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Title: *Surficial Geology of the China Lake 7.5-minute Quadrangle, Kennebec County, Maine*

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Surficial Geology of the China Lake 7.5-minute Quadrangle, Kennebec County, Maine

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INTRODUCTION

This report describes the surficial geology and Quaternary history of the China Lake 7.5-minute quadrangle in southern Maine (CL, Figure 1). Surficial earth materials include unconsolidated sediments (sand, gravel, etc.) of glacial, glaciomarine, and nonglacial origin. These deposits formed within the last 25,000 years during and after the latest episode of glaciation in Maine. Surficial sediments cover the bedrock throughout much of the area and are subject to many uses and environmental considerations. These include extraction of sand and gravel, development and protection of ground-water supplies, siting of waste disposal facilities, and agricultural uses.

Fieldwork for this study was carried out in 2004 for the STATEMAP cooperative between the Maine Geological Survey and the United States Geological Survey (USGS). Two maps accompany this report. The *geologic map* (Syverson and Mans, 2005) shows the distribution of sedimentary units and indicates the sediment age, composition, and origin. It also includes information about the geologic history of the quadrangle, such as features indicating the flow direction of glacier ice. The geologic map provides the basis for the discussion of glacial and postglacial history presented here. A glossary in Appendix A defines technical terms used in this report and on the map.

The *materials map* (Syverson and others, 2005) shows specific data used to construct the geologic map. These data include observations from gravel pits, shovel and auger holes, construction sites, and exposures along stream banks and roads. The materials map also shows boring logs. Woodrow Thompson (unpublished information) conducted reconnaissance field studies of active borrow pits in the China Lake region in 1982 and 1985, and in some cases his data are reported for pits that have closed or been reclaimed. A sand and gravel aquifer study by the USGS provided additional data about the type and thickness of surficial sediments in the quadrangle (Neil and Locke, 2000).

Geographic setting

The map area extends from 44°22’30" to 44°30’00" N latitude, and from 69°30’00" to 69°37’30" W longitude. It encompasses parts of the towns of Albion, China, Vassalboro, and Winslow in Kennebec County. Villages in the China Lake map region include China, East Vassalboro, North Vassalboro, South Vassalboro, and South China.

The China Lake quadrangle is located in the central interior of southern Maine (Figure 1). China Lake is a V-shaped lake that dominates the central part of the map. Two peninsulas separate the lake into two basins. The eastern basin is approximately 6.5 miles (10.4 km) long and oriented northeast-southwest parallel to the structural trend of the bedrock (see the next section). This part of China Lake is surrounded by houses and cabins and is used extensively for recreation. The western basin is approximately 4 miles (6.4 km) long and oriented northwest-southeast. The western basin serves as the water supply for Waterville, so land use is restricted and its shoreline is relatively undeveloped. A small dam on Outlet Stream at East Vassalboro keeps the level of China Lake at approximately 196 ft (60 m). The topography is rolling across much of the area. Elevations range from about 180 ft (55 m) above sea level at Threemile Pond in the southwestern part of the map to 501 ft (153 m) northeast of Dirigo Corner. Small streams drain the China Lake quadrangle. Meadow Brook and the West Branch of the Sheepscot River flow south out of the map area. Outlet Stream flows north from the China Lake basin, and several smaller streams and brooks drain the remainder of the map. China Lake, Threemile Pond, and numerous trails in the quadrangle provide attractive scenery and recreation opportunities for residents and tourists.

Bedrock Geology

Thin Quaternary sediments cover the bedrock throughout much of the China Lake quadrangle, and bedrock outcrops are common on hill crests and in river valleys (Syverson and Mans, 2005). A two-mile-wide section of the westernmost part of the quadrangle was mapped by Osberg (1968) at a 1:62,500 scale. The regional stratigraphic synthesis by Tucker and others (2001) extended the mapping at small scale and changed some formation assignments. The adjacent 7.5-minute quadrangle to the

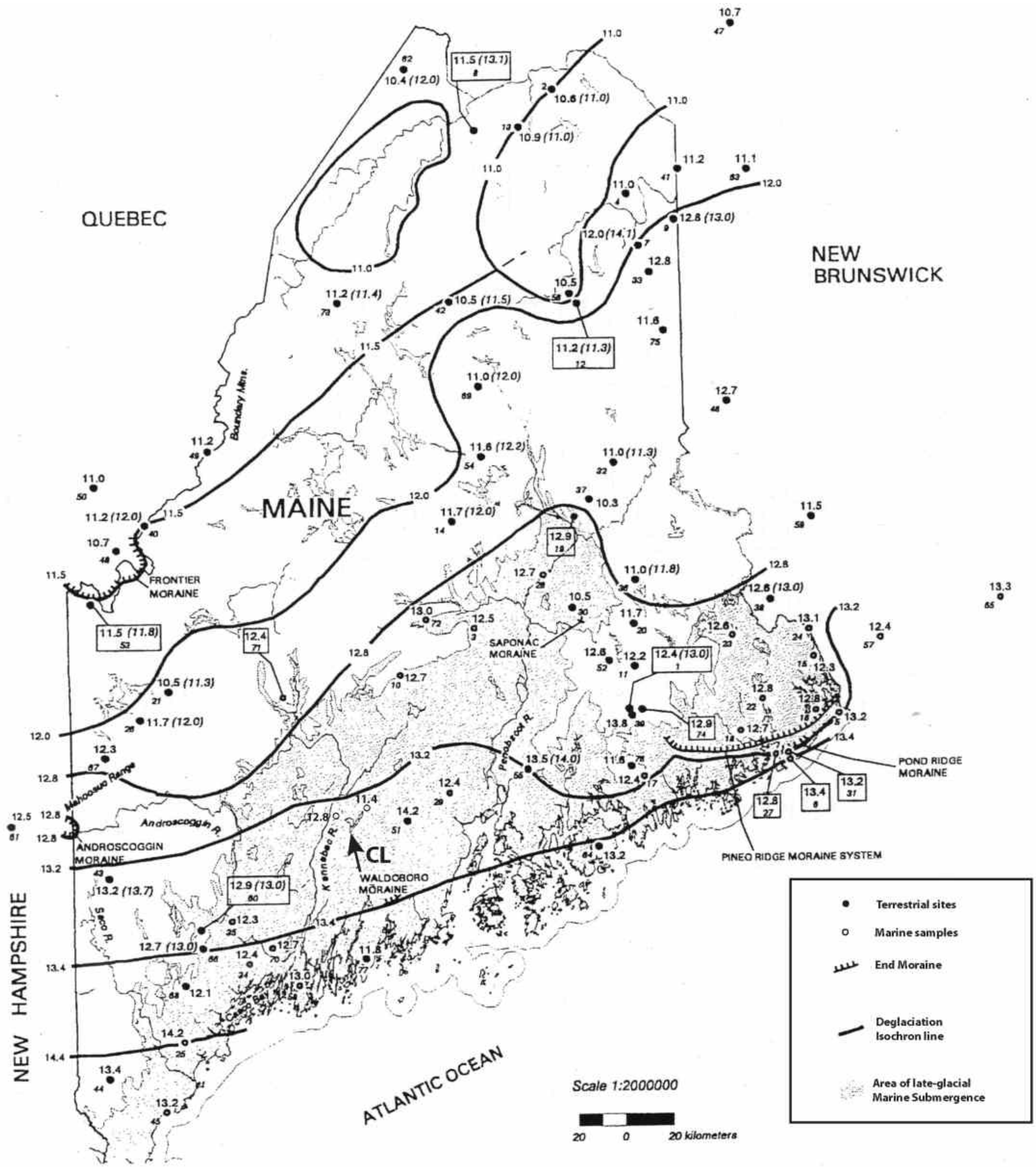

Figure 1. Approximate times of deglaciation for the State of Maine. Ages are reported in thousands of radiocarbon years using a -600-yr marine reservoir correction factor. The location of China Lake (CL) is indicated, as well as the two dates obtained during this study (12.8 and 11.4 to the west and east of China Lake, respectively). China Lake is well within the area submerged by the sea (shaded region) as the area was deglaciated. Modified from Borns and others (2004).

south was mapped by Grover and Fernandes (2003). The China Lake quadrangle is underlain primarily by schist, phyllite, and granofels of the Vassalboro, Waterville, and Hutchins Corner Formations. The rocks weather into a rusty, fractured, mica-rich material, so typically the bedrock does not preserve glacial striations well. The metasedimentary rocks strike northeast to southwest, and where present, the near-vertical foliation has a similar trend. The strike of the bedrock and foliation is clearly reflected by the linear ridges and valleys northeast of East Vassalboro and in the Dirigo Corner area. These rocks were deformed and metamorphosed during the Devonian Period as the Appalachian Mountains were being formed.

The Threemile Pond pluton is present in the southwesternmost part of the quadrangle. The Threemile Pond pluton contains medium- to coarse-grained, gray biotite granodiorite to granite intruded 381±1 million years ago during the Devonian Period (Osberg, 1968; Tucker and others, 2001; Grover and Fernandes, 2003). The oval pluton is oriented northeast-southwest and in places crosscuts the older metasedimentary rocks described previously. The lack of structural trends produces more rounded, nonlinear hills than those observed in the southeastern part of the quadrangle.

PREVIOUS WORK

Stone (1899) conducted a reconnaissance study of glacial gravels in Maine. Stone (1899:165-170, plate XLIII) described gravel deposits in linear features within the China Lake region. Marine deltas and morainal banks have been studied to determine the deglaciation history and relative sea-level chronology in eastern Maine (Thompson and others, 1989; Kaplan, 1999; Hunter and Smith, 2001; Retelle and Weddle, 2001). Borns and others (2004) published a comprehensive article summarizing the radiocarbon ages that constrain the deglaciation history of Maine (Figure 1). Hildreth (2005) and Weddle (2005) have mapped the surficial geology of the adjacent 7.5-minute quadrangles to the west and south, respectively. Although Thompson (1977) and Smith (1986) published reconnaissance-level surficial geologic maps of surrounding areas for the Maine Geological Survey, no surficial geologic maps have been published for the China Lake area.

Neil and Locke (2000) compiled a useful aquifer map of the China Lake quadrangle for the Maine Geological Survey's Significant Sand and Gravel Aquifer Project. Woodrow Thompson supplied information from his 1982 and 1985 reconnaissance field investigations of active borrow pits in the China Lake region, and this was very useful for pits that had ceased operation during the past twenty years. The U. S. Department of Agriculture's soil survey of Kennebec County (Faust and LaFlamme, 1978) supplied useful materials information for sites that the present authors did not visit in the field.

DESCRIPTION OF GEOLOGIC MAP UNITS

The surficial deposits represented on the geologic map have been classified on the basis of their age and origin. Map units are designated by letter symbols, such as "Pt". The first letter indicates the age of the unit:

"P"	- Pleistocene Epoch	(Ice Age, formed between 2-3 million years ago and 10,000 years ago);
"H"	- Holocene Epoch	(postglacial, i.e. formed during the last 10,000 years)

The other letters in the map symbol indicate the sediment type or origin of the sediment. For example, "t" represents glacial till and "g" represents gravelly sediment deposited by meltwater streams. Surficial map units in the China Lake quadrangle are described below, starting with the older deposits that formed in contact with glacier ice.

Till (unit Pt)

Till is sediment deposited directly by glacier ice that contains a more-or-less random mixture of sand, silt, clay, and gravel-size rock debris. The till typically includes numerous boulders. Till is the principal surficial material covering much of the upland portions of the quadrangle, and it may underlie younger glaciomarine deposits in the valleys. Some of the till in Maine may have been derived from glacial erosion of older surficial sediments (either glacial or non-glacial), while the remainder was eroded directly from nearby bedrock sources during the latest glaciation.

Exposures in the China Lake quadrangle reveal till at least 10 ft (3 m) thick, and well logs indicate that the till may be up to 80 ft (24 m) thick in the area of rolling uplands west of China Lake (Syverson and others, 2005). Bedrock commonly is exposed where the till cover is thin. A ruled line pattern on the geologic map shows areas where bedrock outcrops are common and/or the till thickness is inferred to be less than 10 ft (3 m).

Till generally rests directly on bedrock within the China Lake area. Till texture and structure are functions of the sediment source and the processes acting to deposit the sediment. In the China Lake quadrangle, the till matrix is clay-poor and dominated by sandy or silty-sandy micaceous material eroded from the metamorphic and coarse-grained igneous bedrock. The till usually has little or no obvious stratification. In some cases, it is crudely stratified with discontinuous lenses and laminae of silt, sand, and gravel resulting from sorting by meltwater or gravity flows during deposition. Stones are abundant in the till, and they are mainly coarse-grained igneous and metamorphic rocks derived from local bedrock sources. Most stones in the till are more-or-less angular, and some have smooth, flat, striated surfaces caused by subglacial abrasion.

Varieties of till formed below and above the glacial ice sheet. These include lodgement till, basal melt-out till, and ablation till. Lodgement till was deposited under great pressure beneath the ice sheet. It may be very compact and difficult to excavate ("hardpan"), with a platy structure (fissility) evident in the upper, weathered zone. Basal melt-out till is difficult to identify with certainty, but typically shows a crude stratification inherited from debris bands in the lower part of the glacier. Ablation till formed on top of the melting glacier and tends to have a sand-rich, loose-textured matrix with abundant stones and lenses of washed sediment. More than one of these till varieties may occur at a single locality.

Field evidence in southern Maine and elsewhere in New England suggests that till deposits of two glaciations are present in the region (e.g. Koteff and Pessl, 1985; Thompson and Borns, 1985; Weddle, 1989, 1992). The "upper till" was deposited during the late Wisconsinan Glaciation. The late Wisconsinan is the latest glacial event to cover southern Maine approximately 25,000 to 10,000 years ago. Exposures of the upper till can be seen in many shallow pits, road cuts, and temporary excavations. It is not weathered (except in the near-surface zone of modern soil formation) and is usually brown to olive brown in color. Lodgement and ablation facies of the upper till have been recognized in the China Lake quadrangle (Syverson and Mans, 2005; Syverson and others, 2005).

The "lower till" consists of compact, silty-sandy lodgement sediment. In southwestern Maine, as in other parts of New England, it is likely to be found in drumlins and other smooth, glacially streamlined hills where a considerable thickness of till has accumulated. These thick deposits often occur as "ramps" on the gentle northwest slopes of hills, while bedrock is exposed on the steeper, glacially plucked southeastern slopes. The lower till is distinguished by its thick weathering profile, which may extend to depths of 10 ft (3 m) or more. Within this weathered zone, the till is oxidized and has an olive-gray to dark grayish-brown color. Dark brown iron/manganese oxide stains coat the surfaces of stones and joints (Thompson, 1986). This till is thought to have been deposited during the Illinoian Glaciation prior to 130,000 years ago (Weddle and others, 1989). The "lower till" was not observed in the study area.

End moraines

End moraines are ridges of sediment deposited at the margins of glaciers. They may form in many different ways, but generally are sediment accumulations derived from the adjacent glacial ice (or shaped by glacial processes at the ice margin). Moraine ridges commonly are strewn with boulders on the surface. Their interiors are seldom well exposed, but surface indications and shallow pits suggest that most end moraines are comprised largely of till with locally abundant lenses of sand and gravel. In the west-central part of the China Lake quadrangle, several low ridges trending east-northeast to west-southwest are likely end moraines (Syverson and Mans, 2005).

Esker deposits (unit Pge)

Two major esker systems (Pge) are present in the China Lake quadrangle. One is located in the Outlet Stream valley west of East Vassalboro; the other extends south of China Lake immediately west of Route 32. These segmented ridges of sand and gravel were deposited by meltwater streams flowing southward in tunnels at the bottom of the last glacial ice sheet.

Much of the sediment carried through the ice tunnels was deposited into the ocean, with the coarse material forming subaqueous fans and deltas at the glacier margin, while the fine-grained muddy sediments were dispersed across the sea floor and became part of the Presumpscot Formation. A prominent series of glaciomarine deltas and fans occurs along the esker system south of China Lake (Syverson and Mans, 2005; Weddle, 2005). The Outlet Creek system is largely a series of discrete gravel hills rising above the surrounding flat lowland, morphology sometimes referred to as a "beaded esker." Each "bead" likely represents sedimentation at the ice margin to form a miniature version of a submarine fan.

In the China Lake quadrangle, exposed sections in the eskers are up to 50 ft (15 m) high. Pits in the eskers reveal material ranging from stratified gravelly sand to pebble-boulder gravel (Figure 2). Boulder-rich gravel generally lacks stratification and represents extremely rapid sedimentation in a tunnel from high-energy water. Glaciomarine silt and clay of the Presumpscot Formation commonly drape the eskers (Pp/Pge), and this drape thickens away from the esker crest. The eskers are important both as potential aquifers and sources of sand and gravel. The materials map (Syverson and others, 2005) shows

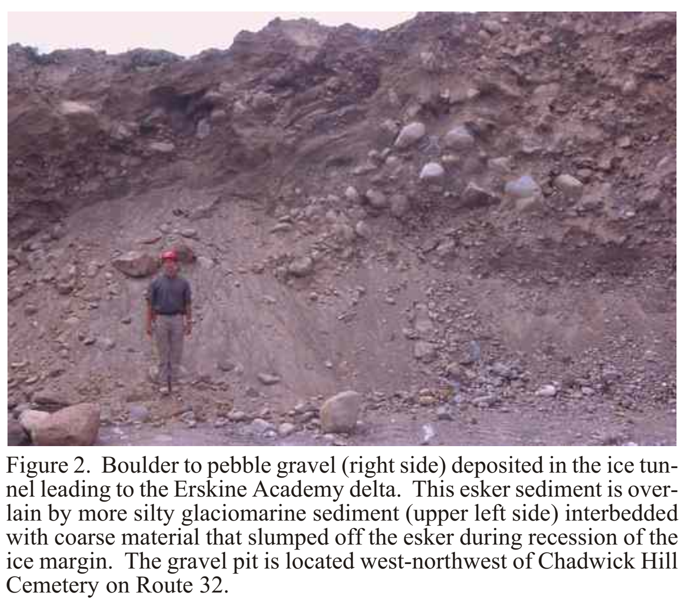

Figure 2. Boulder to pebble gravel (right side) deposited in the ice tunnel leading to the Erskine Academy delta. This esker sediment is overlain by more silty glaciomarine sediment (upper left side) interbedded with coarse material that slumped off the esker during recession of the ice margin. The gravel pit is located west-northwest of Chadwick Hill Cemetery on Route 32.

numerous borrow pits along them. Parts of the eskers have been mined and the original ridge topography leveled.

Ice-contact stream sediment (unit Pgi)

Ice-contact stream sediment is not a common unit in the China Lake area. Ice-contact stream sediment contains highly variable, crudely stratified sandy gravel and sand that may display contorted, faulted bedding and an irregular landscape expression. This sediment is commonly interbedded with sandy ablation till and silty lake sediment. Unit Pgi is presumed to have formed where sediment was deposited adjacent to glacier ice that later melted, causing collapse of the sediment. Mudflows off the glacier or from adjacent exposed till plains deposited the sandy ablation till interbeds.

Presumpscot Formation (unit Pp)

The thick, heavy late Wisconsinan glacier forced the land surface to sink. The ocean submerged the depressed lowlands of southern Maine during retreat of the last glacial ice sheet (Figure 1). Fine-grained clay-silt deposits accumulated on the sea floor during the late-glacial marine flooding of the China Lake region. These sediments are part of the Presumpscot Formation (Pp), which is widespread across Maine's coastal lowland (Bloom, 1960). The sediments are massive to well stratified and range in color from gray to bluish-gray or brownish-gray, depending on oxidation state. The Presumpscot Formation mostly consists of silt and clay in varying proportions and is often called "clay." Sand is locally interbedded with the fine-grained sediments, especially where the sediments were deposited in higher-energy environments near the glacier margin or in shallow waters.

Exposures of Presumpscot clay-silt were seen in many gravel pits in the China Lake quadrangle (Figure 3). The Presumpscot Formation was also encountered in numerous hand-auger holes in low-lying areas around Outlet Stream, China Lake, and Threemile Pond. The widespread distribution of this sediment suggests that much of the map area was flooded by the sea when glacial ice retreated from the area. The Presumpscot Formation is commonly found beneath flat lowlands and broad, gently sloping surfaces located below the marine limit. The Presumpscot Formation commonly drapes esker sediment (Pp/Pge) and submarine fan sediment (Pp/Pmf), as recognized by Stone (1899, p. 170).

Fossil mussel shells and shell imprints were found in the Presumpscot Formation in the China Lake area (Syverson and Mans, 2005). In many cases the shells were crushed, but in other instances the shells were intact (Figure 4). Mussels identified in the marine sediment included *Mytilus edulis* and *Portlandia arctica*. These species lived in arctic marine water conditions close to the ice margin (Dyke and others, 1996). Shell samples were collected from two areas for radiocarbon age analyses. The locations of these samples and the significance of the ages are addressed in the deglaciation section of this report.

Figure 3. Gray, fine-grained Presumpscot Formation overlain by high-energy sandy gravel. The sandy gravel either marks a shift in location of the water-discharge point from the former ice margin or redeposition from wave and current action as relative sea level fell. The gravel pit is located west of Route 32 approximately 0.9 mile (1.5 km) south of South China.

Glaciomarine deltas (unit Pmd)

Glacial meltwater washed sediments into the sea, forming flat-topped deposits of sand and gravel called deltas. The upper limit of marine submergence has been determined by measuring the elevations of contacts between topset and foreset beds in the deltas (Thompson and others, 1989). Thompson and others (1989) obtained one such measurement at a gravel pit in the Erskine Academy delta which starts in the southernmost part of the

Figure 4. Fossil shells collected from silt and clay of the glaciomarine Presumpscot Formation, China Lake area. The small shell closest to the scale is a good example of *Portlandia arctica*.

Figure 5. Sandy gravel foreset beds in the Erskine Academy delta, southern China Lake quadrangle. Water discharged from the ice sheet margin to the right, and the delta built outward into the ocean toward the left. The gravel pit is located west-northwest of Chadwick Hill Cemetery on Route 32.

China Lake quadrangle and extends onto the Weeks Mills 7.5-minute quadrangle (mapped by Weddle (2005)). The survey of this delta indicated a late-glacial sea level of 321 ft (98 m).

The Erskine Academy delta contains sand and gravel deposited in contact with glacial ice. This delta formed at the mouth of an ice tunnel marked by the esker system south of China Lake (Pge). The north side of the delta is steeply sloping where sediment was rapidly deposited next to the ice margin, and the gravel collapsed as adjacent ice melted. In some cases deltaic sediment is observed burying esker sediment deposited when the ice was more extensive. Foreset beds 30 ft (9 m) thick were observed in the southernmost part of the China Lake quadrangle (Figure 5). The foresets mostly consist of large-scale beds of pebble to cobble gravel and gravelly sand that dip 30 degrees to the south-southwest (207 degree azimuth). Near the flanks of the delta silty and clayey sediment of the Presumpscot Formation is exposed. In some cases the fine-grained sediment is interbedded with boulder-rich gravel that has slumped off the eroding esker or delta (Figure 2). In other cases gravelly sediment overlies clayey Presumpscot Formation (Figure 3). The gravelly sediment might represent erosion of higher areas during marine regression, or it also might represent a change in the location of the main water-discharge point from the glacier.

The Meadow Brook delta in the southeastern part of the quadrangle has a typical fan shape but does not display a collapsed, steeply sloping northern side. Thus, it did not form in contact with glacial ice. Thompson and others (1989) classified the Meadow Brook delta as a leeside delta. It formed shortly after the ice melted from the highland surrounding Dirigo Corner to the north. This highland was above sea level, and some meltwater crossed a drainage divide near Dirigo Corner and flowed overland in rivers that discharged into the ocean. No topset-foreset bed contact has been observed within the Meadow Brook delta, but most of the delta surface has an elevation of 310 to 320 ft (94 to 98 m). Meadow Brook delta foreset beds tend to be quite sandy and display faults and soft-sediment deformation associated with the compaction of the rapidly deposited sediment (Figure 6).

Glaciomarine fan deposits (unit Pmf)

Small deposits of sand and gravel are associated with the esker system south of China Lake. These deposits appear as wider portions of the esker and are within the zone of late-glacial marine submergence. A pit south of China Lake shows sandy gravel foreset beds deposited in a subaqueous environment. These beds are overlain by (and probably grade laterally to) silt and clay of the Presumpscot Formation (Pp/Pmf), and in places reveal imprints of marine shells. These sediments are inferred to be submarine fans (Pmf). They formed where subglacial meltwater streams deposited sand and gravel into the ocean, but sediment accumulation did not continue long enough to build deltas

Figure 6. Sandy, more distal sediment of the glaciomarine Meadow Brook delta. Two normal faults (left of the shovel) outline a block of sediment that has settled downward. The folded beds above the faults might represent deformation caused by water expulsion as the fault block settled. The gravel pit is located on the west side of Dirigo Road approximately 0.5 mile (0.8 km) south of Tobey Road.

Figure 7. Ice-contact pebble to boulder gravel deposited in proximal part of glaciomarine fan environment. Sediment collapsed as adjacent ice melted. The gravel pit is located west of Route 32 approximately 0.9 mile (1.5 km) south of South China.

with flat tops graded to sea level. Submarine fan sediment commonly exhibits collapse features where the sediment was initially deposited in contact with glacial ice (Figure 7).

Nearshore glaciomarine sediments, undifferentiated (unit Pmn)

The area west of the eastern arm of China Lake contains water-laid sediment (Pmn) at elevations up to about 280 ft (85 m). The sediment is below the marine limit on the shoulders of till and bedrock uplands. The original surface topography of this unit was generally gently sloping, but in places it has been dissected by modern streams. Textures may range from clay to gravel, but typically the texture is silty sand. Unit Pmn is thought to have been deposited near the coast of the receding marine coastline, but it is poorly exposed and might include sediments formed in other environments.

Wetland deposits (unit Hw)

Wetland deposits in the China Lake quadrangle contain fine-grained, organic-rich sediment deposited in low, flat, poorly drained areas within valleys and small upland basins. The boundaries of unit Hw were mapped primarily from aerial photographs. These boundaries are approximately located and should not be used rigorously for land-use zoning. There is little information on the thickness of wetland deposits in the quadrangle, but the wetlands in Maine have been classified by Davis and Anderson (2001). Cameron and others (1984) reported average peat thicknesses of approximately 15 ft (4.6 m) for the bog 1.5 miles south of East Vassalboro between Nelson Road and Route 32. Cameron and others (1984) report that peat deposits in southern and western Maine usually average less than 20 ft (6 m) thick.

GLACIAL AND POSTGLACIAL GEOLOGIC HISTORY

The following reconstruction of the Quaternary history of the China Lake quadrangle and surrounding area is based on interpretations of surficial earth materials and ice-flow indicators described in this report, as well as published information from surrounding areas of New England. It is uncertain how many episodes of glaciation affected the study area during the Pleistocene Ice Age. Till deposits in Maine clearly record the most recent (late Wisconsinan) glaciation, and probably one earlier event. The deeply weathered lower till found elsewhere in central and southern New England has also been recognized in Maine (Thompson and Borns, 1985; Weddle and others, 1989; Weddle, 1992). Although it is not well dated, the lower till was deposited during the penultimate glaciation of probable Illinoian age.

The late Wisconsinan Laurentide Ice Sheet expanded out of Canada and spread into Maine approximately 25,000 radiocarbon years ago and had reached its maximum position by 22,000 radiocarbon years ago (Stone and Borns, 1986; Schnitker and others, 2001). The ice sheet was several thousand feet thick during the ice maximum and covered most of the mountains in the state. The weight of this ice mass depressed the land-surface elevation. As the glacier flowed across the state for thousands of years, it shaped the surface of the land by eroding, transporting, and depositing tremendous quantities of sediment and rock debris. Ice eroded the China Lake area and smoothed the surface.

Evidence for the glacial erosion is supplied by striations and crag-and-tail features. These features formed as glacial ice dragged rocks and sand grains across the bedrock surface, abraded the bedrock, and formed scratches orientated parallel to the former ice-flow direction. Syverson and Mans (2005) indicate the locations of 18 striation sets and crag-and-tail sets. Fourteen of the flow indicators indicate flow to the south-southeast (162 to 176 degree azimuths). Three indicators showing ice flow to the south-southwest (181, 185, 197 degree azimuths) may represent more rapid iceberg calving and ice drawdown in the Kennebec River lowland to the west as deglaciation progressed. One well developed striation set north of China had a southeasterly azimuth (135 degrees) more typical of ice flow in coastal Maine.

Climatic warming forced the Laurentide ice sheet to start receding prior to 20,000 years ago and the last remnants of glacial ice probably gone by 10,000 years ago (Schnitker and others, 2001; Borns and others, 2004). During the recession of the ice, the earth's crust was still depressed by the weight of the ice sheet and the sea flooded Maine as the glacier margin retreated to the northwest. Glaciomarine deltas in the central part of the state indicate that the sea submerged land to elevations up to 422 feet (129 m) (Thompson and others, 1989).

As the ice melted, the glacier and glacial meltwater deposited vast quantities of sediment in the China Lake region. The glacier deposited poorly sorted till directly from the ice.

Subglacial tunnels transported water and sediment to the ice margin which generally terminated in the ocean. Sand and gravel were deposited near water-discharge points at the ice margin. Initially submarine fans formed. However, if the sediment supply was adequate and the glacier margin remained in one place for sufficient time, these sediments built up to the ocean surface and formed glaciomarine deltas graded to sea level. Fine-grained silts and clays floated farther away from the glacier margin and were deposited more slowly from suspension to create a blanket of fine-grained sediment (the Presumpscot Formation). Sedimentation within the subglacial tunnels formed the large esker segments observed on the quadrangle.

The China Lake quadrangle shows evidence of the marine submergence caused by the great weight of the Laurentide ice sheet. Silt and clay rich sediments of the Presumpscot Formation are found extensively within the quadrangle (Syverson and Mans, 2005). Marine sediments are found at elevations up to at least 300 ft (91 m), indicating that a major portion of the China Lake area was covered by the sea during deglaciation. In-situ shell fossils representing arctic marine conditions were collected within the Presumpscot Formation. Two new radiocarbon ages have been measured as part of this project (Mans and Syverson, 2005). These ages have been modified using a -600-yr marine-reservoir correction factor to allow direct comparisons with the data of Borns and others (2004). The two corrected radiocarbon ages are as follows: the Palermo site, 11,380±230 yrs BP, GX# 31328, *Mytilus edulis*, elevation 240 to 250 ft (73 to 76 m), UTM 460,593mE 4,926,820mN, Zone 19 (located on the Palermo 7.5' quadrangle 0.2 mile (350 m) east of the China Lake/Palermo quadrangle boundary, reached by driving south from Route 202); and the East Vassalboro site, 12,800±70 yrs BP, GX# 31329, *Portlandia arctica*, elevation 190 to 205 ft (58 to 62 m, UTM 450,750mE 4,923,230mN, Zone 19 (see Syverson and Mans (2005) for location).

The date for the East Vassalboro site agrees closely with deglaciation isochrons for Maine (Figure 1, Borns and others, 2004). However, the Palermo site has an age that is much younger than would be expected based on other data reported by Borns and others (2004) and an analysis of relative sea-level changes and postglacial uplift by Retelle and Weddle (2001). By 11,400 radiocarbon years ago, relative sea level should have been much lower in the area. This large age discrepancy is poorly understood at this time. The large error bar associated with this date (±230 years) might be an indicator of poor accuracy (T. Weddle, Maine Geological Survey, personal communication, 2005). Based on the East Vassalboro age, the best estimate of the deglaciation of the northern part of the China Lake quadrangle is approximately 12,800 radiocarbon years ago (Mans and Syverson, 2005). Organic sediment started to accumulate in wetlands (unit Hw) soon after the sea regressed, and this sediment continues to accumulate in wetlands to the present day.

ECONOMIC GEOLOGY

Sand and gravel supplies are plentiful in parts of the China Lake quadrangle, especially in the eskers, glaciomarine deltas, and submarine fans (units Pge, Pmd, and Pmf on the geologic map). Numerous borrow pits have been opened in these deposits to extract high-quality aggregate, especially in the area south of China Lake. Silt and clay of the Presumpscot Formation commonly drape the tops of these deposits and thicken as the land-surface elevation decreases. The fine-grained Presumpscot Formation commonly needs to be mechanically relocated to prevent unacceptably high levels of silt and clay in the aggregate. The Presumpscot Formation, with its high clay content and low permeability, is possibly suitable for use as a landfill liner.

Small pits have been opened in glacial till deposits. The sandy till in this area packs well and is often well suited for fill, especially along small roads. It may also provide favorable sites for septic tank absorption fields.

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APPENDIX A
GLOSSARY OF TERMS USED ON MAINE GEOLOGICAL SURVEY SURFICIAL GEOLOGIC MAPS

compiled by
John Gosse and Woodrow Thompson

Note: *Terms shown in italics are defined elsewhere in the glossary.*

Ablation till: *till* formed by release of sedimentary debris from melting glacial ice, accompanied by variable amounts of slumping and meltwater action. May be loose and stony, and contains lenses of washed sand and gravel.

Basal melt-out till: *till* resulting from melting of debris-rich ice in the bottom part of a glacier. Generally shows crude stratification due to included sand and gravel lenses.

Clast: pebble-, cobble-, or boulder-size fragment of rock or other material in a finer-grained *matrix*. Often refers to stones in glacial till or gravel.

Clast-supported: refers to sediment that consists mostly or entirely of *clasts*, generally with more than 40% clasts. Usually the clasts are in contact with each other. For example, a well-sorted cobble gravel.

Delta: a body of sand and gravel deposited where a stream enters a lake or ocean and drops its sediment load. Glacially deposited deltas in Maine usually consist of two parts: (1) coarse, horizontal, often gravelly topset beds deposited in stream channels on the flat delta top, and (2) underlying, finer-grained, inclined foreset beds deposited on the advancing delta front.

Deposit: general term for any accumulation of sediment, rocks, or other earth materials.

Diamicton: any poorly-sorted sediment, containing a wide range of particle sizes, e.g. glacial *till*.

Drumlin: an elongate oval-shaped hill, often composed of glacial sediments, that has been shaped by the flow of glacial ice, such that its long axis is parallel to the direction of ice flow.

End moraine: a ridge of sediment deposited at the margin of a glacier. Usually consists of till and/or sand and gravel in various proportions.

Englacial: occurring or formed within glacial ice.

Eolian: formed by wind action, such as a sand dune.

Esker: a ridge of sand and gravel deposited at least partly by meltwater flowing in a tunnel within or beneath glacial ice. Many ridges mapped as eskers include variable amounts of sediment deposited in narrow open channels or at the mouths of ice tunnels.

Fluvial: Formed by running water, for example by meltwater streams discharging from a glacier.

Glaciolacustrine: refers to sediments or processes involving a lake which received meltwater from glacial ice.

Glaciomarine: refers to sediments and processes related to environments where marine water and glacial ice were in contact.

Head of outwash: same as *outwash head*.

Holocene: term for the time period from 10,000 years ago to the present. It is often used synonymously with "postglacial" because most of New England has been free of glacial ice since that time.

Ice age: see *Pleistocene*.

Ice-contact: refers to any sedimentary deposit or other feature that formed adjacent to glacial ice. Many such deposits show irregular topography due to melting of the ice against which they were laid down, and resulting collapse.

Kettle: a depression on the ground surface, ranging in outline from circular to very irregular, left by the melting of a mass of glacial ice that had been surrounded by glacial sediments. Many kettles now contain ponds or wetlands.

Kettle hole: same as *kettle*.

Lacustrine: pertaining to a lake.

Late-glacial: refers to the time when the most recent glacial ice sheet was receding from Maine, approximately 15,000-10,000 years ago.

Late Wisconsinan: the most recent part of *Pleistocene* time, during which the latest continental ice sheet covered all or portions of New England (approx. 25,000-10,000 years ago).

Lodgement till: very dense variety of till, deposited beneath flowing glacial ice. May be known locally as "hardpan."

Matrix: the fine-grained material, generally silt and sand, which comprises the bulk of many sediments and may contain *clasts*.

Matrix-supported: refers to any sediment that consists mostly or entirely of a fine-grained component such as silt or sand. Generally contains less than 20-30% clasts, which are not in contact with one another. For example, a fine sand with scattered pebbles.

Moraine: General term for glacially deposited sediment, but often used as short form of "*end moraine*."

Morphosequence: a group of water-laid glacial deposits (often consisting of sand and gravel) that were deposited more-or-less at the same time by meltwater streams issuing from a particular position of a glacier margin. The depositional pattern of each morphosequence was usually controlled by a local base level, such as a lake level, to which the sediments were transported.

Outwash: sediment derived from melting glacial ice, and deposited by meltwater streams in front of a glacier.

Outwash head: the end of an *outwash* deposit that was closest to the glacier margin from which it originated. *Ice-contact* outwash heads typically show steep slopes, *kettles* and hummocks, and/or boulders dumped off the ice. These features help define former positions of a retreating glacier margin, especially where *end moraines* are absent.

Pleistocene: term for the time period between 2-3 million years ago and 10,000 years ago, during which there were several glaciations. Also called the "Ice Age."

Proglacial: occurring or formed in front of a glacier.

Quaternary: term for the era between 2-3 million years ago and the present. Includes both the *Pleistocene* and *Holocene*.

Striation: a narrow scratch on bedrock or a stone, produced by the abrasive action of debris-laden glacial ice. Plural form sometimes given as "striae."

Subaqueous fan: a somewhat fan-shaped deposit of sand and gravel that was formed by meltwater streams entering a lake or ocean at the margin of a glacier. Similar to a *delta*, but was not built up to the water surface.

Subglacial: occurring or formed beneath a glacier.

Till: a heterogeneous, usually non-stratified sediment deposited directly from glacial ice. Particle size may range from clay through silt, sand, and gravel to large boulders.

Topset/foreset contact: the more-or-less horizontal boundary between topset and foreset beds in a *delta*. This boundary closely approximates the water level of the lake or ocean into which the delta was built.