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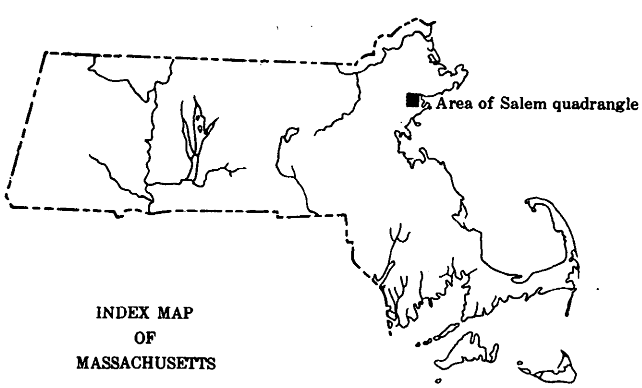
GEOLOGIC QUADRANGLE MAPS OF THE UNITED STATES

SURFICIAL GEOLOGY OF THE SALEM QUADRANGLE MASSACHUSETTS

By
Robert N. Oldale



INDEX MAP
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INTRODUCTION

The Salem quadrangle is located in the northeast corner of the State and is wholly within Essex County. The Ipswich River and its tributaries drain the northern third of the quadrangle; small streams and tidal rivers drain the rest. Salem Harbor, Beverly Harbor, and the Danvers River are the major coastal features.

Glacial erosion, although extensive, only slightly modified preglacial landforms in the quadrangle. The major topographic features of Pleistocene age are the result of deposition on a preglacial erosion surface; they include till in the form of drumlins and ground moraine, and extensive glaciofluvial deposits that partly fill preglacial valleys.

SURFICIAL DEPOSITS

Till.—Tills of two different ages have been identified in the quadrangle. The older till, which occurs mostly as drumlins, but may also be present in areas where the ground moraine is 20 or more feet thick, is composed of a very compact claylike mixture of clay, silt, sand, and gravel. Boulders are distributed throughout, but are fewer than in the younger till. The older till in the drumlins may be as much as 200 feet thick.

Between 1957 and 1960 the best exposures of the older till were in the northwest part of the quadrangle in the drumlin 0.8 mile east of the Essex County Sanitorium and in Nichols Hill 1.1 miles southeast of the sanitorium. At these exposures the claylike older till was capped in places by a sandier, partly stratified till layer 3 to 4 feet thick, which is probably a superglacial or englacial deposit equivalent in age to the older till. The zone of weathering included both the upper sandier layer and the upper part of the more typical older till. Exposures of the older till were also found at Whipple Hill in Danvers, at the base of Folly Hill in Danvers, and just north of the intersection of the Newburyport Turnpike and Lowell Street in Peabody. At this last exposure a thin sheet of older till overlies bedrock.

Stones of unmetamorphosed red arkose and shale occur in the older till and to a lesser extent in the younger till and glaciofluvial deposits in the northwestern part of the quadrangle. These stones are distinctly different from the more common igneous and metamorphic rock fragments found in the drift, and most closely resemble the Triassic arkose and shale in the Connecticut Valley of Massachusetts. The stones of arkose and shale are thought to indicate the presence of a body of Triassic sedimentary rocks a short distance northwest of the Salem quadrangle (Oldale, 1962).

Although no exposures of the older till capped by the younger till were found, the older till is thought to be the oldest glacial deposit in the quadrangle and to stratigraphically underlie the younger till and the glaciofluvial and high-level marine deposits. The older till is thought to be early Wisconsin in age and on the basis of similar lithology and weathering, to be equivalent to the Boston till as described by Judson (Judson, 1949; Oldale, 1961).

The younger till, which makes up most of the ground moraine in the quadrangle, is an unconsolidated and poorly sorted mixture of sand and gravel and minor amounts of silt and clay. Numerous boulders occur on the surface and throughout the younger till. Unusually high concentrations of large granite boulders occur in the younger till in the southwestern part of the quadrangle, in the vicinity of North Beverly, and in the northeastern corner of the quadrangle. These boulder concentrations overlie the Quincy Granite of Mississippian(?) age and are probably the result of glacial ice moving over bedrock in which numerous, well-developed, and easily moved joint blocks were available for transportation and deposition. Weathering of the younger till is confined to the upper foot or less, and the till is weathered from a light gray to a yellow brown or brown. The younger till is generally thin, but between Prospect Street and the Yankee Division Highway in Peabody the till is at least 20 feet thick. The compaction in this deposit is similar to that found only in the drumlin tills and may indicate that this unusually thick deposit represents a subglacial phase of the younger till.

The younger till is stratigraphically overlain by the glaciofluvial and high-level marine deposits and is the ice-laid fraction of the youngest glacial drift in the quadrangle. It is thought to be late Wisconsin in age and equivalent to the Lexington drift of Judson (Judson, 1949; Oldale, 1961).

Glaciofluvial deposits.—The glaciofluvial deposits, for the most part confined to the valleys, make up a large part of the surficial deposits in the quadrangle. These deposits are generally composed of sand and gravel, and vary greatly in texture and structure. The materials within one glaciofluvial unit may range from poorly sorted sand and gravel with many lateral and vertical variations in grain size at the upstream end to well-sorted, fine-grained, even-bedded deposits at the downstream end. Generally the larger glaciofluvial units have few ice-contact features except at their upstream ends and are finer grained and better sorted than the smaller units, which have well developed ice-contact topography.

The glaciofluvial deposits stratigraphically overlie both tills and represent the stream laid fraction of the drift deposited by the last glacial advance. The stratigraphic relationship between the glaciofluvial deposits and the high-level marine deposits is somewhat complicated as they are in part contemporaneous. The earliest glaciofluvial deposits are definitely older than, and partly buried by the high-level marine sediments. The younger glaciofluvial deposits are interbedded with the earlier high-level marine deposits and are equivalent to them in age. The younger glaciofluvial deposits are in turn overlain by postglacial high-level marine deposits. All glaciofluvial deposits in the quadrangle are thought to be late Wisconsin in age and equivalent to the Lexington drift of Judson (Judson, 1949; Oldale, 1961).

High-level marine deposits.—High-level marine deposits of late-glacial and postglacial age are found along the sides and on the bottom of valleys from sea level to approximately 50 feet above sea level. The marine deposits consist of sand, silt, clay, and scattered layers of fine gravel. The few good exposures were in temporary excavations; many old clay pits were slumped, overgrown, and flooded so that very little information could be gained from them. Borings made by the Water Resources Division of the United States Geological Survey showed that as much as 60 feet of marine sediment overlies glaciofluvial and till deposits. The lower part of the marine unit is composed of clay, interbedded with layers of fine- to medium-grained sand that range in thickness from a few inches to 5 feet. The upper part is predominantly sand but contains minor amounts of gravel. Except in a few places where the contact is erosional, the change from the lower part to the upper part is gradational. Unweathered marine deposits are gray or blue gray. Where the marine clay is exposed at the surface it is weathered to a reddish brown or yellow brown to depths as great as 5 feet. In some exposures vertical fractures lined with weathered clay extend several feet into the unweathered clay.

No fossils were found in the high-level marine deposits, but marine fossils from unweathered clay in the Danvers brick pits were described by Sears (1905). The fauna, mostly pelecypods, indicates a marine environment colder than the present one.

The high-level marine deposits overlie the tills and older collapsed glaciofluvial deposits with a sharp contact, which indicates that melting out of buried ice blocks and collapse of the deposits occurred before submergence of the area. They are in turn interbedded with and in part overlie the later glaciofluvial deposits, showing that the marine deposits range in age from late-glacial (when the ice front was within a mile or two of the present coastline) to postglacial (after the ice had retreated much farther to the north.) The high-level marine deposits are thought to be late Wisconsin in age and equivalent to the marine clays found near Fresh Pond in Cambridge (Oldale, 1961).

Eolian deposits.—A thin, discontinuous cover of light-yellow poorly sorted windblown silt, sandy silt, and sand mantles most of the till and glaciofluvial deposits. Stratification is lacking in the eolian deposits except where they were directly or indirectly deposited in water. Wind-polished, fluted stones derived from underlying drift occur throughout the eolian mantle.

GLACIAL HISTORY

The surficial deposits represent only the last two glaciations of the area, both of which are thought to be Wisconsin in age. There is no evidence in the quadrangle for earlier advances, but tills thought to predate the older till are found in the Boston Basin (Judson, 1949; Kaye, 1961). Drift from these earlier ice advances must have been completely buried or incorporated into the younger drift.

Direction of ice motion.—The orientation of the long axes of the drumlins (N. 61 W. to N. 31 W.), all of which are composed of older till, indicates that the direction of flow of the earlier ice advance was similar to that of the last. The suggestion of more than one long axis in Lords Hill, Cherry Hill, and to a lesser extent in Nichols Hill, and the variation in the orientation of drumlin axes from the northwest to the northeast part of the quadrangle, are probably due in part to modification of the drumlins by the last ice sheet and in part to the influence of local topography on the direction of ice movement.

The last glacier advanced from the north or northwest, as indicated by striations and grooves on the bedrock. Minor variations in the orientation of striations and grooves were caused by local topographic features large enough to influence the direction of ice flow.

Late-glacial history.—Late-glacial history in the quadrangle can be divided into three distinct parts: 1) initial stagnation and retreat of the ice from the coast when the coastline was farther east than now, 2) continued stagnation and retreat of the ice and submergence of the coastal areas, and 3) stagnation and retreat of the ice in the Ipswich River valley (Oldale, 1961).

The late-glacial history is based on the glaciofluvial sequences, high-level marine sediments, and eolian deposits. A glaciofluvial (outwash) sequence consists of deposits laid down by meltwaters flowing in a specific route and controlled by a single base level (Jahns, 1941, 1953). The sequences can be correlated in any one outflow route. Correlation between sequences is based on texture and the altitude of graded upper surfaces: coarser and higher deposits are considered to be older than adjacent finer grained, low-level deposits. The upstream end or ice-contact head of a sequence marks the position of the ice front prior to a change of meltwater drainage to a lower route.

Downwasting of the continental ice mass occurred over a broad, deep front trending generally northeast, subparallel to the present coastline. Continued downwasting produced a zone of stagnant ice in front of the active ice. At this time much of the higher land south and east of the Ipswich River valley was free of ice, and meltwater streams flowing between the ice and the valley walls deposited the outwash sequences A_1, A_2, B_3, C_3, and C_4. The graded upper surfaces of these sequences at altitudes of 30 to 50 feet along the present coast indicate that the shoreline was farther east than at present, probably because sea level was lower.

As downwasting continued, the eastern edge of the stagnation zone retreated up the valleys draining into Beverly and Salem Harbors and up the Miles River valley. The retreat of the ice was more rapid than the rise in sea level, and subaerial conditions persisted long enough for the ice blocks to melt and for collapse topography to develop in the earlier sequences. Eventually sea level rose to partly submerge the valleys and the older ice-contact deposits. In the valleys of Crane Brook, Beaver Brook, Miles River and Bass River, the shoreline reached to within a mile or mile and a half of the stagnant ice front. In the Frost Fish Brook valley, silty clay thought to be of marine origin is interbedded with glaciofluvial sand and gravel within 1,000 feet of the ice-contact head of outwash. During the retreat of the ice up the valleys, meltwater streams deposited sand and gravel as outwash between the ice and the marine shoreline and as gently dipping deltaic deposits in the sea. The clay, silt, and fine sand were carried into the sea and deposited in quiet water. Subaerial parts of these deposits make up sequences A , B_2, C_6, and C_7. The thick and continuous outwash deposits formed a barrier to further inundation of the land, but marine submergence continued along the coast well into postglacial time, and high-level marine deposits eventually buried the downstream ends of these sequences.

Sequences D_8, D_9, and D_{10} are the youngest glaciofluvial deposits and were laid down by meltwater streams draining the ice to the west and northwest in the Reading and South Groveland quadrangles. At this time all but the northwestern part of the quadrangle was free of ice and drainage was by way of the Ipswich River valley north and northeastward into the Georgetown and Ipswich quadrangles. Sequences D_8, D_9, and D_{10} continue into these quadrangles, where their downstream ends are interbedded with, and are in part overlain by, the high-level marine deposits (N. P. Cuppels and E. Sammel, personal communications, 1961).

The final late-glacial event was deposition of the eolian cover on the glacial drift. Large amounts of fine-grained material, lacking a protective cover of vegetation, were transported and redeposited by the winds. Eolian material covers the till and glaciofluvial deposits but is absent on the marine clays, indicating that eolian deposition occurred while the coast was still submerged.

POSTGLACIAL HISTORY

There was no definite break between late-glacial and postglacial time. At the end of glaciation in this area, sea level was as much as 60 feet higher than at present. Submergence was due to downwarping of the crust by the weight of glacial ice, and later to a eustatic rise in sea level caused by the addition of water to the seas as glaciers melted. Marine submergence continued into the early part of postglacial time. Thereafter, isostatic rise of the land caused the sea to retreat and eventually sea level was more than 25 feet lower than now. This is shown in the Back Bay area of Boston 15 miles to the south, where fresh-water peat with a radiocarbon date of approximately 5,717 years overlies weathered marine clays at an altitude of minus 16 to 18 feet (Johnson, 1942; Arnold and Libby, 1951). Since then a continued eustatic rise in sea level has caused the sea to submerge the land.

River courses in the quadrangle have changed but little since late-glacial or early postglacial time. The most important changes have been in the tidal rivers, whose lengths and courses are controlled in part by the level of the sea. No major changes in the course of the Ipswich River have occurred since late-glacial time. The topography of the quadrangle is virtually the same as when glacial erosion and deposition and meltwater deposition ceased. The most widespread deposits of postglacial age are muck and peat in the swamps, and the Recent tidal marsh and mud flat deposits along the coast. Minor amounts of slope wash, flood plain deposits, and marine beach deposits are presently being formed.

NATURAL RESOURCES

For economic purposes the surficial materials can be separated into four groups: 1) till, 2) sand and gravel, 3) clay, and 4) swamp deposits. The thickness of the surficial materials can be estimated in part from the distribution of bedrock outcrops and in part from the nature of the deposit. Closely spaced outcrops usually indicate overburden less than 15 feet thick. Where there are few outcrops the thickness generally ranges from 15 to more than 200 feet. Overburden is usually thickest in the valleys (glaciofluvial areas) and in the drumlins.

Till.—Ground moraine is generally too thin to be used as a practical source of artificial fill. Drumlin till is an excellent source of artificial fill, and its ease of compaction and relatively high bearing strength make it a desirable fill material when high permeability is not important. Special planning in slope design and drainage are usually required for highway cuts made in drumlin tills. Design of stable slopes in deeper cuts can be especially difficult.

Sand and gravel.—The most extensive sources of sand and gravel are the glaciofluvial deposits, most of which have been used to some extent. Ice-contact deposits contain a wide range of sand and gravel grain sizes and are an excellent source of permeable fill and subgrade material. The cleaner and better sorted outwash deposits can also be used for concrete aggregate. Highway cuts in the glaciofluvial deposits usually present no special problems in slope stability or drainage.

Clay.—The extensive deposits of marine clay and silt have been used as a source of brick clay, but at present there is little use for this material. The low bearing strength of the clay presents special problems in highway and building construction.

Swamp deposits.—In most places swamp deposits are thin and underlain by till or sand and gravel. Thick deposits of muck and peat probably occur in the larger swamps, and organic deposits are used extensively as a topsoil dressing.

LITERATURE CITED

Arnold, J. R., and Libby, W. F., 1951, Radiocarbon dates: Science, v. 113, p. 111-120.

Jahns, R. H., 1941, Outwash chronology in northeastern Massachusetts [abs.]: Geol. Soc. America Bull., v. 52, p. 1910.

________1953, Surficial geology of the Ayer quadrangle, Massachusetts: U.S. Geol. Survey Geol. Quad. Map GQ-21.

Johnson, Frederick, 1942, The Boylston Street Fishweir: Phillips Acad., R. S. Peabody Found. for Archaeology Papers, v. 2, p. 13-41.

Judson, Sheldon, 1949, The Pleistocene stratigraphy of Boston, Massachusetts and its relation to the Boylston Street Fishweir, *in* Johnson, Frederick, ed., The Boylston Street Fishweir II: Phillips Acad., R. S. Peabody Found. for Archaeology Papers, v. 4, no. 1, p. 7-48.

Kaye, C. A., 1961, Pleistocene stratigraphy of Boston, Massachusetts: Art. 34 *in* U.S. Geol. Survey Prof. Paper 424-B, p. B73-B76.

Oldale, R. N., 1961, Late-glacial marine deposits in the Salem quadrangle, Massachusetts: Art. 171 *in* U.S. Geol. Survey Prof. Paper 424-C, p. C59-C60.

________1962, Sedimentary rocks of Triassic age in northeastern Massachusetts: Art. 71 *in* U.S. Geol. Survey Prof. Paper 450-C, p. C31-C32.

Sears, J. H., 1905, The physical geography, geology, mineralogy, and paleontology of Essex County: Salem, Mass., 418 p.