THE PRESUMPSCOT FORMATION IN SOUTHWESTERN MAINE

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INTRODUCTION AND PREVIOUS WORK

The Presumpscot Formation is a widespread blanket of glaciomarine silt, clay, and sand that covers much of southern Maine. It is often called "marine clay" in reference to its environment of deposition and predominantly fine-grained texture. The Presumpscot Formation consists mostly of finely pulverized rock debris ("rock flour") that had been incorporated in the last ice sheet that covered Maine. As this glacier melted and retreated inland, vast quantities of sediment were released from the ice and washed into the sea that flooded the coastal lowland and lapped against the glacier margin. The coarser sediments sank to the ocean floor near the mouths of the meltwater streams, forming deltas and other deposits of sand and gravel. The finer-grained materials were carried in suspension and dispersed farther into the sea, where they settled to the bottom as a muddy veneer covering older glacial sediments. Within a brief span of geologic time (probably less than 2,000 years after the glacier margin retreated to central Maine), uplift of the land occurred in response to removal of the weight of the ice sheet, and the glaciomarine clay deposits of the Presumpscot Formation were raised above sea level. Figure 1 shows the area of Maine in which these deposits may now be seen.

The purpose of this paper is to briefly review the geology of the Presumpscot Formation, particularly in central to southwestern Maine (from the

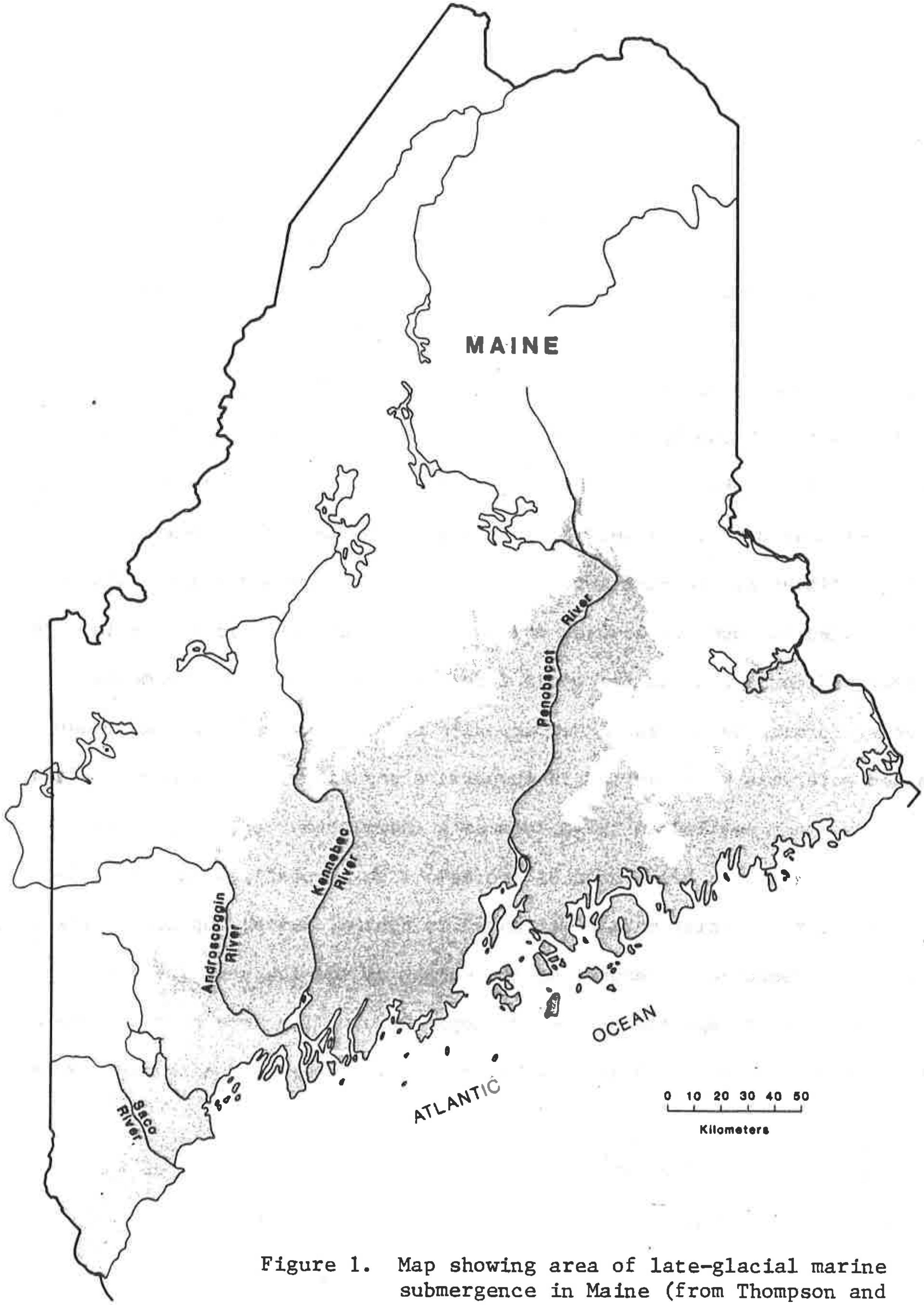

Figure 1. Map showing area of late-glacial marine submergence in Maine (from Thompson and Borns, 1985a). Many islands existed in the submerged area but are not shown here.

Penobscot Valley to the New Hampshire border). The glaciomarine sediments in this part of the state are better known to the author, and have been investigated by numerous workers since the early 1800's. Appendix A (at the end of this volume) lists many of these studies.

One of the earliest geologic descriptions of Maine's glaciomarine clay is that which appears in Jackson's (1837) first report on the geology of the state. Jackson described an interesting exposure revealed by excavation of a canal at Lubec. He collected several species of marine shells from the clay at this locality, and also found barnacles attached to the bedrock surface beneath the clay. These barnacles were located 8 m above the contemporary high-tide level. The glacial source of the marine clay was not recognized in Jackson's time, but he decided that the fossiliferous sediments had reached their position through uplift of the land (a theory that later proved to be correct).

Hitchcock (1861, 1873) briefly commented on the glaciomarine clays. At first (1861) he was uncertain as to their stratigraphic position relative to the "drift" deposits. The glacial origin of the latter material seems to have been gradually accepted by Hitchcock during the mid 1800's. In his 1873 paper on the geology of Portland, Hitchcock was finally a proponent of glaciation and claimed that the clay deposits were the product of marine submergence that postdated the "Glacier Period".

In the late 1800's, Stone carried out a great amount of research on the glacial deposits of Maine. His "Glacial Gravels of Maine" (1899) is a monumental volume that remains useful to this day. However, his less well-known paper of 1890 ("Classification of the Glacial Sediments of Maine") anticipated many of the ideas espoused by geologists several decades later.

In this paper, Stone made a direct connection between the clays of southern Maine and their glacial source: "The transition of the delta sands into the marine fossiliferous clays proves that the latter were chiefly composed of the mud poured into the sea by the glacial streams" (Stone, 1890, p. 132). Moreover, he also published the first map showing the distribution of the glaciomarine clays across the coastal lowland (Stone, 1899, Plate II). Stone's map is strikingly similar to modern compilations (e.g. Thompson and Borns, 1985a) based on the work of many individuals.

Further investigations of the Presumpscot Formation resulted from economic studies by the Maine Geological Survey during the mid 1900's. Some of these studies were chiefly directed toward sand and gravel resource inventory (Leavitt and Perkins, 1935), while others were motivated by the economic potential of the clays themselves (Trefethen, 1945; Trefethen and others, 1947; Goldthwait, 1949, 1951). The program initiated by Trefethen was concerned with improving the quality and marketability of Maine clays, which are impure and dark colored in contrast to the cleaner weathering-product clays that are mined in the South. Later studies dealt with firing and expansion of the Presumpscot clay to develop its potential as lightweight aggregate (Caldwell, 1959). All of the above projects advanced our understanding of the distribution and geology of the glaciomarine clays. Because of economic considerations, however, the commercial use of these deposits is still limited to traditional endeavors such as making bricks and pottery.

The Presumpscot Formation was named by Bloom (1960) in reference to localities where he examined good exposures of the marine clay along the Presumpscot River valley near Portland. Bloom gave one of the most thorough descriptions of the formation. Although his comments referred to the glaciomarine clays of southwestern Maine, most of them apply equally well to similar deposits elsewhere in the state. Thus, the name "Presumpscot Formation" is now used for all of Maine's fine-grained, clayey to silty glaciomarine sediments of late-glacial age.

Most recent studies of the Presumpscot Formation have been topical scientific investigations of the age, stratigraphy, and paleontology of the clay deposits, and their relationship to the retreating margin of the late Wisconsinan ice sheet. The results of much of this work have been discussed by Smith (1982, 1985), Stuiver and Borns (1975), Thompson (1979, 1982), and Thompson and Borns (1985b). The distribution and other aspects of the glaciomarine clays are also becoming better known through the surficial geologic mapping projects of the Maine Geological Survey.

DESCRIPTION OF THE PRESUMPSCOT FORMATION

Distribution and topography

The Presumpscot Formation is very widespread in the coastal lowland of Maine, and extends far inland along the Kennebec and Penobscot River valleys (Figure 1). The Surficial Geologic Map of Maine (Thompson and Borns, 1985a) shows the distribution of the clay deposits as compiled at a scale of 1:500,000. Numerous islands protruded above the late-glacial sea in which the Presumpscot clay was deposited. Data from glaciomarine deltas indicate that the present elevation of the upper marine limit rises from about 67 m along the outer coastline to about 128 m in the central part of the state (Thompson and others, in press). This variation was caused by the greater degree of postglacial uplift in the latter area, which in turn was the consequence of greater depression of the earth's crust due to increasing thickness of glacial ice toward the northwest.

Glaciomarine clay may occur nearly as high as the upper marine limit at any particular locality. Some maximum clay elevations recorded in the principal river valleys are: 120 m at North Jay in the Androscoggin Valley (Attig, 1975) and 122 m in the upper Kennebec Valley (Borns and Hagar, 1965). However, in many places the Presumpscot Formation was deposited to elevations that are 15-30 m lower than the local marine limit, suggesting that the sediments tended to accumulate in the deeper-water, lower energy environments. The undissected, horizontal to gently sloping portions of the Presumpscot land surface are generally higher as one goes inland (because of the crustal tilt mentioned above). The elevation of this surface ranges from as little as 6-12 m along parts of the coastline to over 60 m in central Maine. Where not eroded or overlain by other sediments, it presumably represents the final position of the sea floor prior to uplift and exposure.

The Presumpscot Formation typically overlies till, bedrock, or glacial sand and gravel deposits. It partly or completely filled many valleys, causing a reduction in local topographic relief. In some cases the clay forms a thin blanket that conforms to the surface of underlying materials, but this circumstance may be partly the result of erosion after emergence from the sea (Bloom, 1960). Holocene streams have carved steep-walled gullies in the Presumpscot Formation, the pattern of which is distinctive on topographic maps and air photos. The rills and gullies form intricately branching dendritic networks. Landslides have occurred locally where erosion has oversteepened the gully walls.

The thickness of the Presumpscot Formation may vary greatly over short distances, depending on the terrain and the relief of the underlying surface on which it was deposited. Thicknesses exceeding 30 m have been reported by Bloom (1960), Attig (1975), and Stemen (1979); and comparable thicknesses are probably common where the clay fills broad coastal valleys such as those of the Presumpscot, Stroudwater, and Royal Rivers (to name a few). In places the Presumpscot Formation may even reach 60 m in thickness. Considerable work remains to be done in collecting and compiling available subsurface data on the clay deposits.

Physical properties and stratigraphy

Although it is usually called a "clay", the Presumpscot Formation contains about as much silt as clay, and also has an appreciable percentage of sand. Goldthwait (1951) carried out particle size analyses on 43 samples and found them to contain an average of 39 percent clay, 37.5 percent silt, and 23.5 percent sand. Virtually identical percentages of clay were measured in samples collected by Caldwell (1959) in the Farmington area and Borns and Hagar (1965) in the Kennebec Valley. Like the coarser fractions, the clay-size particles in the Presumpscot Formation are believed to consist mainly of finely pulverized quartz, feldspar, and other common rock-forming minerals. Some true clay minerals (mineral weathering products) may be present, too, especially those formed by alteration of micas. The latter minerals are to be expected since minor amounts of illite, vermiculite, and other clay minerals occur in New England glacial tills.

The glaciomarine clays range from massive to very well stratified. Exposures of the latter type often show interbeds of silt, clay, and sand that are up to several centimeters in thickness. Leavitt and Perkins (1935) claimed that nearly all of the Presumpscot Formation is nonstratified, but Bloom (1960) pointed out the stratified character of some exposures. Bloom also noted the lack of varves, which are annual couplets of silt and clay laminae found in lake-bottom sediments. In the author's experience, laminated Presumpscot Formation seems to be as common (or more so) as the massive variety in southwestern Maine. Both types are present in some cases, with the overall sediment coarseness and degree of stratification usually increasing toward the top and/or bottom of the section. Influx of the coarser-grained sediments occurred when the ice margin was nearby (represented by lower part of many sections) or when current velocities increased in the shoaling sea during crustal uplift (upper part). The massive Presumpscot sediments often appear to be those which are most clay-rich. These clays are thought to have been deposited rather quickly by flocculation in the saline marine waters.

Ice-rafted glacial debris is common in the Presumpscot Formation, and is more-or-less randomly scattered through the clay deposits. Isolated stones, including sizable boulders, detached from icebergs and fell to the ocean floor. Many of these "dropstones" are faceted and striated from having been glacially transported. Small pods of ice-rafted gravel or till have also been found in the Presumpscot Formation.

The color of unweathered Presumpscot Formation is usually gray to dark bluish gray; deposits with the latter color are often called "blue clay". This blue clay locally contains black patches that may be due to concentrations of organic matter or some kind of discoloration resulting from inorganic processes. The upper part of many sections (and the entire section at some sites) has a brownish gray to pale brown color. Trefethen and others (1947) thought that the "brown clay" was slightly coarser than the underlying blue clay, and that it was deposited as a separate unit in a shallower marine environment (as on tidal flats). However, Goldthwait (1951) compared samples of both colors from each of five sites, and he found no consistent difference in particle size distribution, plastic and liquid limits, organic content, or carbonate content. Goldthwait concluded that the brown clay is simply the oxidized equivalent of the blue clay, and that the color boundary is usually gradational and approximately coincident with the water table. Later workers have expressed the same opinion concerning the brown clay (e.g. Caldwell, 1959; and Bloom, 1960).

Vertical desiccation cracks penetrate the upper part of the Presumpscot Formation, and they commonly are so well developed that the clay has a columnar joint structure. In places where the clay is stratified, the combination of bedding and jointing gives the sediment a blocky structure, enabling it to be more readily excavated. Dark purplish-brown manganese-oxide staining typically occurs on joint surfaces.

The contact between the base of the Presumpscot Formation and underlying glacial sand and gravel deposits may be sharp or gradational. The gradational contacts generally are seen where the clay overlies ice-marginal deposits, including stratified end moraines, submarine fans, and deltas. Retelle and Konecki (1986) described a good example of a transitional zone at the Webber Pit in Topsham. These zones show interbedded sand, silt, and clay in the lower part of the Presumpscot Formation (Figure 2). Sand becomes more abundant with depth, and gravel may also be present in near-ice facies. The downward coarsening reflects the higher energy environment that prevailed when meltwater currents were still issuing from the nearby ice margin. Local unconformities at the contacts with units underlying the Presumpscot Formation

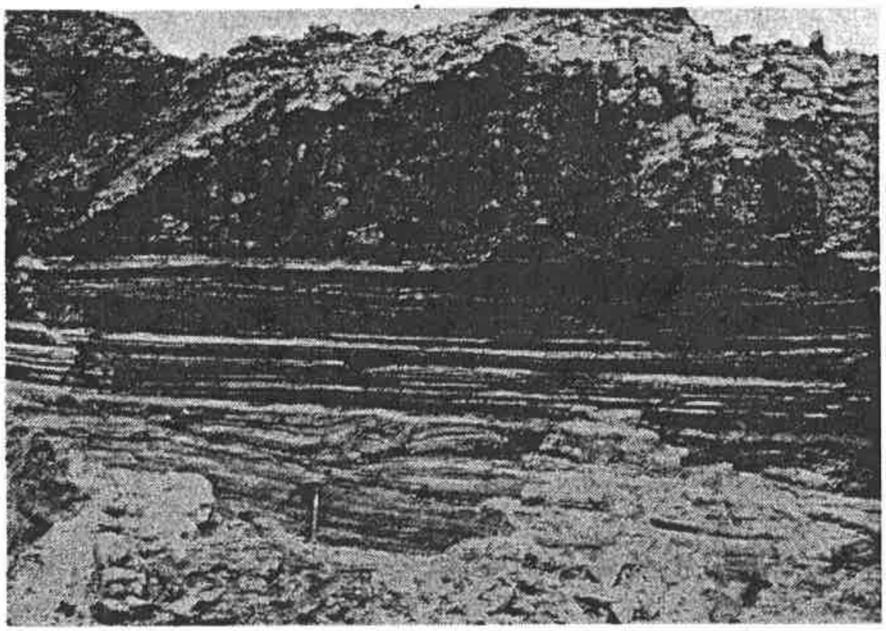

Figure 2

Exposure at the Webber Pit in Topsham, Maine, showing gradational contact between sand (submarine fan deposit) and Presumpscot Formation (top).

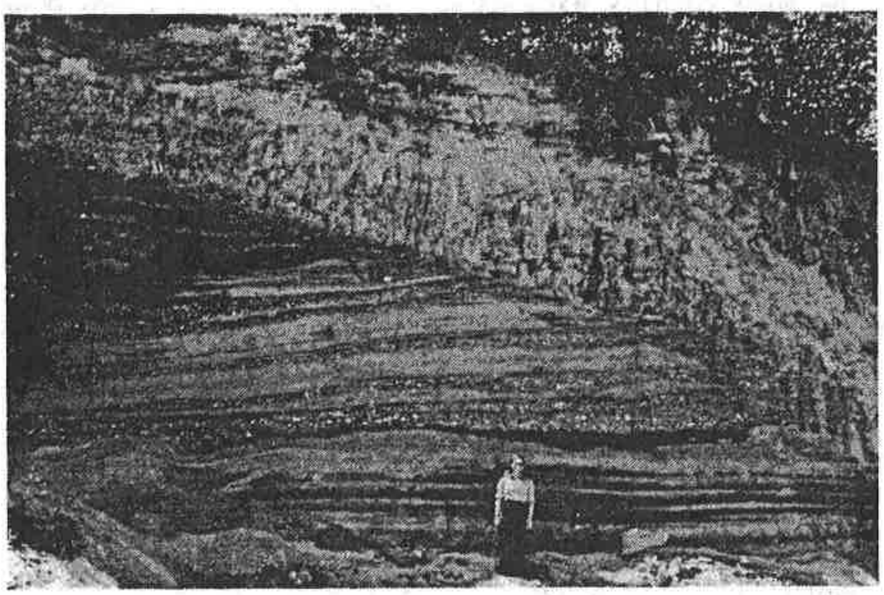

Figure 3

Exposure of Presumpscot silty clay unconformably overlying sand and gravel (submarine fan) in the Kennebec River valley, Pittston, Maine. Note vertical desiccation cracks in the clay. (From Thompson, 1982, with permission of Kendall/Hunt Publishing Company.)

are thought to have resulted from scouring by these currents, since there is no evidence of intervening marine offlap and subaerial erosion. Figure 3 shows an example of one such unconformity. The author has also seen similar unconformable contacts within the fine-grained laminated sediments of the Presumpscot Formation itself. Slumping of the sea-floor deposits is another mechanism that may be responsible for this type of contact.

There are broad areas where the Presumpscot clay is overlain by sand and gravel deposits. Many of these sequences probably developed as crustal uplift caused regression of the sea. Migrating shorelines and the initiation of postglacial fluvial systems would have eroded delta fronts, submarine fans, and other coarse glacial deposits, redistributing sand and gravel across the ocean floor. Rivers also carried sediments from inland sources and graded them to the falling sea level. The resulting contact between the Presumpscot Formation and overlying coarser-grained deposits is abrupt and erosional in some places. Elsewhere there is a gradual transition marked by a coarsening-upward sequence of interbedded sand, silt, and clay (the reverse of the basal sequence described above).

Extensive deposits of sand and fine gravel overlie the Presumpscot clay in Cumberland and York Counties. In the Brunswick area they appear to have been deposited by the Androscoggin River as it shifted laterally and began to develop its postglacial course. Attig (1975) traced these fluvial deposits up the Androscoggin Valley and identified them as glacial outwash. The Embden Formation (likewise considered to be outwash) is the equivalent unit overlying the Presumpscot Formation in the upper Kennebec Valley (Borns and Hagar, 1965).

The gradational nature of many upper and lower Presumpscot contacts raises a question as to how the formation is defined, and whether its definition should be extended to include the accompanying coarser-grained facies of glaciomarine sediments. Bloom's (1960) definition of the Presumpscot Formation is limited to the "silty clay" deposits. The overlying sediments are sometimes called "sandy Presumpscot Formation" (e.g. on reconnaissance surficial maps of the Maine Geological Survey), but this is an informal name.

Some of the sand and gravel beds within or above the glacimarine clay are very local deposits resulting from minor oscillations of the ice margin. An example of this situation was shown by Smith (1981), who demonstrated that the Kennebunk glacial advance of Bloom (1960) was only one of many small-scale fluctuations of the receding glacier margin. Folding and faulting within the Presumpscot Formation resulted both from fluctuations of this sort and from later collapse of the sediments adjacent to melting blocks of stagnant ice.

Yet another kind of overlying sand and gravel unit was formed on a local scale during the drop of relative sea level as uplift of the land occurred. Where the Presumpscot Formation lapped against higher surficial deposits such as eskers and till slopes, shoreline erosion of these coarser materials caused sand and gravel to be washed out over the clay. Goldthwait (1951) remarked that he saw a great number of these offlap deposits capping the Presumpscot Formation in the Portland-Sebago Lake area. On the rocky islands and peninsulas of coastal Maine, one can find many more examples of shoreline gravels covering small remnants of glaciomarine clay in sheltered locations. Much of the glacial sediment cover on the hills in this region probably was swept away by marine erosion during the period of isostatic crustal uplift.

Paleontology

A diverse assortment of fossils occurs in the Presumpscot Formation, though their abundance and degree of preservation vary greatly according to local depositional environment and postglacial weathering conditions. These fossils represent a broad range of marine organisms ranging from foraminifers and diatoms through mollusk shells to whales. Among the more common fossils are the remains of clams, mussels, scallops, barnacles, and other shellfish. Mollusk shells in the glaciomarine clay were noted in the early writings on the surficial geology of Maine by Hitchcock (1837) and Jackson (1837). There are dozens of later references in the literature, many of which are listed in Appendix A at the end of this volume.

Species lists of invertebrate macrofauna observed in the Presumpscot Formation were compiled by Hitchcock (1861, 1873), Packard (1867), Clapp (1908), Little (1917), Bloom (1960), and Stuiver and Borns (1975). Bloom, and Stuiver and Borns, discussed the broad environmental significance of several mollusks, and pointed out that some of the Presumpscot species now live only in colder Atlantic waters north of Maine. However, many of the fossils represent species that are still found off the Maine coast. The ecological significance of fossils from specific sites in the Presumpscot Formation has been discussed in various studies including recent papers by Crossen (1978) and Retelle and Konecki (1986).

Stone (1899) and Leavitt and Perkins (1935) are among the authors who list reports of vertebrate remains found in the Presumpscot Formation. Such finds are not frequent, but are said to include the bones of mammals (seals, walruses, and whales), fishes, and birds. The Presumpscot microfauna reported in the literature chiefly consists of various species of foraminifers. These have been listed by Hitchcock (1861, 1873), Morton (1897), and Buzas (1965). Cotter (1985) carried out an in-depth study of the ecology of foraminifers in the Presumpscot Formation in the Penobscot Valley.

Few authors have noted plant fossils in the Presumpscot Formation (other than seaweed). An unusual discovery is the occurrence of well-preserved spruce logs with other tree remains, shrub leaves, and associated marine shells. These were found by the author in 1976 at a gravel pit near the Fore River in Portland. The tree remains were described in detail by Hyland and others (1978).

AGE AND DEPOSITIONAL ENVIRONMENT OF THE PRESUMPSCOT FORMATION

The age of the Presumpscot Formation in Maine has been determined principally from radiocarbon dates on shells and seaweed collected from the glaciomarine clay. Virtually all of these dates fall within the interval between 14,000 and 11,000 yr B.P. (Stuiver and Borns, 1975; Smith, 1985). However, the glacier margin retreated to the inland marine limit in central Maine by about 13,000-12,500 B.P. (Smith, 1985; Thompson and Borns, 1985a, 1985b). Thus, there was a time lag between deglaciation of the coastal lowland and marine regression to the level of the present coastline.

The glacial source of the Presumpscot clay was recognized by Stone (1890), but as recently as the mid 1900's it was thought that a brief period of subaerial erosion occurred between ice retreat and the onlap of the sea (Goldthwait, 1951; Bloom, 1960). However, evidence accumulated by numerous workers in the last 20 years indicates that the sea was directly in contact with the receding ice margin in all parts of the submergence zone shown in Figure 1. Ice-contact deltas and submarine fans are widely distributed in this zone (Thompson, 1982; Thompson and others, in press), as are stratified end moraines deposited in the sea (Smith, 1982; Thompson, 1982). Site-specific studies have demonstrated that these ice-contact deposits locally intertongue with the Presumpscot Formation and thus were deposited contemporaneously with it (e.g. Stemen, 1979; Retelle and Konecki, 1986; Thompson and Smith, in press).

Near the present Maine coast, a floating ice margin may have existed where the glacier terminated in the sea, depending on whether the water was deep enough. In this event, end moraines (and submarine fans) would have been deposited along the grounding line of the ice sheet, while the finer-grained sediments of the Presumpscot Formation were deposited in more distal locations as shown in Figure 4.

On the other hand, water depths inferred from glaciomarine deltas indicate that the sea was shallow (< 80 m) over much of southern Maine. Therefore, it is likely that the ice margin was grounded in the vicinity of the inland marine limit (i.e. it was now a tidewater glacier), and lacked a fringing ice shelf (Thompson and others, in press). Moraines and submarine fans continued to form, but under these shallow conditions numerous glaciomarine deltas were graded to the ocean surface. At the same time, Presumpscot sediments also accumulated where the subaerial and englacial meltwater streams terminated in the sea. The clay fraction may have remained suspended and dispersed widely into the marine waters, depending on the rate at which flocculation occurred, but the coarser sediment was concentrated close to the ice margin. Frequent changes in the distribution, velocity, and sediment load of meltwater currents entering the sea -- together with variable conditions in the marine environment -- caused equally rapid fluctuations in

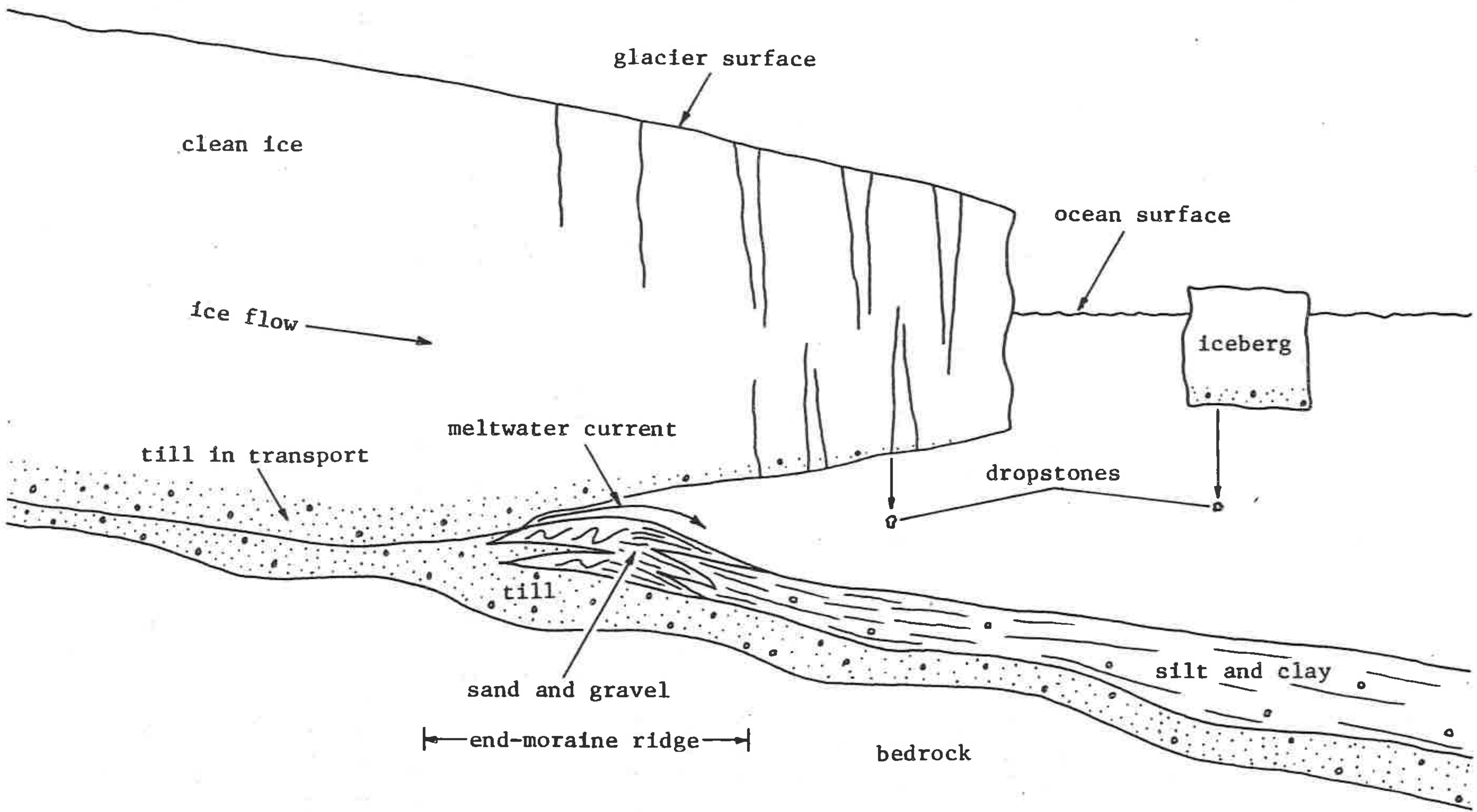

Figure 4

Schematic cross section of the glacier margin in contact with the sea during ice recession from southern Maine. Glaciomarine silt and clay (Presumpscot Formation) accumulated on the sea floor and is locally interstratified with coarser glacial sediments deposited along the ice margin. (From Thompson, 1979.)

the relative amounts of sand, silt, and clay that were deposited in the more proximal facies of the Presumpscot Formation. Depositional processes and sediment facies that are probably similar to those in Maine have been described for modern tidewater glaciers by Powell (1983).

Besides the influx of glacial meltwater, meteoric streams may have transported a certain amount of the Presumpscot sediments to the ocean. The importance of this contribution is difficult to evaluate, but it probably was not large in proportion to the meltwater source. The great majority of the marine deltas, for example, are ice-contact deposits; and a vast amount of Presumpscot silt and clay must have entered the sea as these deltas were constructed.

CONCLUSIONS

Geologic mapping and topical studies of Maine's glaciomarine sediments have advanced our understanding of the Presumpscot Formation. Its age and general characteristics are now reasonably well known. However, a great amount of work remains to be done on this formation, starting with its definition in relation to other glaciomarine deposits that formed in contiguous environments. What is -- or should be -- included in the Presumpscot Formation if Bloom's original definition can be expanded?

The range of sedimentary structures and corresponding depositional environments, as well as the mineralogical composition and provenance of the Presumpscot Formation, have yet to be studied in detail across most of southern Maine. A substantial body of information needs to be gathered on the clay-size fraction in particular. This kind of data could be useful in assessing the economic value of the clay deposits. Also, a modern, systematic inventory and collection of fossils from the Presumpscot Formation should be undertaken. This collection would yield scientifically valuable information regarding the marine environments of the clays, and could be used to enlarge the data base of radiocarbon dates from the Presumpscot Formation.

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