Pleistocene Stratigraphy of the Augusta and Waldoboro Areas, Maine

By
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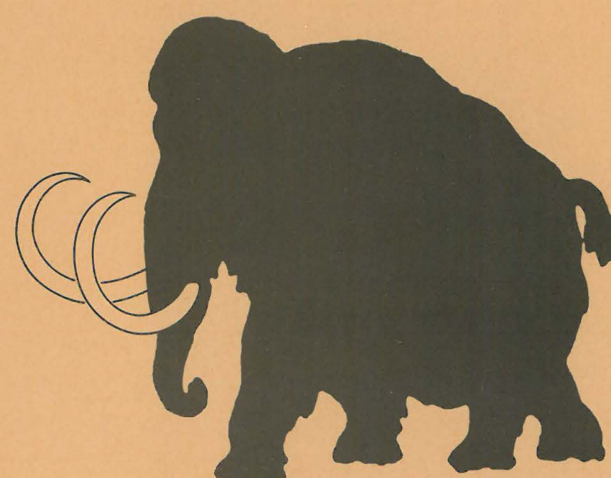

Guidebook for the
46th Annual Meeting of the
Friends of the Pleistocene
May 14 and 15, 1983

Maine Geological Survey
DEPARTMENT OF CONSERVATION

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INTRODUCTION

The 1983 Friends of the Pleistocene trip will examine the glaciomarine deposits and till stratigraphy of the Augusta-Waldoboro region in southern Maine. This area includes parts of Kennebec, Lincoln, and Knox Counties. It is part of the coastal Maine lowland, with elevations over much of the area being less than 152 m (500 ft). The bedrock consists of Precambrian to middle Paleozoic metasediments that are variably metamorphosed and intruded by Devonian granite plutons. The northeast strike of the metamorphic rock formations locally imparts a strong grain to the topography, which in turn has localized the formation of certain glacial deposits.

From the standpoint of Quaternary geology, coastal Maine is notable for its varied assemblage of glaciomarine sediments. Extensive deposits of marine silt and clay, ice-contact deltas, subaqueous outwash fans, and clusters of end moraines were formed along the retreating margin of the late Wisconsinan ice sheet. These deposits were emplaced during the marine submergence that accompanied deglaciation. Lingering isostatic depression allowed the sea to invade lowland areas of southern and central Maine to a maximum present-day elevation of 128 m (420 ft). However, the submergence was short-lived. Radiocarbon dates obtained by Stuiver and Borns (1975) and the present authors indicate that deglaciation of the coast began about 13,500 years ago, and was complete within a few hundred years. Rapid uplift occurred, bringing the area above sea level by 11,500 yr B.P.

The history of investigations on the glaciomarine deposits of Maine has been summarized by Thompson (1982). The former existence of a marine submergence was recognized in the early 1800's by Jackson (1837), although he did not perceive the glacial origin of the elevated marine clay deposits. The glaciomarine sediments were better understood by the end of the century, when Stone (1899) described the end moraines and deltas of the coastal lowland. Excellent descriptive studies were published in the mid-1900's by Leavitt and Perkins (1935) and Goldthwait (1949, 1951). Bloom (1960) studied the marine silt and clay deposits, which he named the Presumpscot Formation.

In recent years, our knowledge of the glaciomarine deposits has increased greatly as a result of quadrangle mapping throughout the coastal zone by the Maine Geological Survey, and from research by H. W. Borns, Jr., and other members of the Quaternary Studies Institute (Univ. of Maine at Orono). The USGS Hydrologic Atlas map series and compilations of subsurface data by Glenn C. Prescott, Jr., have assisted in interpreting the stratigraphy of the deposits, and much additional information is currently resulting from MGS-USGS gravel aquifer studies. This growing data base is helping researchers in southern Maine to improve existing models for the genesis of the glaciomarine sediments and the modes of deglaciation in a marine environment. These studies have added importance because of their application in various problems ranging from ground water exploration to low-level nuclear waste disposal.

This year's Friends of the Pleistocene trip will also briefly examine the till stratigraphy of south-central Maine. Multiple-till exposures are rare in this part of the state, but we will visit a locality where two very distinct varieties (and ages?) of till can be seen. Another stop will be made to examine an unusual layered till deposit of uncertain origin. Interesting till exposures also occur in some of the end moraines.

FIELD TRIP A

GLACIAL AND GLACIOMARINE DEPOSITS IN THE AUGUSTA AREA, MAINE

Trip Leader: Woodrow B. Thompson

INTRODUCTION

The following itinerary comprises seven localities that have been selected to illustrate the Pleistocene stratigraphy of the Augusta region in south-central Maine (Figure 1). The surficial geology of this area has been mapped and described by Thompson (1976; 1982). However, certain aspects of the localities included here have not been studied in detail, and it is expected that many productive discussions will arise during the trip.

A variety of glacial landforms and deposits occur in the Augusta region. Most of them formed during late Wisconsinan time, with the probable exception of the lower till seen at Stop 6. Two principal tills are present in the study area, and they are believed to be equivalent to the two tills that have been described by numerous workers in southern New England and New Hampshire. Both of these tills will be seen at Stop 6, and the rationale for assigning them different ages will be discussed.

Water-laid glacial deposits are abundant in the Kennebec River Valley and neighboring lowland areas. One major esker follows the Kennebec Valley, and another (DeGeer-type) esker with associated glaciomarine deltas trends southward through the Belgrade region and terminates at the delta beneath the Augusta airport. Fine-grained glaciomarine sediments of the Presumpscot Formation commonly mantle these and other sand and gravel deposits, and are locally interbedded with them. The Presumpscot Formation was deposited during the period of marine submergence that accompanied ice retreat from southern Maine. Deglaciation of coastal Maine began about 13,500 years ago (Stuiver and Borns, 1975), and field studies have shown that recession of the active ice margin was accompanied by maximum marine transgression (Thompson, 1982). Thus, end moraines and other ice-marginal deposits that occur below the limit of submergence formed in a submarine environment. The present altitude of the marine limit in Augusta is about 104 m (340 ft).

Part of Trip A will examine water-laid sediments that were deposited during the recession of the last ice sheet from the southern Kennebec County region. Although these deposits vary considerably, all of them are believed to have formed in the marginal zone of the glacier, and the majority were deposited into the sea. Where possible, the glaciomarine origin of the latter units was identified directly on the basis of stratigraphic evidence. This evidence includes the presence of marine fossils, similarity to the Presumpscot Formation as described by Bloom (1960), or interlayering of deposits with the fine-grained sediments typical of the Presumpscot Formation. In other cases a marine depositional environment was inferred on the basis of altitude with respect to the marine limit.

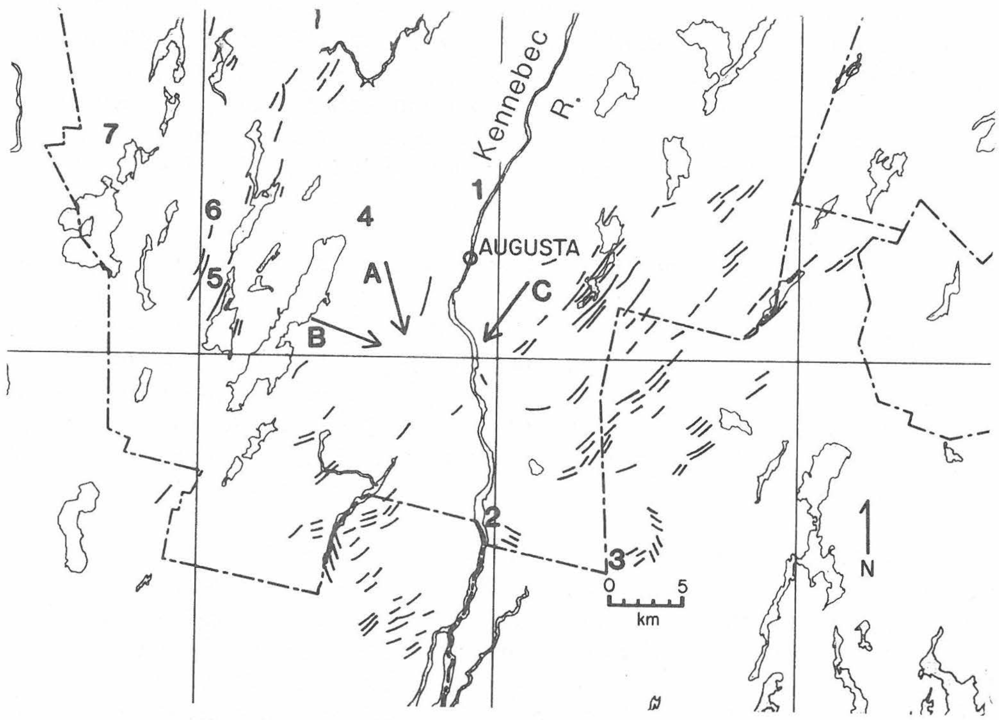

Figure 1

Map showing end moraines and ice-flow directions in the Augusta area. Numbers indicate locations of field trip stops. Arrow "A" shows regional flow direction of late Wisconsinan ice. Arrows "B" and "C" indicate local flow directions during deglaciation.

FIELD TRIP ITINERARY

Note: All of the stops described below are located on private property. Permission to visit them has been granted for this trip only, so persons wishing to return at a later date should contact the owners. Trip participants are also advised to use extreme caution at each stop, being careful to avoid injury from falling rocks, cave-ins, and other hazards that may occur in gravel pits.

Mileage

0.00 Leave U.S. Route 202 at traffic circle at west end of Kennebec River bridge in Augusta, and proceed north on Route 104. Follow signs carefully, first going north on State Street, then turning right on Bond Street, then left on Water Street, which becomes Northern Avenue going out of town.

3.80 Turn right and park at entrance to gravel pit road. Walk downhill about 0.1 mile to pit.

STOP 1 - BONENFANT CONSTRUCTION CORP. PIT
(Augusta; NE 1/9 of Augusta 7.5-minute quadrangle)

This pit exposes about 30 m of section in the Kennebec esker and overlying glaciomarine deposits. The oldest unit is the bouldery esker gravel, which is well exposed in the deepest part of the pit. This gravel is quite rusty in places, and exhibits an openwork texture. The next higher unit consists of well-stratified interbedded sand and gravel, which is locally collapsed. The latter unit is much thicker and better exposed in the southern end of the pit complex (which belongs to the City of Augusta and is off-limits to visitors).

The interbedded sand and gravel is believed to have been deposited as subaqueous outwash fans at the mouth of the esker tunnel as the ice margin receded northward. This unit becomes finer toward the top of the section, but there are still some gravel lenses high on the west wall of the city pit.

A small zone of bluish-gray glaciomarine silt is present high in the northwest corner of the Bonenfant Pit. This is part of the Presumpscot Formation. Similar patches of marine silt overlie or intertongue with subaqueous outwash in several places in the pit complex. No fossils have been observed *in situ*, but a few marine shells were collected from a spoil pile on the boundary between the Bonenfant and city pits.

Large boulders occur near the top of the section in the northwestern part of the pit. Some are present in the silt, while others are in the overlying sand. At least some of these boulders probably are dropstones that fell from icebergs. (The maximum water depth over the highest part of this deposit would have been about 23 m). A thin gravel layer that is seen just below the ground surface in several places is believed to have formed by reworking of older materials as sea level fell. A thicker unit of beach(?) gravel overlies the Presumpscot Formation at the south end of the city pit.

Leave Bonenfant Pit and go south on Route 104. Proceed directly toward center of Augusta on Water Street.

6.95 Turn left at traffic light and cross bridge over Kennebec River. Continue uphill to traffic circle. Take second exit from circle, onto Route 9 "west". Continue south out of town on Route 9.

10.85 Cross bottom of deep stream gully cut in the Presumpscot Formation. Note recent earthflow on north side of gully (west of Route 9).

13.40 Traffic light in Randolph village. Continue straight ahead, leaving Route 9 and proceeding south on Route 27.

18.55 Turn right off Route 27, onto unnamed paved road (Everson Road on Gardiner 7.5-minute quadrangle).

19.05 Turn right and park at entrance to dirt road. Follow dirt road to gravel pit on east side of Kennebec River.

STOP 2 - WILLIAMS CONSTRUCTION CO. PIT
(Pittston; SE 1/9 of Gardiner 7.5-minute quadrangle)

This gravel pit exposes about 30 m of section and shows most of the water-laid glacial deposits that occur in the lower Kennebec Valley. Boulder gravel of the Kennebec esker is seen in the lowest part of the section in the western part of the pit. The large boulders in nearby spoil piles were excavated from this deposit. The esker is overlain by a well-stratified sand and gravel unit, which is faulted where it adjoins the esker. This sand and gravel unit is also exposed at higher levels on the southern and eastern sides of the pit. Its low altitude above sea level (30 m or less) and relationship to the Presumpscot Formation indicate a submarine depositional environment. The deposit may be considered deltaic, but is was not built up to the contemporary sea level. This characteristic is typical of many other glaciomarine sand and gravel deposits in coastal Maine, including portions of the stratified end moraines. Evidently they were deposited by meltwater currents entering the ocean from within the ice at a position below sea level. Thus, they are "subaqueous outwash" as described by Rust and Romanelli (1975).

The upper level on the south side of the pit exposes about 10 m of section. (This may not be freshly exposed during our trip, but is seen in Figure 11 of Thompson (1982)). The vertical face shows massive clayey silt (typical Presumpscot Formation) overlying the sand and gravel mentioned above. Two wide channels have been cut into the sand and gravel and subsequently filled with the glaciomarine silt. Here the contact between the two units is sharp and unconformable. The bottom of one channel is floored by gravel that may have been eroded from the underlying deposit. A similar relationship between the subaqueous outwash and overlying marine silt can be seen along the entrance road in the southeast part of the pit.

Slumping has concealed much of the east wall of the pit, but it is evident that at least two facies of the Presumpscot Formation sharply overlie cobble gravel in this area. The lower facies consists of about 2 m of unstratified blue clay with abundant shells (principally Mytilus edulis). This clay is overlain by a few meters of non-fossiliferous interbedded clay and sand. The latter unit in turn grades upward into a sand unit whose thickness is about 2 m. The sand is probably correlative with the thicker, well-stratified sand that is seen in the north wall of the pit. The origin of this sand is uncertain, but it may be a shallow-water deposit that formed during the regression of the sea.

Leave Williams Pit and return to Route 27.

19.55 Turn left on Route 27 and go north toward Randolph.

23.40 Turn right onto Route 194.

28.95 Bear left at fork in East Pittston, staying on Route 194.

29.30 Turn right (south) on unnamed paved road.

30.70 Junction, keep to left.

32.65 Turn right. Park at entrance to gravel pit.

STOP 3 - CROOKER PIT
(Whitefield; SE 1/9 of East Pittston 7.5-minute quadrangle)

The Crooker Pit is located in the distal part of a glaciomarine delta. It is a fine example of a particular type of ice-contact delta that is fairly common in southern Maine: deltas that formed where meltwater streams issued from gaps along northeast-trending bedrock-controlled ridges. In this case, the highly collapsed and kettled proximal margin of the delta is situated between Palmer Hill and the unnamed hill to the southwest (Figure 2). The surface of the delta has been cleared for blueberry cultivation, and displays numerous shallow kettles and meltwater channels. An especially prominent channel parallels the road, across from the entrance to the Crooker Pit. Bedrock striations on the southerly spur of Palmer Hill trend 145°, and a bouldery drumlinoid ridge on the unnamed hill likewise trends southeastward.

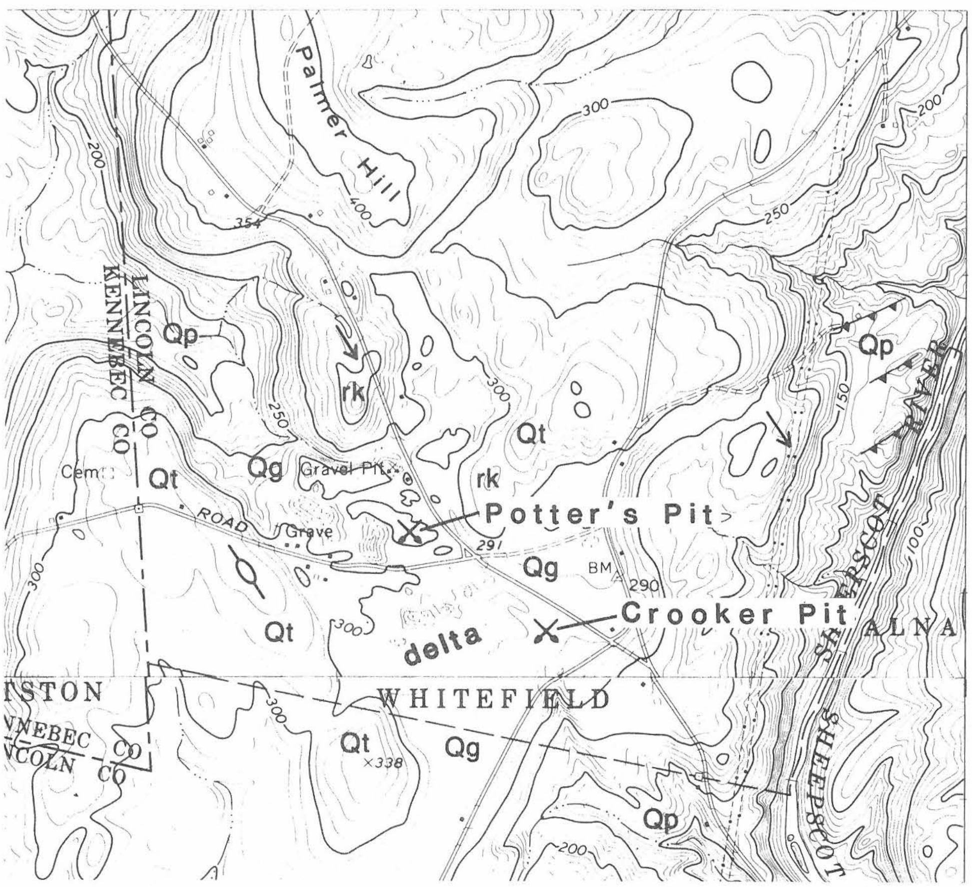

Figure 2

Map showing location of Crooker Pit (Stop 3) and topography of the glaciomarine delta. Contour interval is 10 feet. Scale is 1:24,000.

The Crooker Pit exposes about 10 m of section in the distal part of the delta. The topset beds consist of up to 3 m of poorly stratified cobble-boulder gravel, while the foreset beds consist of well stratified sand and lesser gravel. The foresets dip in various directions, but generally to the east or southeast. Scattered lenses of marine clay have been encountered among the foreset beds, though none are exposed at present.

The altitude of the topset-foreset contact has been surveyed in Potter's Pit, which is located in the proximal part of the delta (northwest of the Crooker Pit). It was found to be 89 m (291 ft) above present sea level. Many other deltas have been surveyed as part of a neotectonic study, and the resulting isobase map indicates an apparent postglacial tilt of 2.6 ft/mi across south-central Maine (Thompson and others, 1983). The altitude of the topset-foreset contact may vary by 3-5 m in a single delta, and tends to be lower in the seaward direction. Thus the highest altitudes were selectively used in contouring the maximum level of marine submergence.

Leave Crooker Pit and return by previous route to Route 194 near East Pittston.

36.00 Turn left on Route 194.

41.90 Turn right (north) on Route 27.

43.20 Turn left, staying on Route 27, and cross bridge over Kennebec River.

43.40 Turn right at end of bridge. Continue north on Route 27.

47.40 In Hallowell village, turn left on Winthrop Street (watch closely for street sign). Ascend steep hill and proceed west on this unnumbered road.

48.60 Cross over Maine Turnpike.

49.90 Pass historic Hallowell granite quarries on left.

51.70 Turn left on U.S. Route 202.

51.90 Turn right at traffic light in Manchester onto Route 17.

52.65 Turn right onto unmarked street (formerly Myrtle Street).

52.90 Turn left and park at pit entrance.

STOP 4 - MANCHESTER TILL PIT
(Manchester; NW 1/9 of Augusta 7.5-minute quadrangle)

This pit exposes about 15 m of an unusual type of till deposit that is not commonly seen in New England. Most of the pit face shows layers of till alternating with sand and gravel layers (Figure 3). The thickness of the beds is generally less than one meter, and they dip uniformly to the south at 10-15°. Some of the beds are clearly composed of till, while others appear intermediate between till and gravel. Angular striated stones are common in both the till and washed layers.

The till at the north end of the pit is not so prominently stratified, but it does contain numerous deformed lenses of sand, silt, and gravel. The nature of the contact with the well-stratified part of the deposit to the south is in need of investigation to determine whether it is transitional or unconformable.

Unstratified cobble-boulder gravel overlies part of the till deposit. The surface altitude of the gravel is about 104-107 m (340-350 ft), which is right at the limit of marine submergence in this area. Thus it was originally thought that the gravel might be a beach deposit. However, numerous till inclusions were recently noted in the gravel unit, and the gravel is too coarse grained to have been derived from reworking of the underlying stratified till. Therefore, it seems more likely that the gravel is an ablation deposit.

The age of the till is believed to be late Wisconsinan. With the exception of the washed layers, its field properties resemble those of fresh late Wisconsinan till that occurs in similar geologic terrain throughout southern Maine. However, the origin of this particular deposit is still uncertain. The types of structures that occur in subaquatic flow tills (Evenson and others, 1977) have not been found here. In 1980 this pit was examined by the INQUA Commission on Genesis and Lithology of Quaternary Deposits. Their consensus was that the layered unit is probably a basal melt-out till--a conclusion supported by the presence of both lodgment and ablation characteristics, and features such as elongated stones that are perched on-end where they dropped into position from the base of the ice (A. Dreimanis, pers. comm.). It is noteworthy that a northeast-striking bedrock ridge occurs at the proximal end of this deposit (Figure 4). Ice-flow over this ridge may have produced a zone of reduced stress in the lee of the ridge, where conditions favored accumulation of basal melt-out till. The author has observed similar thick deposits of laminated till at two other localities in southwestern Maine. One of these is the core of the Great Hill drumlin in Eliot, Maine.

Figure 3

Eastward view of the Manchester till pit. Stadia rod (bottom center) is 10 ft high.

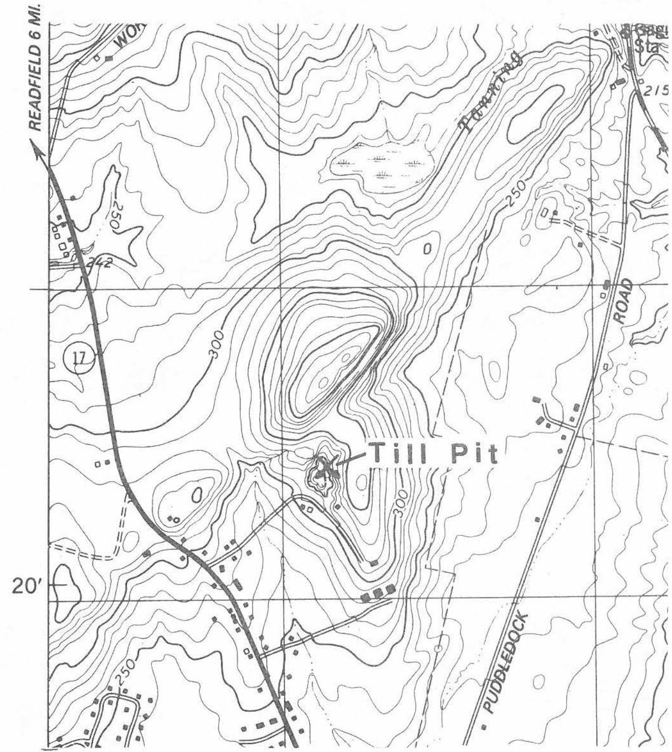

Figure 4

Map showing topographic setting of Manchester till pit (Stop 4). Contour interval is 10 ft. Scale is 1:24,000.

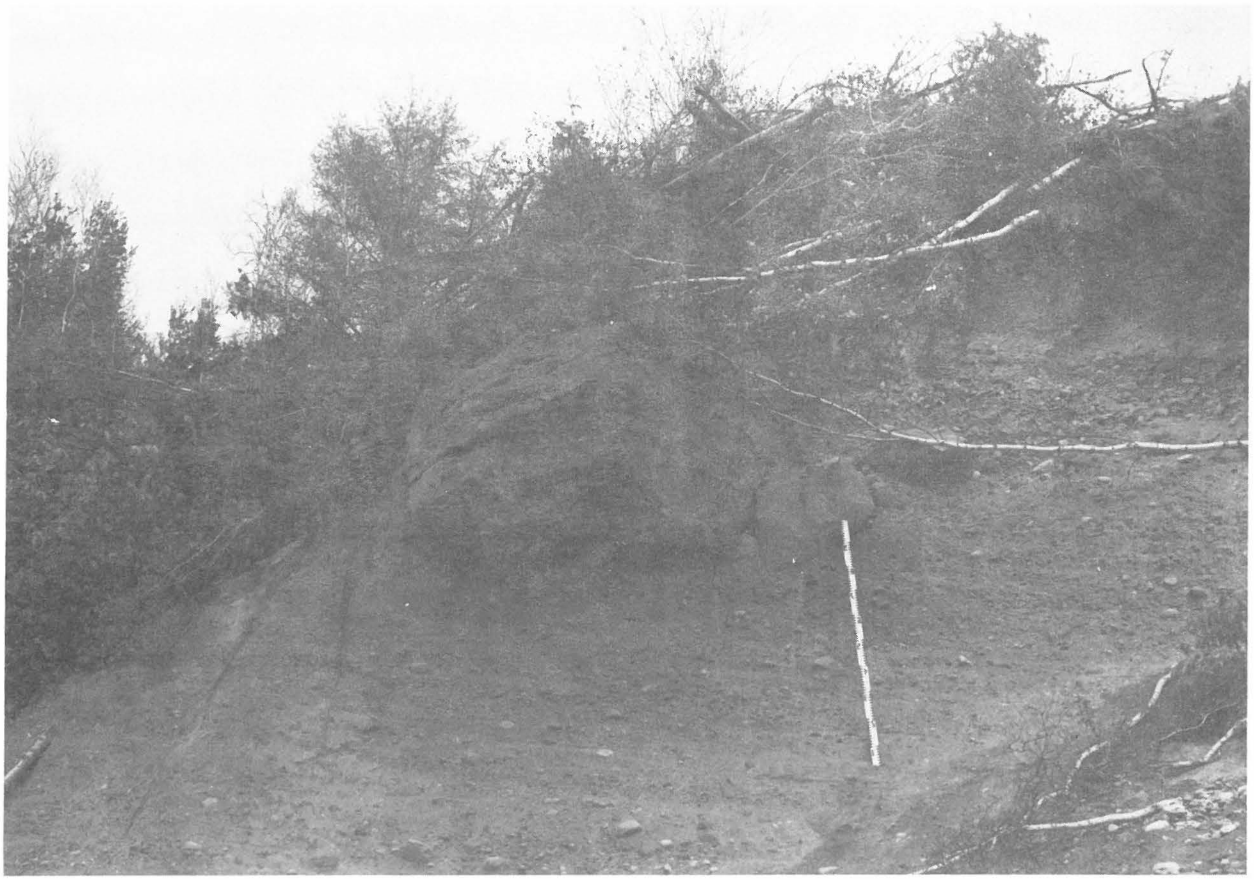

Figure 5

Large boulders (ablation deposit) on top of stratified till unit, Manchester, Maine. Stadia rod is 10 ft high.

Return to intersection in Manchester, turn right, and continue west on Route 202.

59.55 Turn left onto Annabessacook Road at Bruneau's Market.

60.05 Turn left onto unnamed paved road. Bear left at next fork.

60.25 Turn right and park at entrance to gravel pit.

STOP 5 - MASON PIT

(Winthrop; SW 1/9 of Winthrop 7.5-minute quadrangle)

This sand and gravel deposit is part of a linear feature that trends north-northeastward along the west side of Lake Annabessacook. Up to 15 m of mostly well-stratified sand and gravel are exposed here. The bedding is locally collapsed and dips in various directions, though exposures in 1982 showed a uniform eastward dip in the east wall of the pit. Silty sand of the Presumpscot Formation occurs in a highly collapsed zone in the northeast part of the pit. The lower part of this deformed marine unit is fossiliferous. Many of the shells have dissolved, but relatively well-preserved *Hiatella arctica* shells formerly were abundant here. They have been radiocarbon dated at 12,445 $\pm$ 100 yr B.P. (SI-4649). Articulated specimens were common, so the shells probably had not been transported very far.

This sand and gravel deposit is believed to be an end moraine. It is one of a series of drift ridges that occur in northeast-trending valleys in the lakes region west of Augusta and which have been described by Thompson (1976b). The orientation of these valleys is controlled by the strike of adjacent bedrock ridges, and the end-moraine ridges generally occur in the valley bottoms. The majority of the end moraines are stratified and occur below the marine limit. Local interlayering with the Presumpscot Formation indicates that they formed during the period of submergence. Clusters of till ridges also occur in this setting (Stop 6), but they are slightly above the marine limit.

The stratified ridges in this area resemble eskers in some cases, and they trend more northerly than most end moraines in southern Maine. However, they are identified as end moraines for several reasons, including the following: (1) they are on strike with and close to definite end moraines composed of till, such as the one seen at Stop 6; (2) the current indicators at several localities show sediment transport mainly to the east, rather than parallel to the ridges; and (3) bedrock striations at one locality southeast of Readfield Depot indicate ice flow normal to the neighboring ridge. Moreover, an esker ridge from the northwest appears to have fed part of the end moraine west of Lake Annabessacook.

At the time of the INQUA visit (1980), the deformed fossiliferous sand mentioned above appeared to lie on-strike with a prominent ice-shove(?) structure in the eastern part of the pit. The latter structure comprised a large mass of glaciomarine silt that had been underthrusted to the east, beneath a zone of subaqueous outwash. If these structures actually resulted from ice-shove (vs. slump), the shell date should closely indicate the time of deglaciation.

Turn left out of pit and return to Route 202.

60.95 Turn right on Route 202, toward Winthrop.

61.00 Exit right onto Routes 133 and 41.

62.80 Road forks. Keep left on Route 133 toward Wayne.

63.40 Turn left onto Pamela Drive (watch closely for sign).

63.50 Turn left and park at entrance to small pit.

STOP 6 - WINTHROP TILL PIT
(Winthrop; WC 1/9 of Winthrop 7.5-minute quadrangle)

This pit shows two major varieties of till that occur in the Augusta area. It is one of the few places where they can be seen in superposition (Figure 6). At this locality the upper till happens to form an end moraine that overlies a mound of the lower till. The sharp-crested topography of the moraine can be observed by following it into the woods southwest of the pit. Several other short, steep-sided moraines occur in the woods on the northeast side of Route 133.

The upper till is sandy and extremely stony. It is the source of the large boulders that litter the pit floor. The moist Munsell color of the till is 5 Y 5/3 (olive). Stratified sand lenses formerly were exposed in the core of the end moraine, and the distal part (seen in the southeast wall of the pit) is well washed and gravelly.

Figure 6

View to southeast of Winthrop till pit. Note the sharp contact between the two tills (center) and the abundance of boulders in the upper till. Highest part of pit face is about 8-10 m.

The lower till is finer grained than the upper till. It has a silty matrix and contains few stones larger than cobble size. Its color is 5 Y 4/2 (olive gray). Fissility is developed below the contact with the upper till, and dark brown iron/manganese-oxides coat joints and fracture surfaces. The lower till is also very compact and hard to excavate.

It is difficult to determine the macrofabric of these tills because most of the stones are sub-equidimensional. After considerable effort, a 25-stone sample was obtained from the lower till in the small trench that is presently seen on the pit floor. In spite of the small sample size, the fabric displays a strong NNW-SSE orientation (Figure 7). This trend is essentially the same as the orientation of several drumlin axes in the Sturtevant Hill area, about 1.5 km north of here. Bedrock striations in the vicinity trend 160-170°. The lower till may constitute many of the drumlins and other streamlined hills in southern Maine, as it does in southern New England.

The age relationship between the tills at Stop 6 is uncertain. However, they may be stratigraphically equivalent to two tills that have been described from localities in New Hampshire and southern New England (Pessl, 1971; Newton, 1979). The latter are referred to informally as the "old" and "new" tills since field evidence has show them to be of different ages. The new till clearly is late Wisconsinan, while the age of the old till is probably early Wisconsinan. Some of the criteria used to demonstrate that these tills are of different ages have also been observed at Stop 6. First, the iron/manganese-oxide staining of the lower till seems to indicate a greater degree of weathering than in the upper till. Second, the contact between the tills (which formerly was much better exposed) is sharp and erosional. Rounded inclusions of the lower till were found in the lower part of the upper till.

The regional extent of the tills seen at Stop 6 and their relationship to several tills that have been described in central and northern Maine are yet to be defined. Perhaps the lower till at this locality is equivalent to Caldwell's New Sharon till in the vicinity of Farmington, Maine (Caldwell, 1959), or one of the lower tills studied by Borns and Calkin (1977). An investigation is planned to sample key till localities around the state and compare several of their properties in an attempt to correlate the tills.

Return to Route 133, (note end moraine on other side of road), turn left, and continue northwest through Wayne village.

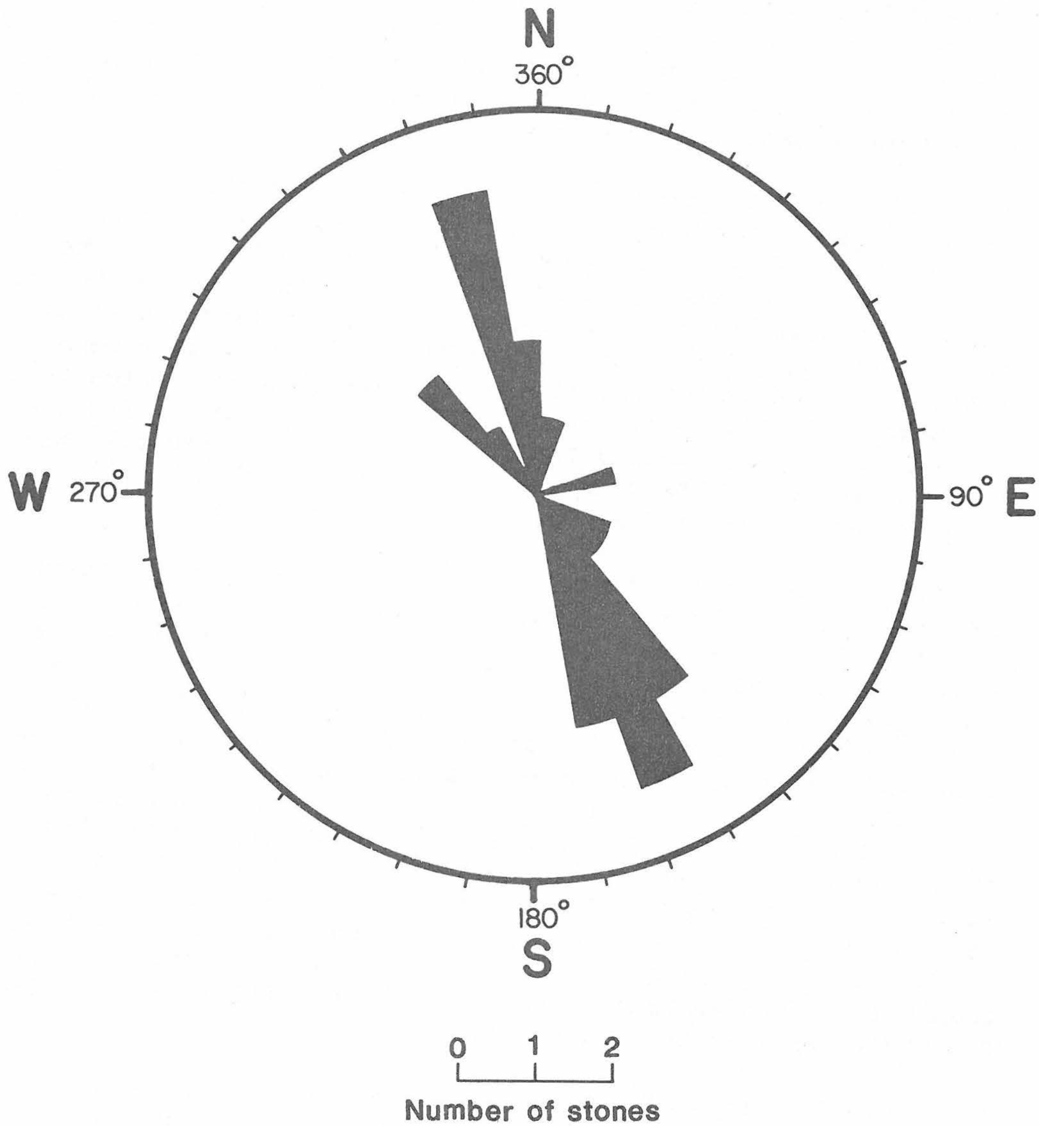

Figure 7

Rose diagram showing long-axis orientations of a 25-stone sample from the lower till at Winthrop. Azimuths were plotted in direction of plunge.

70.2 Turn right onto unnamed paved road (resembles private drive). Stay on this road, which curves sharply to right about 0.5 mile from Route 133.

70.9 Park on right side of road and walk across to large area of exposed sand.

STOP 7 - "DESERT OF WAYNE"
(Wayne; SW 1/9 of Fayette 7.5-minute quadrangle)

If time permits, we will visit this interesting deposit of eolian sand. It is part of an extensive area of windblown sand that occurs in the northwestern corner of the Wayne Quadrangle and the southwestern part of the Fayette Quadrangle. It is similar to a more famous eolian deposit in Freeport, which is a tourist attraction known as the "Desert of Maine".

Caldwell (1965 NEIGC) demonstrated that the eolian sand in Wayne was derived from glacial sand deposits in the Androscoggin River valley, a few kilometers to the west. He noted the wind-polished west sides of boulders, the thicker sand accumulations on the east (lee) sides of hills, and other lines of evidence for a westerly source. Southeast-trending longitudinal dunes are clearly seen on the 7.5-minute quadrangle maps. McKeon (1972) likewise concluded that the dominant late-glacial wind direction in central Maine was from the northwest.

The dune field in Wayne is believed to have been deposited in late-glacial time, before the establishment of a vegetation cover. However, local tradition claims that the dunes were reactivated in historical time. This recent activity is indicated by the broad areas of exposed sand and partly buried trees. The renewed sand movement presumably resulted from poor agricultural practices, such as overgrazing.

END OF TRIP

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FIELD TRIP B

LATE WISCONSINAN GLACIOMARINE DEPOSITS AND END MORAINES, LINCOLN AND KNOX COUNTIES, MAINE

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INTRODUCTION

The object of this field trip is to examine the variety of stratigraphic units and morphologic features produced in a portion of central coastal Maine during retreat of the Late Wisconsinan ice sheet. The exposures for this trip have been selected to illustrate some of the evidence that has led to the belief that ice retreat in this area was accomplished by actively flowing marine-based ice. The mechanics of ice retreat and the sedimentology of the sequence of glaciomarine deposits is, as yet, not well understood. It is therefore hoped that there will be open comment and discussion during the course of the trip.

The surficial geology of the quadrangles covered on this field trip has been mapped at a scale of 1:24,000. The original mapping by Smith and Anderson (Maine Geological Survey Open-File Reports) was undertaken during the early phases of the Maine Geological Survey's inventory mapping program. As a result, much of this work is already in need of revision. More detailed study of portions of the Union and Waldoboro East 7.5-minute quadrangles has been completed by Stemen (1979) and Jong (1980). In addition, information bearing on the stratigraphy and glacial geologic history of this part of the Maine coastal zone can be found in the following publications: Smith, 1974; Smith, Stemen, and Jong, 1982; Smith, 1981; Smith, 1982; and Smith, in press. Publications by Thompson (1979; 1982) provide helpful general references for the surficial geology of the entire coastal zone.

GENERAL GEOLOGIC SETTING

Retreat of Late Wisconsinan ice from its maximum position on the continental shelf was underway between 17,000 BP and 15,000 BP, and ice had withdrawn to the position of the present coastline in central Maine by approximately 13,000 BP (Smith, in press). Stratigraphic evidence from the coastal region (Borns and Hughes, 1977; Thompson, 1982; Smith, 1981, 1982, in press) indicates that marine submergence of the isostatically depressed landscape was contemporaneous with ice withdrawal, and that ice retreat was accomplished, in large part, by calving into the open sea. Withdrawal of the marine-based ice sheet across the coastal zone proceeded rapidly, so that ice had reached a position above the marine limit along its entire extent between 12,600 BP and 12,400 BP. The late-glacial marine transgression reached its maximum extent at this time. Emergence of the central coastal zone, resulting from isostatic recovery, was complete by 11,500 BP.

GLACIAL STRATIGRAPHY

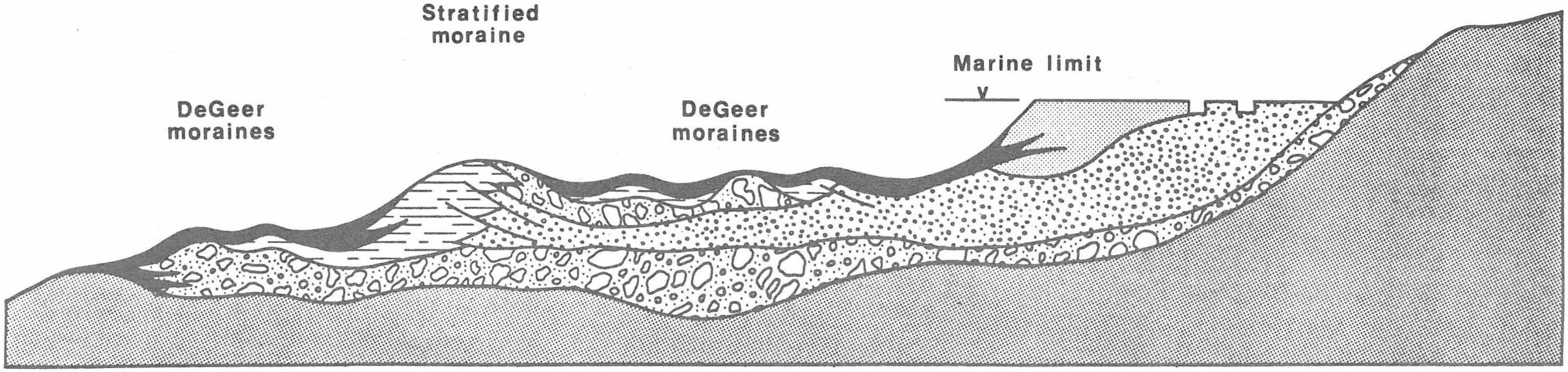
Glacial and glaciomarine deposits of the central Maine coastal zone include, in ascending stratigraphic order: till, ice-contact stratified drift, subaqueous outwash, and marine silt and clay of the Presumpscot Formation (Figure 1). All of these deposits are assigned to the Late Wisconsinan stage of glaciation, and the great majority of exposed deposits below the marine limit are related to final ice retreat and marine submergence.

TILL occurs throughout the coastal zone, both above and below the marine limit. Below the marine limit, till is found in a variety of genetic types, not yet adequately studied or fully understood. Lodgment and flow till comprise the cores of many small moraines, and lodgment till commonly forms a carapace over the proximal slopes of large moraines. Locally, tills appear to be waterlain. The tills exposed below the marine limit imply, both by virtue of their close association with marine sediments and by the waterlain character of some, that ice was in contact with the sea during glacial retreat and during deposition of the tills.

ICE-CONTACT STRATIFIED DRIFT in the coastal zone overlies till and is overlain by a variety of sediments of the recessional sequence (Figure 1). The most frequent occurrence of ice-contact stratified drift below the marine limit is within the cores of both large and small end moraines in the recessional sequence.

Stratified sand and gravel that underlies and intertongues with the Presumpscot Formation has been interpreted (Smith, et al., 1979; Smith, 1982; Thompson, 1982) as SUBAQUEOUS GLACIAL OUTWASH (Rust and Romanelli, 1975). These deposits typically display both fluvial sedimentary structures and tectonic deformation. The character of deformation suggests that ice remained active during retreat, and that general withdrawal of ice was interrupted by periodic local advances of the ice front. The stratigraphic relationships of the outwash deposits, both within moraines and intercalated with Presumpscot Formation sediments, indicate that they were deposited in a subaqueous (submarine) setting in proximity to the ice front (Smith, 1982).

The PRESUMPSCOT FORMATION is a marine deposit of glacial rock flour that occurs as a discontinuous cover of sediment up to 50 m thick throughout the area of late-glacial marine submergence. It bears a complex stratigraphic relationship to other glacial sediments below the marine limit. Although it generally overlies till with sharp contact, some



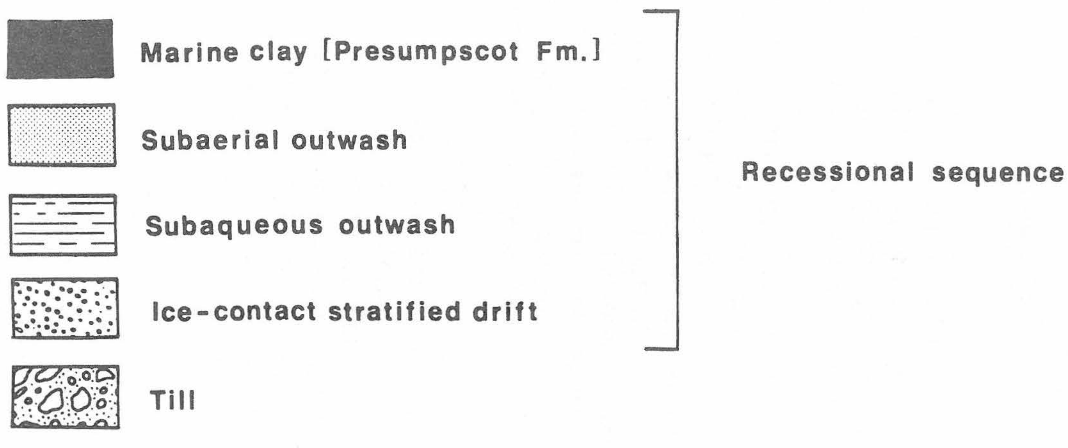


Figure 1. Stratigraphy of glacial and glaciomarine deposits in central coastal Maine.

waterlain tills contain thin layers of the marine sediment. Subaqueous outwash generally underlies and intertongues with the Presumpscot Formation.

END MORAINES

End moraines and related ice-frontal features have been mapped throughout the coastal region of Maine from the present coastline to the inland limit of late-glacial marine submergence. There is, in addition, some evidence that larger moraines can be traced well inland above the marine limit. The most abundant of the ice-frontal features are DeGeer (washboard) moraines that occur as regularly-spaced linear ridges overlain by marine sediments. Interspersed between groups of DeGeer moraines are larger stratified moraines and ice-frontal deltas ("moraine banks") composed of ice-contact fluvial sediments that intertongue with marine deposits.

Although end moraines occur throughout the coastal zone, their size and concentration varies both regionally and locally. Whereas DeGeer moraines can be found most anywhere below the marine limit, larger moraines are more restricted in their occurrence. The moraines are best developed in eastern coastal Maine (Washington and Hancock Counties) and central coastal Maine (Lincoln, Knox, and Sagadahoc Counties). Here, moraines are larger and more continuous than elsewhere in the coastal zone. While end moraines are abundant in central coastal Maine, there is a general lack of ice-frontal deltas, though some have been mapped in the vicinity of the marine limit.

Pertinent aspects of the distribution of moraines can be summarized as follows: (a) DeGeer moraines occur exclusively below the marine limit, and larger moraines are optimally developed below the marine limit. This implies a genetic relationship between moraine development and marine submergence. (b) The axes of moraine ridges are aligned perpendicular to the direction of last ice movement as recorded by glacial striations on adjacent bedrock outcrops. (c) The moraines define a lobate pattern, generally concave downvalley in topographic lows and convex downvalley over topographic highs (Figure 2). This pattern mirrors the configuration of calving bays developed in glaciers that terminate in the sea. (d) Axes of large and small moraines are generally parallel to one another. In central and southern coastal Maine, there is no evidence of large-scale, regional cross-cutting as has been described in eastern Maine (Borns, 1973; Borns and Hughes, 1977). However, there are numerous instances of local cross-cutting relationships in the traces of DeGeer moraines (Figure 3).

This field trip will examine aspects of the morphology and composition of both large and small end moraines. More detailed information treating these aspects of the moraines can be found in Smith (1982) and Smith, Stemen, and Jong (1982), copies of which will be available on the field trip.

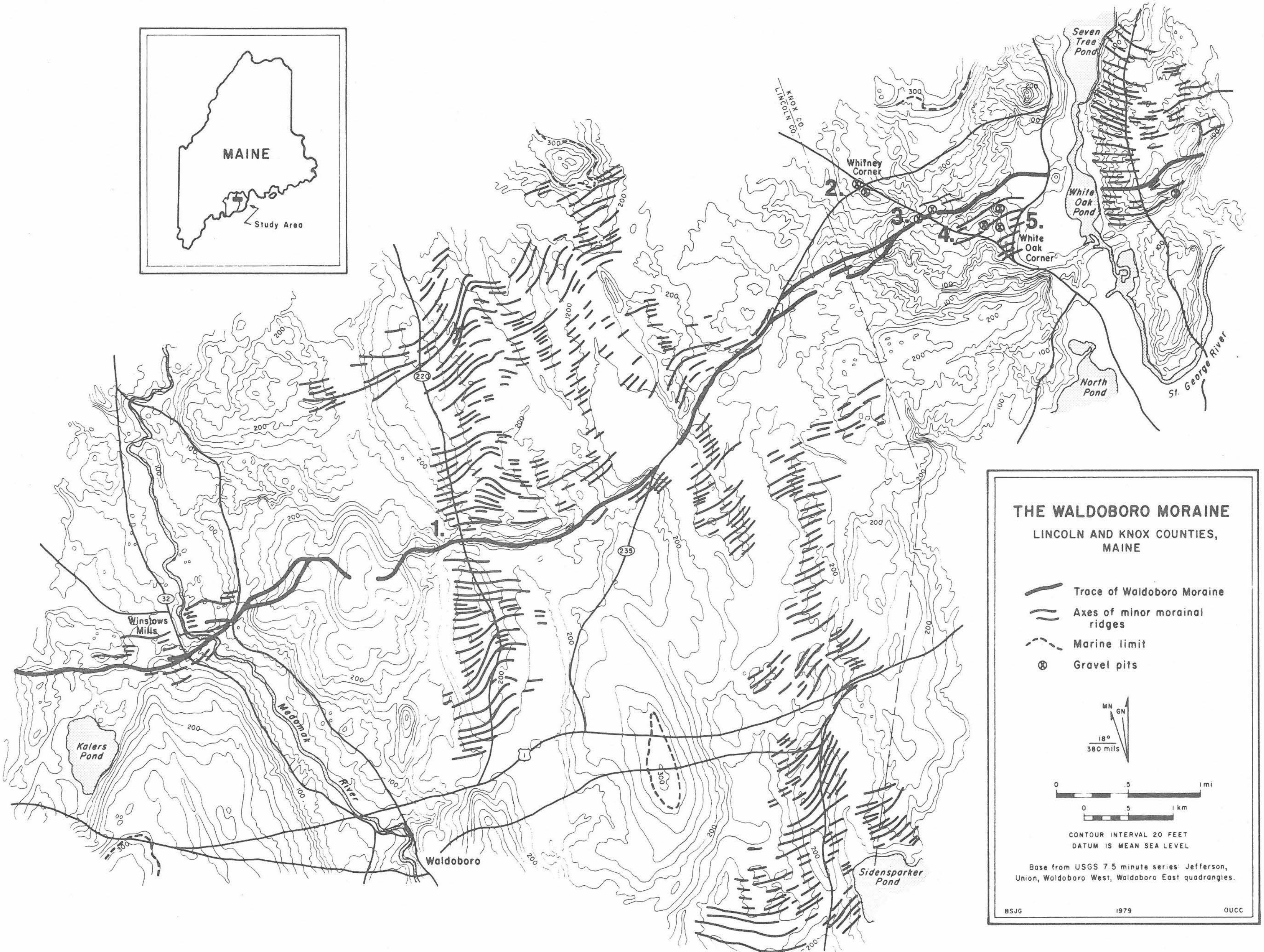


Figure 2. Map of the Waldoboro Moraine in Lincoln and Knox Counties, Maine, showing distribution of principal moraine ridges and relationship to DeGeer moraines (from Smith, 1982). Numbers indicate field trip stops.

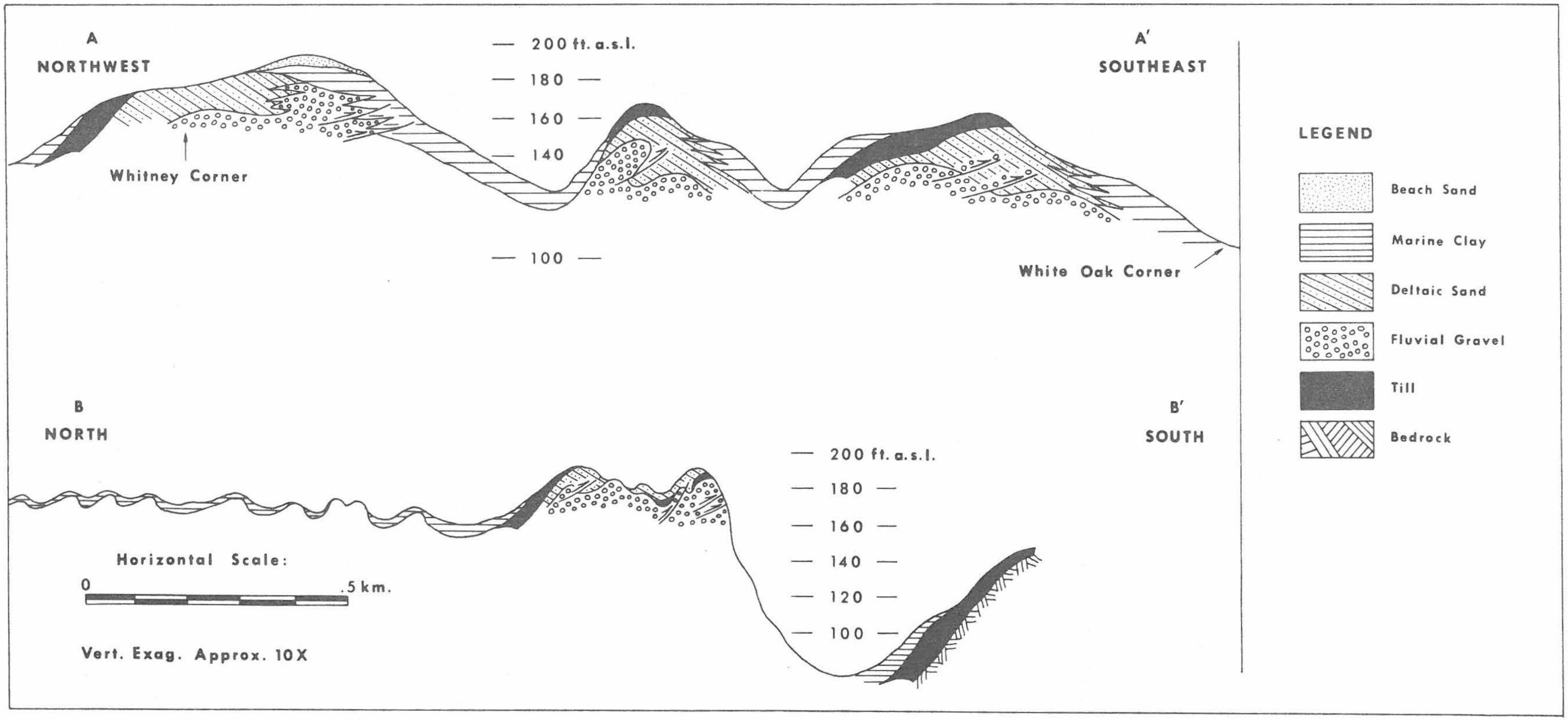


Figure 3. Stratigraphy of the Waldoboro moraine complex between Whitney Corner and White Oak Corner, Knox County, Maine (from Smith, 1982).

FIELD TRIP ITINERARY

Leave Holiday Inn (Augusta) and proceed east via Route 17 to Route 220 (approximate distance 22 miles). Turn right (south) on Route 220. Within 0.5 mile, route crosses flat surface of broad ice-frontal delta. The delta surface is at an elevation of 290+ feet a.s.l., and is the highest marine feature in the immediate area. It represents the limit of late-glacial marine submergence in this part of the coastal zone. The delta was fed by an esker that can be traced northward through the low hills to Sheepscot Pond. The surface of the delta is marked by kettleholes that indicate the proximity of ice during delta construction. Distributary levees and channels are clearly visible on the delta surface. Distal delta sediments cover small DeGeer moraines.

Mileage for the remainder of the field trip will be measured from the junction of Routes 220 and 126 at Globe.

Mileage

0.0 Junction of Routes 220 and 126 at Globe. Continue south on Route 220. The delta extends both east and west of the road. The esker mentioned above emerges from beneath the delta and parallels Route 17 for approximately 1 mile before turning south to Medomak Pond. Though poorly exposed south of Medomak Pond, the esker can be traced into the valley of the St. George River, where it underlies the moraines seen at Stops 2, 3, and 4.

Route continues south, leaving delta sediments and crossing marine clay (Presumpscot Formation). DeGeer moraines occur in the area of marine clay immediately north of the Medomak River.

1.4 Enter Lincoln County.

2.2 Cross Medomak River. Route rises above marine clay to till cover over bedrock. Within a mile or two south of the Medomak River, numerous east-west-trending DeGeer morains occur in clusters that can be traced southward to the Waldoboro Moraine (Figures 2, 3).

5.3 Leave Jefferson Quadrangle; enter Union Quadrangle.

6.8 Turn right onto unmarked road and park vehicles. Be careful walking along road to Stop 1.

STOP 1 - WALDOBORO MORAINE

This moraine was first described by G. Stone in 1899, and has been discussed by several workers since that time. It is one of the larger and more continuous moraines thus far mapped in the central coastal region. The moraine here consists of a single till ridge 10-15 m high and approximately 150 m wide at the base. The ridge form is distinctly asymmetrical, with the proximal slope (north) less steep than the distal slope. The occurrence of numerous large boulders along the moraine crest is typical of both the large and small moraines of the coastal zone.

The DeGeer moraines seen both north and south of the Waldoboro Moraine are representative of those found throughout the coastal region. These features:
(a) occur only below the marine limit;
(b) tend to concentrate in topographic lows and against the flanks of till uplands;
(c) are controlled in their orientation by topography;
(d) are regularly spaced within groups.

Spacing of the DeGeer moraines in this area ranges from 35 m to 100 m, averaging 65-70 m. The moraines range in height from 1-4 m, in width from 6-15 m, and are generally less than 0.5 km in length. The tonal difference between the moraines and the adjacent ground (marine clay) observed at this locality reflects the greater permeability of the sediments comprising the moraines. This tonal distinction is an essential aid in mapping the moraines by use of aerial photographs.

There is some suggestion that the larger moraines also occur with a regularity of spacing. Preliminary work on the moraines of this part of the coastal zone indicates that there may be as many as three or four distinct clusters of large moraines that parallel the DeGeer moraines. Spacing of the large moraine clusters is measured in kilometers rather than meters.

Return to cars, and continue south on Route 220.

7.1 Leave Union Quadrangle; enter Waldoboro East Quadrangle.

Road crosses thin mantle of till and marine clay over bedrock, and a series of DeGeer moraines. The character of the DeGeer moraines here is typical of their occurrence throughout much of the coastal zone. They are very subtle features, often discontinuous and without distinct ridge morphology. Commonly, as along the route south of the Waldoboro Moraine, the location of houses and cemeteries is coincident with the occurrence of the DeGeer moraines, a further aid in mapping the features.

8.7 Junction with Route 1. Turn left (east) for a distance of 0.9 mile. Turn left (north) on Route 235. Road crosses marine clay, then rises to till cover over bedrock. Again, both large and small end moraines can be seen (if you look closely) on either side of the road. A few inactive gravel pits mark the locations of some of the larger moraines.

10.8 Leave Waldoboro East Quadrangle; enter Union Quadrangle.

11.5 Waldoboro Moraine visible to west (left) of road. Height of the distal face of the moraine here is 5-6 m. The road parallels the moraine for a short distance, crosses a small stream in marine clay, then rises onto the moraine crest for a distance of about 1 mile. Note the hummocky aspect of the moraine crest and the abundance of large boulders. The moraine here consists of 2-3 distinct ridges. South (right) of the road, the moraine bifurcates before crossing the St. George River esker system seen at Stops 2, 3, and 4.

The route turns northeast, leaving the moraine to the south. The road then crosses marine clay and an area of DeGeer moraines before rising onto the esker/moraine complex at Stop 2.

13.8 Enter Knox County. Cross Fuller Brook.

14.1 Turn left into gravel pit.

STOP 2 - WHITNEY CORNER MORAINE EXPOSURE

This exposure is located within a group of large end moraines (referred to as the Waldoboro Moraine complex), here developed on an esker core (Figures 3, 4). The shallow pit north of the road exposes small (3 m high) till and gravel ridges overlain by well-sorted and stratified sand. The ridges, which are composed of highly-deformed waterlain till (?), are considered to be DeGeer moraines. The trend of the moraines can be reconstructed from scattered accumulations of large boulders within the pit. This exposure illustrates why many of the DeGeer moraines are so difficult to see on the ground surface.

The sand that overlies the moraines comprises an apron of subaqueous outwash that is traceable to the south where it intertongues with silt and clay of the Presumpscot Formation. An interesting variety of sedimentary structures in the sand suggests that it was deposited in a high-energy aqueous environment, probably close to the retreating ice front.

Excavations south of the road expose coarse sand and gravel (esker sediments) overlain by subaqueous outwash, fossiliferous marine clay, and beach deposits. The stratigraphy of the marine

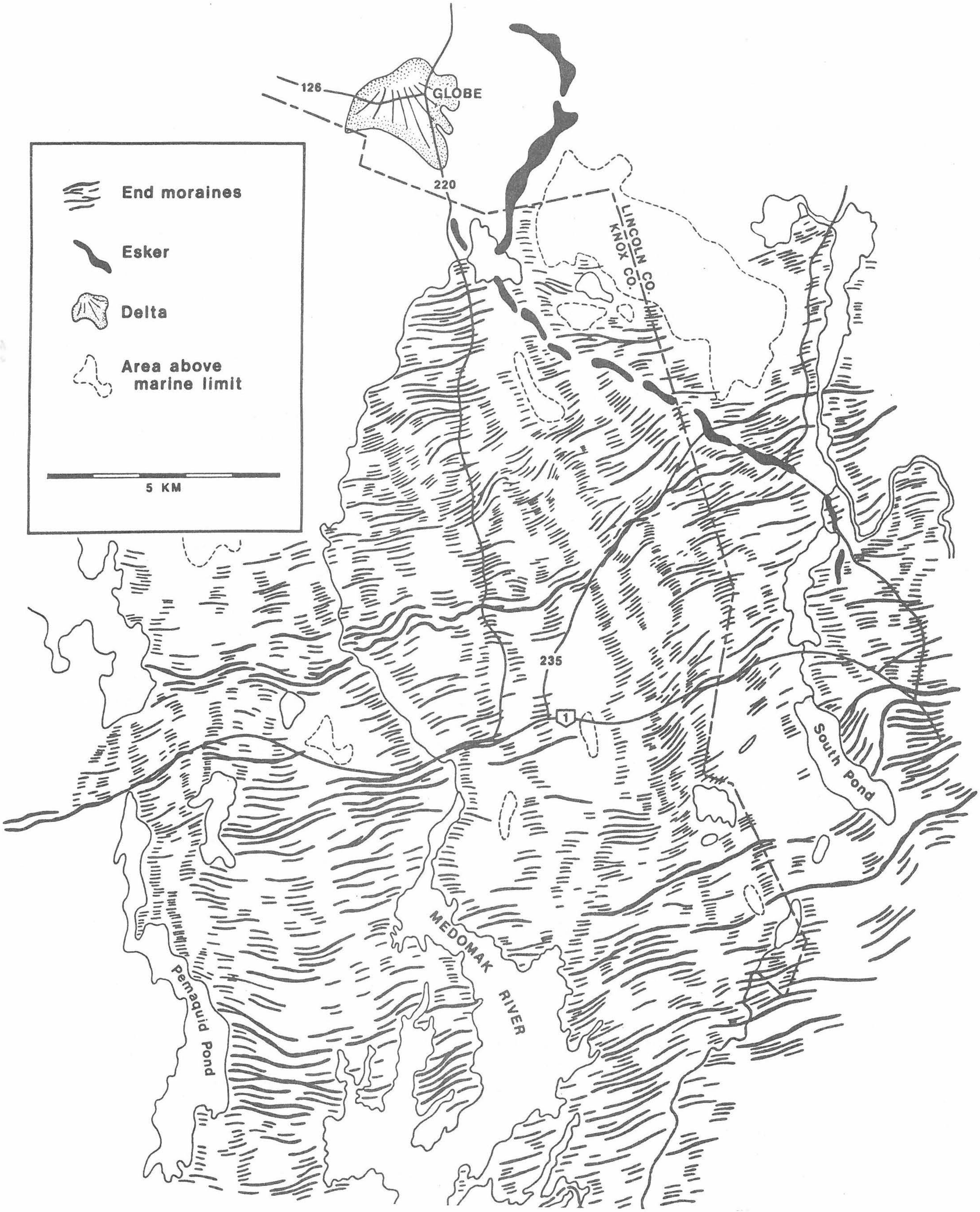


Figure 4. End moraines and glaciofluvial deposits of portions of Lincoln and Knox Counties, Maine (provisional).

and beach sediments exposed on the south face of the pit (top to bottom) is as follows:

4-5 m	Predominantly sand and pea gravel; cross-beds dip to SW. Basal zone of pebble and cobble gravel. Abrupt basal contact. BEACH SEDIMENTS washed from moraine and esker deposits.
1 m	Gray plastic clay and sandy clay.
1 m	Black plastic clay; wet. Mytilus zone. TIDAL FLAT. 11,760/105 BP (DIC-1600).
2 m	Gray plastic clay; moist. Abundant fauna, though less so than Mytilus zone. Abundance of shells diminishes with depth. Few sand lenses. 11,720/125 (DIC-1599).
3 m	Barren clay zone. Upper part plastic, becoming less so with depth. Sand lenses common. Basal contact abrupt.
undet.	Well-sorted medium-coarse gray-brown to brown sand. SUBAQUEOUS OUTWASH.

Fauna collected from the marine clay include: Chlamys islandicus, Hiatella arctica, Macoma sp, Mya truncata, Mytilus edulis, Natica clausa, Neptunea sp, Serripes groenlandicus, barnacles, echinoids, bryozoa, crabs. The radiocarbon dates on shells probably record the rapid influx of fauna to this site during a late phase of marine submergence following ice retreat.

Return to buses (cars), turn left out of pit, and continue northeast for 0.1 mile on Route 235. Turn right (southeast) on unmarked road. Rise to moraine crest. Shallow excavations on right expose beach deposits seen at Stop 2. Road descends distal slope of moraine, crosses marine clay, then rises to next moraine crest.

14.7 Turn left or right into gravel pits (if open) or park along shoulder of road. Be careful in crossing road.

STOP 3 - WALDOBORO MORAINE

The moraine exposed at this stop is considered to be the lateral equivalent of the moraine seen at Stop 1. Recent excavations both east and west of the road expose the stratigraphy and structure of the moraine, and have provided a clear picture of the interrelationships of the moraine sediments. The generalized stratigraphy of these pits is illustrated in Figure 3.

In the gravel pit on the east side of the road, till, comprising the proximal slope of the moraine, overlies deformed sand and gravel, considered to be both esker and subaqueous outwash sediments. Immediately to the north of this exposure, marine clay overlies the till. Of particular interest here is the nature of the till, best seen above the east face of the exposure. The till actually consists of a variety of genetic types, including lodgment till and basal melt-out till. Interbedded fine sand and silt within the till suggest that it was deposited, in part, in a subaqueous setting. Small-scale shearing, both within the till and within the washed sediments, indicates that ice was active during moraine construction. The till itself has been thrust southward over the underlying esker and outwash sediments. These latter sediments display both large- and small-scale shear phenomena as well as collapse structures related to melting ice. It should be noted that the till extends only to the moraine crest, forming a carapace over the proximal (north) slope of the moraine. The possible mechanisms of moraine formation can be discussed as we examine the deposits at this stop.

Cross road and enter pit on the west side of the road. The till in this pit is not well-exposed. Most of it has been removed as overburden. However, the character of the underlying sedimentary sequence is well-exposed. Sedimentary structures within this sequence indicate chaotic and very rapid deposition of these materials. Again, large- and small-scale shear structures indicate the presence of active ice during moraine formation. An overall decrease in grain size toward the distal (south) face of the moraine has been recorded here. Intertonguing of sand (moraine sediments) and clay (Presumpscot Formation) can be observed along the south face of the exposure. (Might these features be a variety of morphosequence?)

Return to buses (cars) and continue southeast for 0.6 mile. Turn left on dirt road into clearing.

15.3 STOP 4 - GLACIOMARINE SEDIMENTS

Shallow exposures here provide an opportunity to observe the character of the Presumpscot Formation in some detail as it occurs within the moraine complex. Till, comprising the proximal slope of a moraine, is exposed at the base of the section. The till is overlain, in sharp contact, by a stratified sequence of marine clay and till (flow till?). This sequence grades upward into dark colored organic clay and silt (tidal flat) that is highly fossiliferous. The section is capped by beach sand, similar to that seen at Stop 2.

This exposure is relatively new, and has not been worked on in any detail. I welcome any discussion concerning the nature of the tills and the depositional setting that is recorded here. Where was the ice when these sediments were deposited? When were these sediments deposited relative to the time of formation of the moraine?

Return to buses (cars) and continue southeast for 0.2 mile. Turn sharp left, and drive north for 0.3 mile.

15.8 Turn left (west) into large gravel pit. Park to the side of the main pit access road.

STOP 5 - WHITE OAK CORNER ESKER EXPOSURE

Over the years, this pit has provided perhaps the clearest picture of moraine stratigraphy in this part of the coastal zone. The pattern of gravel excavation (along the esker axis) and the depth of the excavation have presented a unique opportunity to view the moraine and the esker in all dimensions. The esker core, exposed in the main pit, is overlain by till and marine sediments. Till fabrics collected from the proximal slope of this moraine average N35-40W, paralleling the younger set of striae on nearby bedrock outcrops. Thrusting of ice-contact (esker) gravel upward into the overlying sand has been observed at several stages in the development of the pit. The upper sand is interbedded with marine clay south of this exposure.

Return to buses (cars). Leave pit and turn right (south). At White Oak Corner, bear left (southeast).

19.1 Leave Union Quadrangle; enter Waldoboro East Quadrangle.

19.4 Junction with Route 90. Turn right (southwest).

20.0 Junction with Route 1. Turn right (west). Proceed west on Route 1 for 0.7 mile.

20.9 Turn right (north) onto small unmarked dirt road. Park in field.

STOP 6 (optional) - DEGEER MORAINE EXPOSURE

This small pit has exposed the full dimensions of a till and gravel DeGeer moraine. The moraine is roughly 6-7 m high and 10-15 m wide at its base. It is overlain by an apron of subaqueous outwash sand, and is underlain by marine clay. The stratigraphy here would indicate that the moraine was formed entirely in a submarine setting.

The north face of the pit exposes interbedded marine clay and subaqueous outwash sand. Folds within the layers of clay have been considered to be the result of either (a) soft sediment deformation, or (b) ice push.

Return to buses (cars). Return to Route 1. Turn right (west), and proceed to Augusta via Routes 1, 32, and 17. (Approximate distance: 35 miles; approximate travel time: 1 hour)

END OF TRIP

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