveyed topset-foreset contacts) and raised beaches in adjacent field areas, Thompson et al. (1989) suggest that the marine limit in the field area ranges between 240 to 270 feet above sea level. Since the highest elevation in the field area is 228 feet, during maximum marine submergence (immediately after deglaciation) the entire quadrangle was submerged below sea level. Submarine fans were deposited along the ice margin on the sea floor at depths ranging from 50 to 150 feet, and graded laterally and distally to finer-grained deposits. Along with some large and small end moraines, the pattern of ice retreat through the quadrangle is documented by submarine fans and associated deposits. Ice retreat in the area was likely accomplished through a combination of ice thinning (through melting) and calving into the sea. Retreat through the area was interrupted by numerous minor forward oscillations of the ice margin, creating the many moraines seen in the quadrangle.

The first major ice marginal position trends east-northeast to west-southwest through the quadrangle from north of Milliken Pond through Goosefare Hills to the Tingley Pit in the southwest corner of the field area. The position is marked by several small moraines in the east, several larger moraines north of Smithwheel Road, the Goosefare Hill moraine, and a large ice-contact submarine fan in the borrow pits in the southwestern corner of the quadrangle. Progressive northward ice marginal retreat from this position can be inferred from various moraines and submarine fan deposits, however a systematic description of correlative positions and relative timing of these positions would be futile due to lack of exposure.

Marine sediments accumulated in the field area until isostatic rebound caused relative sea level to fall beyond the present coastline and onto the continental shelf. As sea level fell, and wave base came into contact with the unconsolidated glacial and glaciomarine sediments, nearshore deposits and shallow marine sands were deposited across virtually the entire quadrangle. In some exposures fine-grained silty marine clay coarsens transitionally upward with the introduction of lenses and layers of sand to be finally succeeded by a thick sand unit extending to the top of the sequence. In other exposures the change is abrupt with the regressive sand unit overlying till or sand and gravel deposits with a distinct unconformity. With the rate of isostatic emergence of the recently deglaciated landscape exceeding sea level rise, relative sea level continued to fall until the coastal zone emerged. Based on submarine geomorphology, Schnitker (1974) estimates that the lowstand of sea level was approximately -60 meters below present.

With the field area subaerially exposed, drainage developed on the marine lowland. In poorly drained areas, swamps and other wetlands formed. A modified dendritic drainage pattern formed over the area and drainage was directed into the Saco River and in a general easterly direction into the ocean. Clinch and Thompson (1999a,b) suggest that the present Nonesuch River may follow the preglacial course of the Saco River, with the latter having excavated a lower outlet to the south.

When isostatic rebound of the land surface slowed enough to allow sea level rise from the melting ice sheets to overcome rebound, relative sea level began to rise. Belknap et al. (1986) suggest that relative sea level began to rise from the lowstand at about 9000 yr B.P. Sea level rise continues to the present and has caused the formation of the modern coastal environment and coastal wetland deposits such as the sandy Old Orchard Beach, Scarborough Marsh, and the Ocean Park marsh as the low-lying areas were flooded by marine waters.

REFERENCES CITED

Belknap, D. F., Andersen, B. G., Anderson, R. S., Anderson, W. A., Borns, H. W., Jacobson, G. L., Kelley, J. T., Shipp, R. C., Smith, D., Stuckenrath, R., Thompson, W. B., and Tyler, D. A., 1986, Late Quaternary sea-level changes in Maine, *in* Nummedal, D., Pilkey, O., and Howard, J. (eds.), Sea level rise and coastal evolution: Society of Economic Paleontologists and Mineralogists, Special Paper 41, p. 71-85.

Bloom A. L., 1963, Late Pleistocene fluctuations of sea level in southwestern Maine: American Journal of Science, v. 261, p. 862-879.

Borns, H. W., 1985, Changing models of deglaciation in northern New England and adjacent Canada, *in* Borns, H. W., Jr., LaSalle, P., and Thompson, W. B. (eds.), Late Pleistocene history of northeastern New England and adjacent Quebec: Geological Society of America, Special Paper 197, p. 135-138.

Borns, H. W., and Calkin, P. E., 1977, Quaternary glaciation of west-central Maine: Geological Society of America, Bulletin, v. 88, p. 1773-1784.

Boulton, G. S., 1971, Till genesis and fabric in Svalbard, Spitsbergen, *in* Goldthwait, R. P. (ed.), Till-a symposium: Ohio State University Press, Columbus, p. 41-72.

Clinch, J. M., and Thompson, W. B., 1999a, Surficial geology of the Prouts Neck quadrangle, Maine: Maine Geological Survey, Open-File Map 99-97.

Clinch, J. M., and Thompson, W. B., 1999b, Surficial geology of the Prouts Neck 7.5-minute quadrangle, Cumberland and York Counties, Maine: Maine Geological Survey, Open-File Report 99-128, 33 p.

Dickson, S. M., 1990, Coastal sand dune map of Old Orchard and Ocean Park Beaches, Old Orchard Beach, Maine: Maine Geological Survey, Open-file Map 90-15.

Hartshorn, J. H., 1958, Flowtill in southeastern Massachusetts: Geological Society of America, Bulletin, v. 69, p. 477-482.

Hussey, A. M., II, 1981, Preliminary bedrock and brittle fracture map of the lower Androscoggin-Casco Bay area: Maine Geological Survey, Open-File Map 81-29.

Hussey, A. M. II, Bothner, W. A., and Thomson, J. A., 1986, Geological comparisons across the Norumbega fault zone, southwestern Maine, *in* Newberg, D. W. (ed.), Guidebook for field trips in southwestern Maine: New England Intercollegiate Geological Conference, p. 53-78.

Koteff, C., and Pessl, F., Jr., 1985, Till stratigraphy in New Hampshire: correlations with adjacent New England and Quebec, *in* Borns, H. W., LaSalle, P., and Thompson, W. B. (eds.), Late Pleistocene history of northeastern New England and adjacent Quebec: Geological Society of America, Special Paper 197, p. 1-12.

Prescott, G. C., Jr., and Thompson, W. B., 1976, Reconnaissance surficial geology of the Old Orchard Beach quadrangle, Maine: Maine Geological Survey, Open-File Map 76-32.

Retelle, M. J., 1998, Surficial materials of the Old Orchard Beach quadrangle, Maine: Maine Geological Survey, Open-File Map 98-180.

Retelle, M. J., 1999, Surficial geology of the Old Orchard Beach quadrangle, Maine: Maine Geological Survey, Open-File Map 99-94.

Retelle, M. J., and Bither, K. M., 1989, Late Wisconsinan glacial and glaciomarine sedimentary facies in the lower Androscoggin Valley, Topsham, Maine, *in* Tucker, R. D., and Marvinney, R. G., Studies in Maine Geology: Vol. 6 - Quaternary geology: Maine Geological Survey, p. 33-52.

Rust, B. R., 1987, Subaqueous outwash of the Ottawa area, *in* Fulton, R. J. (ed.), Quaternary of the Ottawa region and guides for day excursions: National Research Council of Canada, XIIth INQUA Congress guidebook, Ottawa, Canada, p. 23-24.

Rust, B. R., and Romanelli, R., 1975, Late Quaternary subaqueous outwash deposits near Ottawa, Canada, *in* Jopling, A. V. and McDonald, B. C. (eds.), Glaciofluvial and glacioloacustrine sedimentation: Society of Economic Paleontologists and Mineralogists, Special Paper 23, p. 177-192.

Schnitker, D., 1974, Postglacial emergence of the Gulf of Maine: Geological Society of America, Bulletin, v. 85, p. 491-494.

Sharpe, D. R., 1987, Glaciomarine fans built within and marginal to the Champlain Sea, *in* Fulton, R. J. (ed.), Quaternary of the Ottawa region and guides for day excursions: National Research Council of Canada, XII[th] INQUA Congress guidebook, Ottawa, Canada, p. 63-74.

Smith, G. W., 1977, Reconnaissance surficial geology of the Portland Quadrangle, Maine: Maine Geological Survey, Open-File Map 77-16.

Smith, G. W., 1981, End moraines and glaciofluvial deposits of Cumberland and York Counties, Maine: Maine Geological Survey, scale 1:250,000.

Smith, G. W., 1982, End moraines and the pattern of last glacial retreat from central and south central Maine, *in* Larson, G. J., and Stone, B. D. (eds.), Late Wisconsinan glaciation of New England: Kendall Hunt, Dubuque, Iowa, p. 195-210.

Smith, G. W., 1985, Chronology of late Wisconsinan deglaciation of coastal Maine, *in* Borns, H. W., LaSalle, P., and Thompson, W. B. (eds.), Late Pleistocene History of Northeastern New England and Adjacent Quebec: Geological Society of America, Special Paper 197, p. 29-44.

Smith, G. W., and Hunter, L. E., 1989, Late Wisconsinan deglaciation of coastal Maine, *in* Tucker, R. D., and Marvinney, R. G. (eds.), Studies in Maine Geology: Volume 6 - Quaternary Geology: Maine Geological Survey, p. 13-32.

Stuiver, M., and Borns, H. W., 1975, Late Quaternary marine invasion in Maine: its chronology and associated crustal movement: Geological Society of America, Bulletin, v. 86, p. 99-104.

Thompson, W. B., and Borns, H. W., Jr., 1985, Till stratigraphy and late Wisconsinan deglaciation of southern Maine: a review: Geographie Physique et Quaternaire, v. 29, no. 2, p. 199-214.

Thompson, W. B., Crossen, K. J., Borns, H. W., Jr., and Andersen, B. G., 1989, Glacial-marine deltas of Maine and their relation to Late Pleistocene-Holocene crustal movements, *in* Anderson, W. A., and Borns, H. W., Jr. (eds.), Neotectonics of Maine: studies in seismicity, crustal warping, and sea-level change: Maine Geological Survey, Bulletin 40, p. 43-68.

Tucholke, B. E., and Hollister, C. D., 1973, Late Wisconsin glaciation of the southwestern Gulf of Maine: new evidence from the marine environment: Geological Society of America, Bulletin, v. 84, p. 3279-3296.

Weddle, T. K., Stone, B. D., Thompson, W. B., Retelle, M. J., Caldwell, D. W., and Clinch, J. M., 1989, Illinoian and late Wisconsinan tills in eastern New England: a transect from northeastern Massachusetts to west-central Maine, *in* Berry, A. W. (ed.), Guidebook for field trips in southern and west-central Maine: New England Intercollegiate Geological Conference, p. 25-86.

APPENDIX 1. DRILLER'S LOGS FOR TEST HOLES DRILLED ALONG MAINE TURNPIKE IN THE OLD ORCHARD BEACH QUADRANGLE. SEE MATERIALS MAP FOR TEST HOLE LOCATIONS.

TH 1. SACO RIVER

Thickness (feet)	Description
0.5	topsoil
4.0	fine sand
6.0	fine silty sand
6.3	coarse sand
3.2	silty sand
3.5	clayey silt
15.0	silty clay
6.0	clayey sandy silt
37.0	silty fine sand

TH 2. SACO INTERCHANGE

Thickness (feet)	Description
11.4	clay
18.0	sand and clay
9.0	gravel
1.6	clay

TH 3. BUXTON ROAD (STATE ROUTE 112)

Thickness (feet)	Description
2.0	soil
14.0	clay
4.5	clay and gravel

TH 4. FLAG POND ROAD

Thickness (feet)	Description
2.0	soil
1.0	gravel
2.0	clay
	bedrock

TH 5. BROAD TURN ROAD

Thickness (feet)	Description
3.0	soil
4.0	sand
1.0	clay
3.5	rock and clay
	bedrock

TH 6. BEECH RIDGE ROAD

Thickness (feet)	Description
3.0	soil
6.0	silty sand
23.0	clay
52.2	soft clay
12.0	hard clay
1.6	sand
	bedrock

TH 7. TWO ROD ROAD

Thickness (feet)	Description
5.0	soil
17.0	hard packed clay
9.0	medium clay
4.0	sand and clay
18.0	clay and gravel
3.0	clay
10.3	clay and sand

APPENDIX 2. TEST BORING LOGS FROM TOWN OF SCARBOROUGH, CONTRACT 4. DEPTHS OF DESCRIBED INTERVALS REPORTED IN FEET. REFER TO MATERIALS MAP FOR LOCATIONS.

Boring Number	Thickness	Description
224	0-0.5	soil
	0.5-4.3	brown poorly sorted sand and gravel
	4.3-10.0	silty fine sand with clay
225	0-0.7	black topsoil
	0.7- 5.0	silty fine sand
	5.0-12.0	dense fine to medium sand with gravel
227	0-13	fine to medium sand
	13-24.5	fine-medium sand, trace silt, gravel
	24.5-26	dense fine to medium sand
229	0-3.8	fine sandy silty clay, trace fine gravel
	3.8-7.2	med sand with layers of stiff silt
	7.2-14.1	layered brown clay with silty fine sand
233	0-0.5	black sandy gravel
	0.5-	gravelly sand with cobbles, gravel withcobbles
	13	refusal (bedrock)
	note - no depths available	
235	0-0.3	topsoil
	0.3-5.5	gravelly silty fine sand
	5.5-12	brown sandy silt, clay, fine gravel
246	0-0.8	soil
	0.8-11.9	fine sand with trace clay
248	0-0.8	topsoil
	0.8-3.2	loose brown fine sand with trace gravel
	3.2-12.0	gray silty clay
249	0.5	topsoil
	0.5-2.2	silty fine sand with gravel, coarse sand
	2.2-12.0	gray silty clay
252	0-0.2	topsoil
	0.2-5.2	fill (?)
	5.2-15.0	silty clay
254	0-3.3	dense sand with gravel, trace silt
	3.3-14.7	silty clay
	14.7-21	layered silty clay, silty sand
255	0-2.5	sand and gravel
	2.5-7.2	gray silty clay with 1-2" sand layers
	7.2-25	fine sand layered with silty sand
256	0-0.8	sand and gravel
	0.8-6.0	loose light brown silt and fine sand
	6.0-7.5	clay with sand (trace gravel)
	7.5-12	stiff blue gray clay
257	0-2.2	sand and gravel
	2.2-11.0	brown-gray silty clay
258	0-0.7	topsoil
	0.7-1.2	fine-medium sand with gravel
	1.2-13.0	medium-coarse sand, fine gravel, layers of silty sand
259	0-1.5	fine to medium sand with coarse sand, silt, gravel
	1.5-5.5	layers of sand and clay
	5.5-8.6	silty clay
	8.6-12.0	gray silty clay with fine sand
260		sand and gravel
	-6.8	gray silty clay
261	0-1.2	fine sandy clayey silt
	1.2-3.3	silty sand with gravel
	3.3-10.0	stiff clay
262	0-2.8	fine-medium sand
	2.8-9.0	silty fine-medium sand, silty clay
	9.0-15.0	dark gray silty clay
263	0-2.3	silty fine sand with gravel, trace silt
	2.3-12.0	silty clay
264	0-4.1	dense medium sand with gravel
	4.1-12.0	silty clay
266	0-2.3	silty fine sand with gravel
	2.3-8.0	stiff silty clay
	8.0-12.0	blue clay
267	0-0.7	silty sand
	0.7-12.3	stiff silty clay
	12.3-15.0	blue gray silty clay
269	0-3.1	medium sand with gravel
	3.1-5.3	stiff silty clay
	5.3-10.0	clay with silt
270	0-4.2	fine-medium sand with gravel
	4.2-6.2	gray clay
	6.2-13.5	gray silty clay
	13.5-17.0	clay
271	0-3.1	silty sand and gravel
	3.1-14.0	silty clay
272	0-4.0	fine-medium sand with fine gravel
	4.0-10.1	gray clay with trace silt
	10.1-13.0	soft blue-gray clay
273	0-4.2	sand and gravel with trace silt
	4.2-8.9	fine sand and silty clay
	8.9-12.0	soft silty clay
280	0-0.2	topsoil
	0.2-1.7	sand with gravel
	1.7-11.5	stiff silty clay
281	0-1.5	silty clay with gravel
	1.5-10.0	stiff silty clay
285	0-3.6	fine sand with silt
	3.6-15.0	stiff silty clay