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THE GEOLOGY AND EARLY HISTORY OF THE BOSTON AREA OF MASSACHUSETTS, A BICENTENNIAL APPROACH

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THE GEOLOGY AND EARLY HISTORY OF THE BOSTON AREA OF MASSACHUSETTS, A BICENTENNIAL APPROACH

By Clifford A. Kaye

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The role of geology in the important events that took place around Boston 200 years ago

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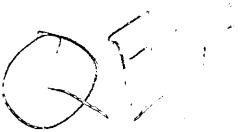

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THE GEOLOGY AND EARLY HISTORY OF THE BOSTON AREA OF MASSACHUSETTS, A BICENTENNIAL APPROACH

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INTRODUCTION

The revolt of the 13 British Colonies against their mother country and the founding of the United States began with oratory and musket fire from the peaceful countryside of New England. The town of Boston and its surrounding villages, midst stony fields and boulder fences, were the focus of the growing grumbling of discontent that finally turned into gunfire and bloodshed at Lexington, Concord, and Bunker Hill. Dissatisfactions with the oppressive rule of George III's government existed in other Colonies, but something in the character of the people of New England seemed to make rebellion come easier. The colonists were born and bred in a glacially molded landscape, and perhaps something of its uncompromising hard icy origin had permeated their thinking. Man is after all a creature of the Earth, and it is only natural that man's history should become mixed with the history of the Earth—its geology. It is appropriate, therefore, to consider, in this year of the 200th anniversary of the birth of the Nation, the role of geology in those important events that took place around Boston just two centuries ago.

GEOLOGIC SETTING OF THE BOSTON AREA

Boston lies at the head of a broad, island-studded harbor, formed by a deep indentation in the coastline of Massachusetts. This harbor was noted by many early explorers and was shown on Captain John Smith's 1614 map of the New England coast. We know that

this coastal indentation exists primarily because the bedrock under Boston is softer and erodes more readily than does the harder granitic rock that crops out to the north and south (fig. 1). Boston Harbor had its beginning when the land was covered by thick glacial ice during the Ice Age. The relentless movement of countless tons of ice during hundreds of thousands of years wore a valley, or depression, into the bedrock. Later, as the great glaciers melted, sea level rose and flooded this depression, producing the harbor as we know it. The harbor is part of a large topographic depression, commonly referred to as the Boston Basin. The margins of the basin are seen as an escarpment stretching almost continuously from Lynn and Saugus on the northeast through Malden, Medford, Arlington, and Waltham to the west. A visitor coming from the direction of Lexington and Concord and entering the Boston Basin on Route 2 suddenly notices, as he descends the escarpment at Arlington, the extensive lowland stretched below and the towers of the city in the distance.

Pre-Pleistocene Geologic History

The softest Boston rocks are argillite (related to slate and shale but harder) and volcanic ash. The argillite was originally deposited as clay in either a lake or marine embayment; the volcanic ash was blown out of the many volcanoes that were active in the area during the time the clay or mud was being deposited.

Gravel was interlayered with the clay and cemented into a hard rock called "conglomerate," locally called "puddingstone." This rock crops out widely in Roxbury, Dorchester, and Brookline. Also interlayered with these sediments were volcanic flows, ashes, cinders, and the great variety of deposits formed by volcanoes. These deposits—now hard rock—are best seen in nearby Mattapan, Hyde Park, Milton, Lynn, and Saugus.

Hundreds of millions of years have elapsed since these deposits were laid down, and the ash and mud not only has been compressed, cemented, and solidified into rock, it has also been deeply buried by later deposits and drawn deeper into the Earth's interior, where it was squeezed, folded, broken, and turned up on end. Today, these badly distorted rocks are at the surface again only because of the erosion of the many thousands of feet of rock that once overlay them.

What was the ancient landscape like at the time the Boston rocks were being laid down? In all probability, the region was a broad lowland surrounded by hills or mountains of granite. A large body of water, either a large lake or perhaps an arm of the sea, occupied part of the lowland. Small volcanoes and at least one large cone

that rose a mile or more in height dotted the plain and surrounding uplands. The ash from these volcanoes blanketed the plain and was carried by the rivers to the lake or sea where it mixed with silt and clay that was being carried by rivers from the upland. The rivers descending onto the plain from the surrounding highlands also carried gravel, which was deposited in flood plains and which makes up much of the Roxbury "puddingstone."

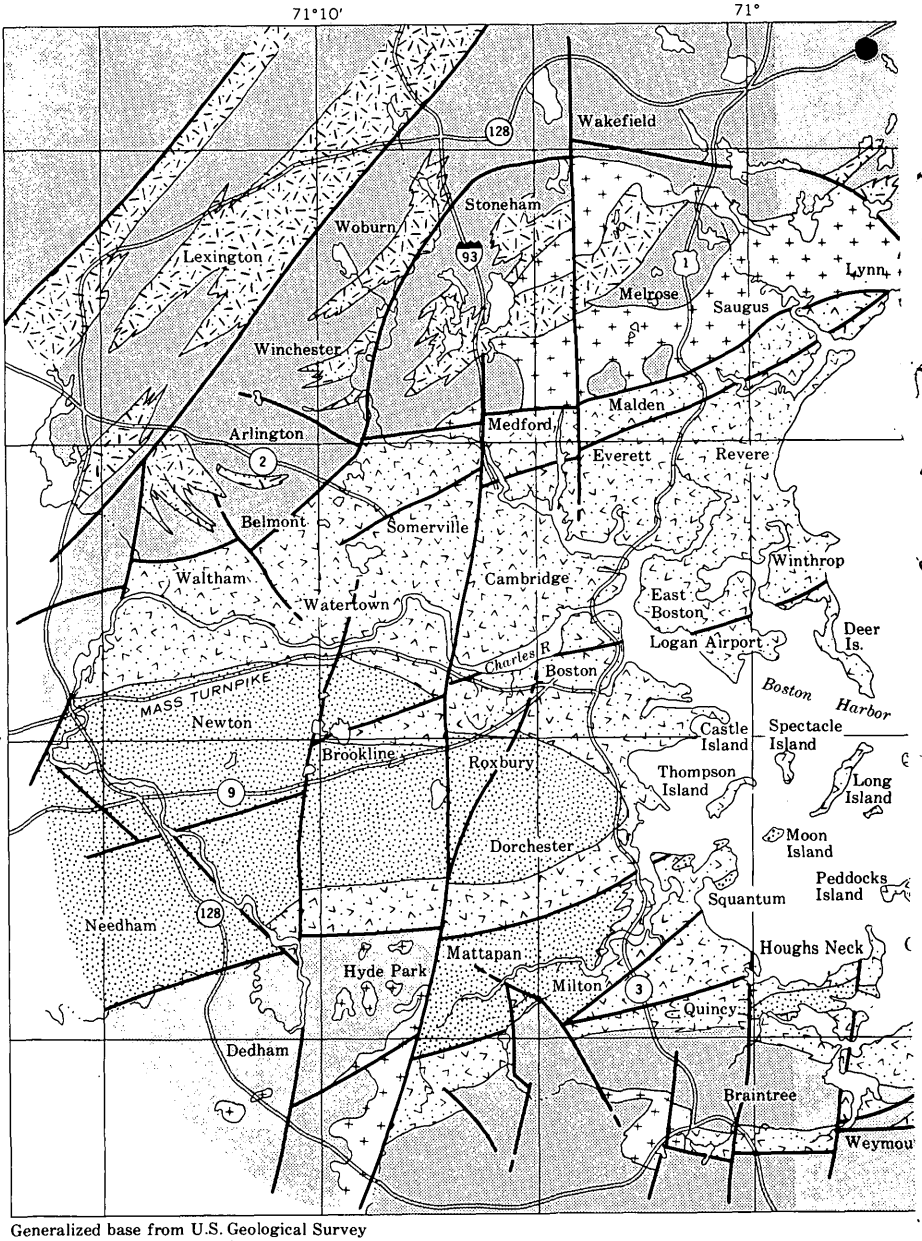
This landscape of remote Paleozoic time can be matched with landscapes existing today. One can see similarities in the Puget Sound lowland and the nearby Cascades in the State of Washington; the Sacramento Valley, with Marysville Buttes and Mounts Shasta and Lassen in the distance; the Imperial Valley, at the head of the Gulf of California depression, where volcanic centers existed until very recent time; the Po River Plain in northern Italy, where a volcanic center existed not long ago near Rimini; and many of the great rift valleys of Africa that contain deep lakes and nearby active volcanoes.

The erosion that has sculpted Boston's surface during the last million or so years has worn down these rocks, but at different rates, depending principally on their hardness. Most of this erosion is the result of glacial ice. Imagine the abrasive effect on the landscape of an endless belt of moving ice, a thousand or more feet thick, whose bottom was densely studded with rock fragments ranging in size from dust to boulders. The effect must have been like that of extremely coarse sandpaper. Today's bedrock surface, therefore, shows, by its highs and lows, the varying amounts of resistance given to this type of sanding by different kinds of rock. Harder volcanic rocks and conglomerates stand out as hills and knobs, whereas the softer argillites and volcanic ashes form valleys and are mostly buried beneath deposits of clay, sand, and gravel.

The Pleistocene Epoch—or the Ice Age

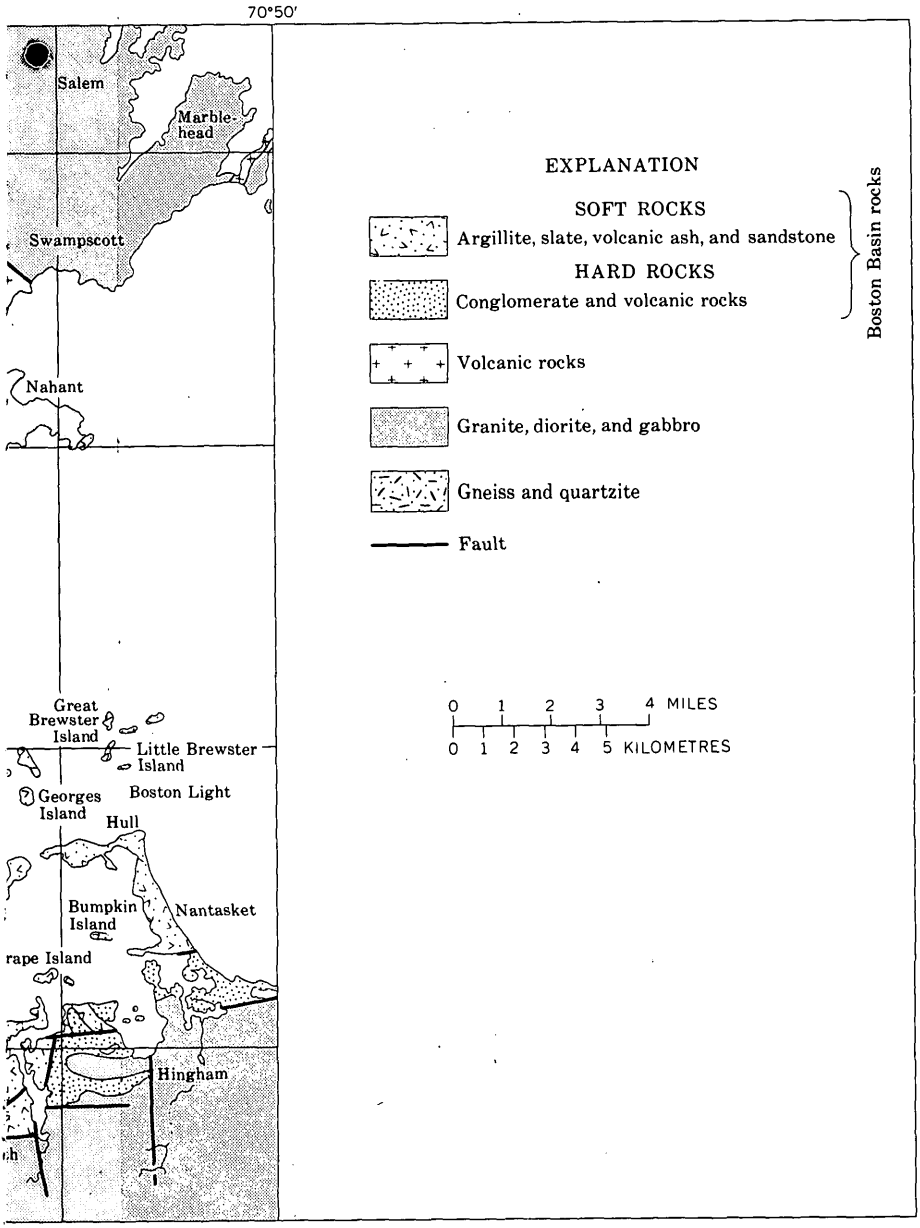
The Pleistocene Epoch was a remarkable and important episode in Boston's prehistory. For a million years or longer, the Earth's climate fluctuated from cold to warm—perhaps as many as 10 times. During each of the cold intervals, the snow that accumulated in the higher latitudes compacted under its own weight into ice and then slowly flowed or spread southward. These ice sheets attained thicknesses of thousands of feet and completely buried mountain ranges as high as the White Mountains in New Hampshire. Where the ice sheets reached the ocean, they floated for some distance before breaking apart to form large icebergs.

Boston was for a long time a busy crossroads of glacial activity, and remnants of this complex history litter the area today. This



Generalized base from U.S. Geological Survey
Road alinements are approximate

FIGURE 1.—Generalized geologic map of



the bedrock surrounding Boston, Mass.

activity is well expressed by Boston's many drumlins, which are glacially formed smooth-sloped hills, generally circular to elliptical in plan. Drumlins (the word comes from Ireland where they are a common feature of the landscape) usually are found in swarms in which the hills are elongated all more or less in the same direction. The hills are made up mostly or entirely of glacial debris called *till,* which is clay containing pebbles, cobbles, and even boulders, somewhat like fruit in an old-fashioned plum pudding.

The list of Boston drumlins is impressive and includes such well-known eminences as Prospect and Spring Hills in Somerville; Breeds and Bunker Hills in Charlestown; Camp Hill in East Boston; Mt. Washington in Everett; Powder Horn Hill in Chelsea; Fennos Hill, Orient Heights, and Beachmont in Revere; Cottage Hill in Winthrop; Parker, Meeting House, and Monterey Hills in Boston; Corey, Aspinwall, and Walnut Hills in Brookline; and Chestnut Hill and Mt. Ida in Newton. Some of the harbor islands are drumlins, including Deer, Thompson, Spectacle, Long, Georges, Great Brewster, Peddocks (five drumlins), and Bumpkin, among others (figs. 1, 2).

The Boston drumlins are somewhat unusual because unlike most drumlin fields, where the hills are all elongated in the same direction, like a school of fish with their noses to the current, Boston's drumlins resemble a school of fish that has been frightened by a pebble falling into the water. Adjacent drumlins diverge in orientation by as much as 70°. Some drumlins are almost circular in plan, others rise to two or more peaks, and a few are cored with bedrock. Also, many drumlins contain gravel, sand, and silt in addition to till. In places, sorted and stratified sediments seem to be more abundant than till.

How were drumlins formed? We really do not know, although certain things can be deduced. Clearly, drumlins were made by glacial ice, for they are only found in areas that were glaciated, and they consist largely of till, a sediment peculiar to glacial deposition. Also, their elongation is parallel to the direction of glacial flow. The wide variations of elongation directions in Boston drumlins can best be explained by the complex glacial history and the many directions taken by glacial flow. Boston drumlins were deposited and molded by glacial ice at various times and were not all formed at the very end of glaciation, as seems to have been the origin of drumlin fields in some other localities.

Except for the drumlins and the bare-rock exposures, the glacial landscape of Boston is the result of ice wastage. As the ice melted, it released the rock flour (that is, clay and silt-size sediment), sand, gravel, and boulders that had been frozen into it. These were carried as sediment by the melt-water streams and deposited in

flood plains, in lakes and ponds, and finally in Massachusetts Bay. Ponds and lakes were numerous over partially melted dead ice and in valleys that were temporarily dammed by large stagnant ice blocks. During the long period of slow glacial melting, which appears to have lasted several thousand years, little if any vegetation existed, and the landscape was truly arctic and desolate.

It was not until about 12,000 years ago that the last ice disappeared, and the Boston landscape, almost as the colonists knew it, came into existence. There was one important difference: 12,000 years ago sea level was lower by several scores of feet, which means that instead of a harbor there was a broad clayey valley across which the Charles and Neponset Rivers flowed. Long before the arrival of the first European settlers, however, this valley was flooded to form the harbor as we know it.

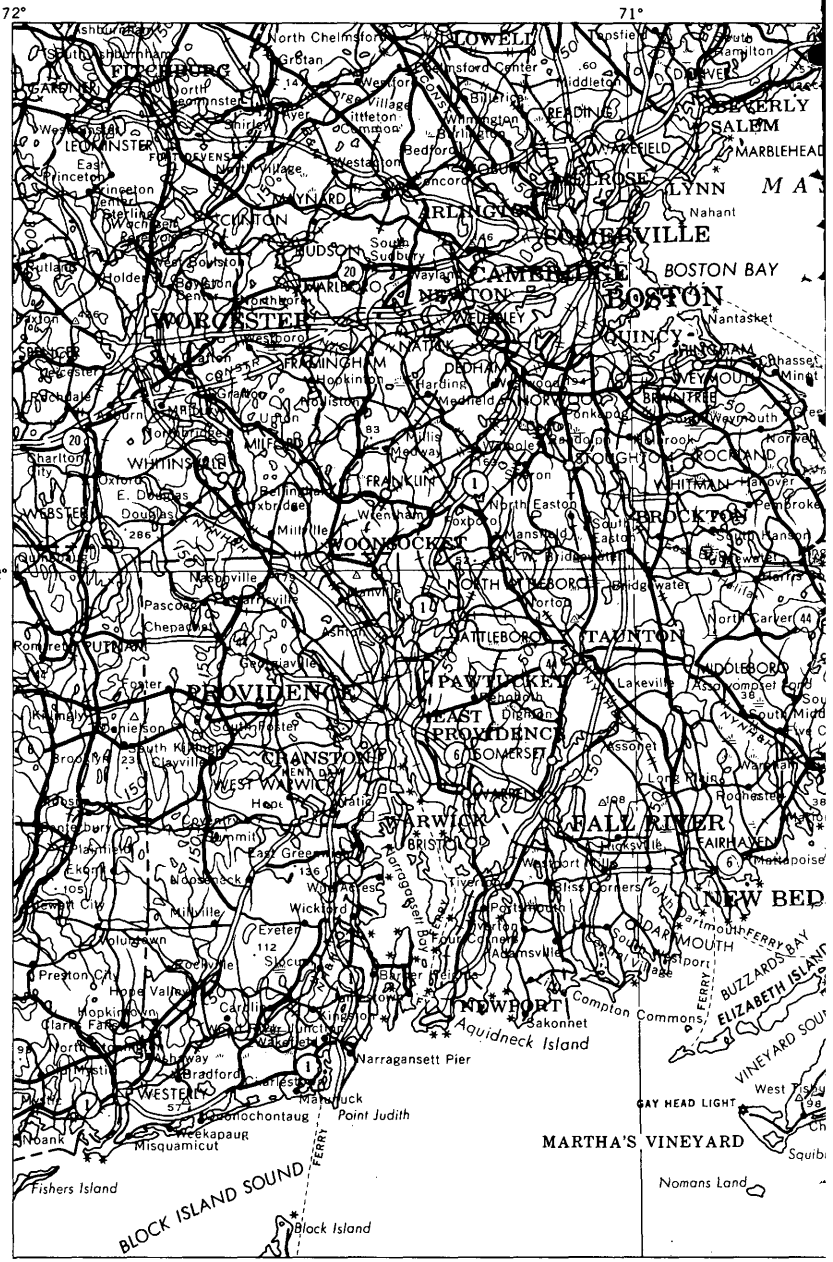
EARLY SETTLEMENTS

Of the several settlements founded in the early 17th century on the Massachusetts coast, the two most important were those of the Pilgrims at Plymouth in 1620 and the Puritans of the Massachusetts Bay Company at Boston in 1630. The selection of both town sites was based on almost identical geological considerations—the availability of tillable soil and a plentiful supply of good ground water.

The Pilgrims of Plymouth

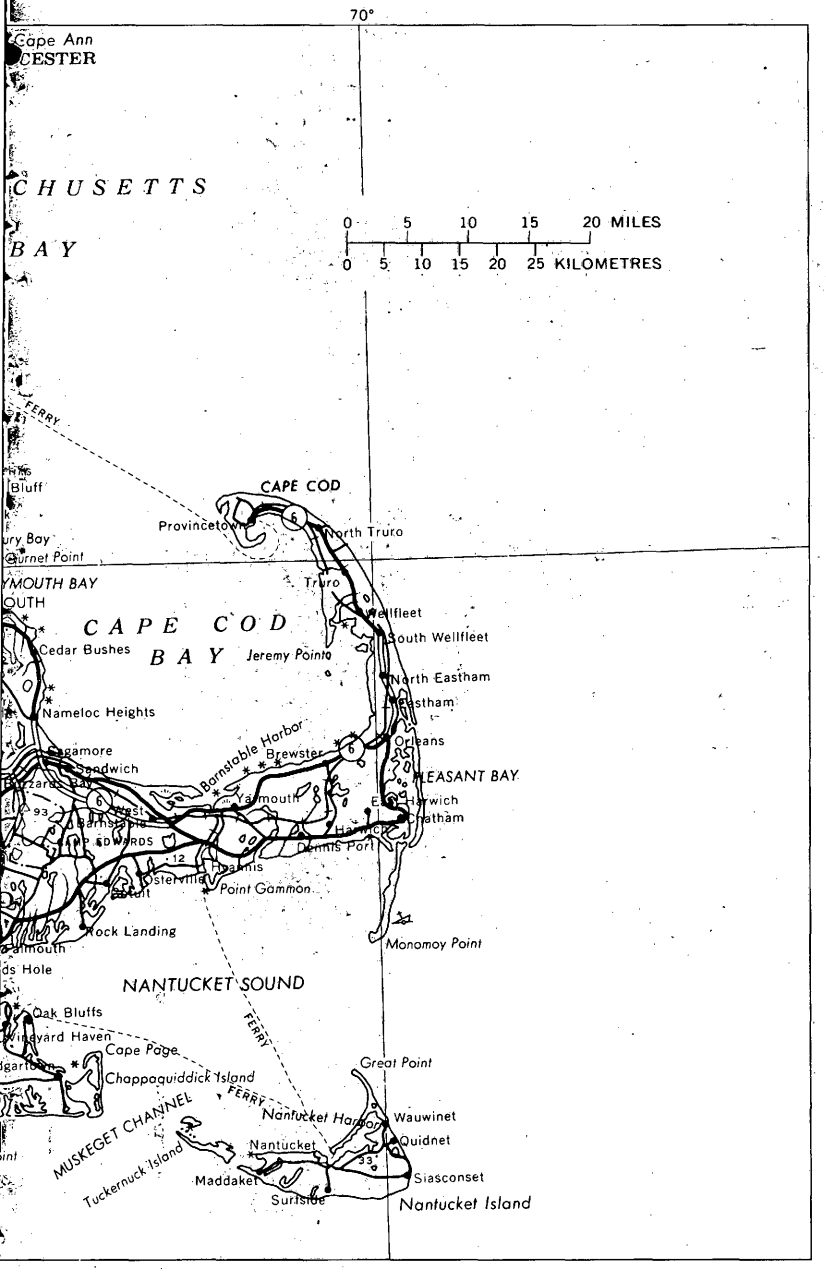
The ship *Mayflower* and the 102 pilgrims aboard set sail from Plymouth, England, in September 1620 for an undefined destination, described as being somewhere near the mouth of the Hudson River. They drifted far off course because of a series of storms and, instead, made landfall on Cape Cod, which was recognized by one of the crew who had seen it on an earlier journey. On November 21, they put into Provincetown Harbor, tucked in back of the sand hook that forms the northern tip of the Cape (fig. 3). After several weeks of desperate struggle to find food, water, and protection in the face of oncoming winter, they decided to look for a more promising place to establish their home. They were particularly bothered by the excessively sandy soil and the scarcity of fresh water. There were few fresh-water springs, and the wells they dug yielded only brackish water or no water at all.

The northern tip of Cape Cod is a great field of sand dunes and a sandy hook that curves deeply to the bay on the west. The hook is the work of ocean currents that wash northward along the beach



Base from U.S. Geological Survey
Boston 1:1,000,000, 1955

FIGURE 2.—Index map of the eastern Massachuset



Cape Cod area, showing place names mentioned in text.

of the eastern shore of the Cape, and the great shifting dunes represent beach sand blown inland by strong onshore winds. Except for these, the Outer Cape is entirely the work of glacial melt waters that carried sediment westward from the vast field of ice that once covered the entire Continental Shelf to the east as far as Georges Bank. The sand and gravel under Cape Cod are well over 100 feet thick, as can be seen in the sea cliffs on the Outer Cape. Several miles south of Provincetown, on the uplands of Truro, the low-level dunes disappear, but the soil is still sandy and dry, and ground water is deep—too deep for people who could only dig shallow wells.

When the decision was made to reconnoiter for a better site for a settlement, the main search party sailed westward from Cape Cod in a shallop, a large open rowboat provided with a sail. The party found the confusing entrance to Plymouth harbor during a fierce ice storm and nearly lost their vessel on the bouldery shore of Clarks Island—a drumlin within the harbor. After hasty repairs to their craft, they gained the mainland at the site of the present town of Plymouth, stepping to shore on a large glacial boulder, Plymouth Rock.

The essentials they were looking for were rapidly discovered: flowing springs, good streams, and land that seemed both fertile and tillable. In fact, they found several cleared fields that had been abandoned by the local Indians a short time before. The shallop returned to Provincetown with the good news, and the *Mayflower* sailed into Plymouth harbor on December 29, 1620.

The geological explanation for the water and soil conditions at Plymouth is again a glacial story. Two deposits were found at the town site—relatively impervious glacial till and sand and gravel. The till was deposited directly by the melting glacial ice and overlies granitic bedrock. It, in turn, is overlain by water-bearing sand and gravel. The ideal geologic relationship for flowing springs is the presence of pervious sand and gravel overlying impervious materials such as clay, till, or bedrock. The stream and spring that were found that day can still be seen in Plymouth.

Agricultural soils at Plymouth were better than those on Cape Cod mainly because, in the new locality, a surface layer of silty loam covered the less fertile sand, gravel, and stony till. This fertile silt blanket, which at one time was widespread over much of New England, particularly in low-lying areas and valley floors, is found today only in places that have not been intensively cultivated or that have not had the surface disturbed by digging. It is a dust deposit, rarely more than 2 feet thick, that was laid down when strong winds, blowing off the great glacial expanse, whipped up fine sand and silt from valley floors, exposed as they were to wind erosion by the absence of vegetation. This windblown silt layer

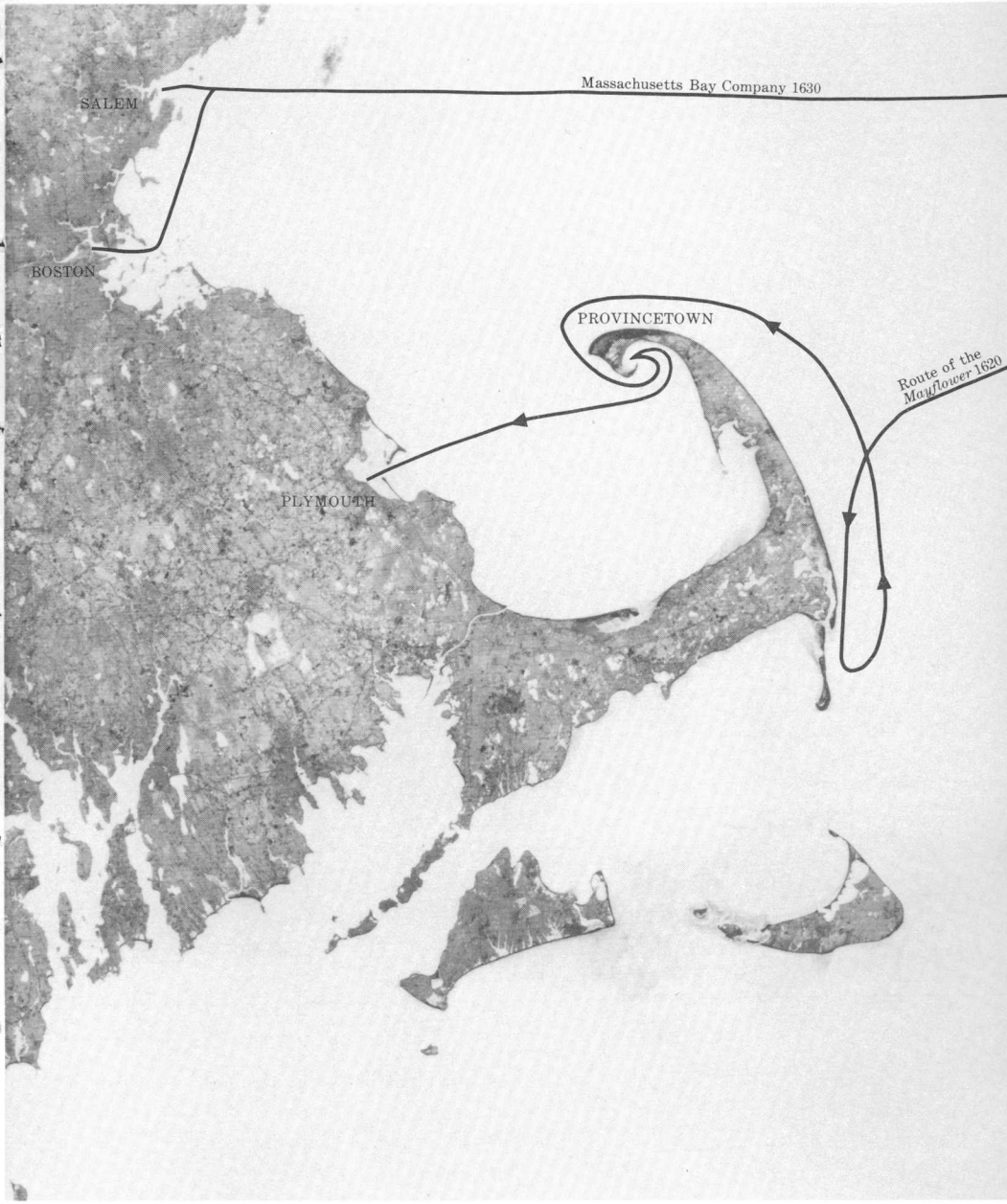


FIGURE 3.—Landsat image of eastern Massachusetts and part of Rhode Island, showing routes of the *Mayflower* (1620) and Puritans of the Massachusetts Bay Company (1630).

FIGURE 4.—Three-foot surface layer of windblown silt overlying glacial outwash gravel. The zigzag pattern of the bedding in the gravel shows that the wasting ice had a renewed lease on life and pushed forward against the gravel from left (north) to right (south). Photograph taken at Peacedale, Rhode Island.

(fig. 4) is similar to the very much thicker loess deposit in the central part of the United States. This silt may well have contributed substantially to the prosperity of early farming in New England. As a result of extensive cultivation, the silt washed and blew away from many fields, exposing the underlying stony soils that have since characterized New England farms.

Not only was the fate of the new settlement of Plymouth tied to the glacial geology of the area, but the famous Plymouth Rock served as an early portent of this tie. Before the arrival of the Pilgrims, this 7-foot boulder had been eroded by wave action from the glacial till that forms the shore here. The boulder is a glacial

erratic, that is, a block of bedrock that has been carried from its original outcrop by glacial ice to its present location. It was not carried far, however, because identical rock—light-gray fine-grained granite—crops out on the shore of Kingston only 3½ miles to the northwest.

The Puritans of Boston

About 1,000 people set sail in 11 ships from the small English Channel port of Cowes, on the Isle of Wight, in the spring of 1630 to establish a settlement under the sponsorship of the Massachusetts Bay Company and the leadership of John Winthrop. Their destination was Salem, about 15 miles north of Boston, where more than 100 English had been living for about a year. Unlike their countrymen 10 years before on the *Mayflower,* their navigation was true, and they made the harbor of Salem in June of that year.

When we stop to consider that these settlers were mostly from southern England, a region of deep soils and rich farmland, we can readily imagine their dismay on arriving at Salem to find a landscape of barren rock and little soil. They had not been forewarned that Salem is in a rocky belt that stretches for many miles from the rim of the Boston Basin as far east as Cape Ann. After the long confining sea voyage, the first view of their new home must have been difficult for even the strongest of them to bear. The newcomers demanded that their leader seek a better place to settle.

Within a week of arrival at Salem, Governor Winthrop headed south on foot, over Indian trails. He soon descended to the lowlands of the Boston Basin where the rock terrain was replaced by gentle forested slopes, rivers, marshes, and here and there smooth soil-covered hills (drumlins). His destination was Charlestown where a group of English belonging to the same group as those of Salem had settled before. There, on the lower slopes of a drumlin, Breeds Hill (the same hill that played such an important role 145 years later, erroneously called Bunker Hill), by the shores of a river—the Charles—and at the head of a splendid harbor, a second start was made. The Puritans reembarked at Salem and sailed into Boston Harbor in their small fleet to pitch tents and start building. Almost instantly, however, sickness broke out, and within a week or two, some of the most prominent members of the community had died. Bad water was blamed, as a single spring served the entire community of approximately 1,100 people (counting the earlier settlers).

It was fortunate that across the narrow Charles River from the settlement, a lone Englishman, William Blackstone, lived on the

western end of the hill now called Beacon Hill. He met the newcomers and told them that he had an excellent spring on his land. In consequence, Winthrop ordered his group to pack up once more and to move across the river to share Blackstone's good fortune. This third site became the town of Boston because the colonists indeed found water in abundance. In addition to Blackstone's spring, several other springs were found, and shallow dug wells produced water of good quality under artesian pressures. The reason for this hydrologic situation has only lately been revealed by studies of the geology exposed in excavations for new large buildings. These investigations have shown that most of the area is underlain by a sandwich of thick highly pervious gravels between till and clay; this sequence has been deformed and folded upward to form Beacon Hill.

GROUND WATER, WELLS, AND SPRINGS

Underground water is rainwater that has seeped into the ground. It does not come from subterranean sources or from "deep down within the Earth." Furthermore, the spaces occupied by water in the ground are not great caverns, subterranean channels, or underground rivers, but simply the network of tiny voids that always exist between pebbles, sand grains, and even between microscopic particles. If one needs proof of this, it can be easily demonstrated. Fill a drinking glass with dry pebbles and then fill the same glass with water. The two substances are not mutually exclusive; the pebble-filled glass accommodates a fairly large quantity of water. Now tilt the glass, holding the pebbles in, and most of the water will spill out. If one does this with a glass full of sand, the sand also absorbs water, but much less water can be poured from the glass. In this simple experiment, we have the essence of several of the major principles governing water underground. Gravel and coarse sands, which have a network of large intergranular spaces filled with water, readily yield this water in wells. This coarsely porous earth material is called an *aquifer* and is the kind of material we hope to reach by means of a water well. Fine sands, silts, and clays, on the other hand, are not aquifers because water cannot readily flow through the network of capillary-size pores. This type of earth material does not yield water in a well and is called an *aquiclude*. When the two types of sediment are interlayered, that is, if an aquifer is sandwiched between two aquicludes, the system is then comparable to a pipe, the aquicludes effectively forming the walls of the pipe. One can understand the mechanisms

of an artesian well (a flowing well) by comparing such a system with an inclined or vertical pipe filled with water. If a hole is punched in the lower end of such a pipe, water will escape, squirting out as a jet, the height of which depends on the height of water in the pipe (the *hydraulic head*). Water rises in wells, or bubbles up out of the ground in flowing springs, for the same reason—the hydraulic head in the aquifer.

We know that many houses in colonial Boston had their own wells, because some of these wells have been unearthed in recent building excavations. Some households, however, drew water from the town well and the town spring. The town well was about 50 feet from the intersection of Washington, State, and Court Streets, on what is now called Washington Mall. Water came from shallow gravel that overlay silt and till. The flowing town spring was, appropriately enough, in Spring Lane, just downhill from Washington Street. William Blackstone's famous spring was near the western end of Beacon Hill, perhaps south of Louisburg Square in the vicinity of Acorn Street.

The quality of well water in old Shawmut Peninsula varied. Wells in the lower part of town, close to sea level, tended to be slightly brackish. The best water probably was found on the north slope of Beacon Hill above Cambridge Street, because there the wells did not have to go so deep that they were influenced by salt-water intrusion from the harbor.

Foundation excavations for new buildings in the Beacon Hill section of old Boston have exposed many water wells, all of which tap thick gravels that are interlayered with, or underlie, clay, fine sand, and till. Today, little if any water seeps into these gravels, which at one time were full of water, because Boston is now so completely covered with paving and buildings that almost all rainwater is carried off by sewers, and little gets into the ground.

Wells must be kept open and protected from caving. Recently collected data show that colonial water-well technology improved through the years. Very early wells were simply lined with coarse slabs of local rock, laid flat like bricks. Later, the wells were lined with large cobbles retained by a wooden sheathing of vertical planks held together by wooden rings. Still later, a double wooden sheathing with cobbles in between was used, and, later yet, well-laid brick, loosely mortared.

Pumps have been found in some of the deep wells. The device consisted of a hollow log pipe extending down the center of the well, on the bottom of which was a moving wooden piston fitted with a wooden flap-valve. This was attached to the piston block by a leather hinge. Thin lift-rods must have been attached to the valved piston and activated by a pump handle at the surface.

Log pipes were used for water and gas until the mid-19th century; they have been unearthed in many localities. The pipes were octagonal or hexagonal in cross section and about 10–12 inches in diameter. The size of the holes ranged from 3 to 4 inches. Sections of the pipe, generally 20 feet long, were coupled by means of tapered male and female ends. A variety of wood was used, including oak and pitch pine.

A privately owned water company was organized in Boston in 1795. The system, involving about 40 miles of hollow log pipes, carried water downslope from Jamaica Pond, in Jamaica Plain. Wells continued to be used in the higher elevations of Beacon Hill, however, because the system did not have sufficient pressure to raise water very far above sea level. In 1848, a new and more ample public supply system was inaugurated by the city. The water came from Lake Cochituate, about 15 miles west of the city. A retaining reservoir was built on the top of Beacon Hill at the place where Sentry Hill formerly stood and where the State House Annex now stands. Water was pumped up to the reservoir, from which it flowed by gravity to all parts of Beacon Hill.

EARTHQUAKE OF NOVEMBER 18, 1755

At about 4 o'clock in the morning of November 18, 1755, just 18 days after the catastrophic Lisbon earthquake had destroyed that city and had shaken most of Europe, a very severe earthquake tumbled Bostonians out of bed. This is the strongest known earthquake in the Northeastern United States on record.

On the scene at the time was Professor John Winthrop of Harvard University, who transmitted his detailed description of the event to the Royal Society, London, where it was published in the Philosophical Transactions of the Society for 1757. To quote from that paper by Professor Winthrop (1757, p. 2–3):

The night, in which this earthquake happened, was perfectly calm and serene. In the evening there was a fog over the marshes bordering on the river Charles, which runs through this town: but this I found entirely dissipated at the time of the earthquake, the air being then quite clear, and the moon, which wanted but 36h of the full, shining very bright. The earthquake began with a roaring noise in the N.W. like thunder at a distance; and this grew fiercer, as the earthquake drew nearer; which was almost a minute in coming to this place, as near as I can collect from one of my neighbours, who was then on the road in this town. He tells me, that, as soon as he heard the noise, he stopt, knowing, that it was an earthquake, and waiting for it; and he reckoned he had stood

still about 2′ [2 minutes], *when the noise seemed to overtake him, and the earth began to tremble under him: but, as I doubted, whether it were so long, I counted several numbers to him as slowly as a clock beats seconds; and then he said, he believed he could have counted half an hundred, at that rate, before the noise and shake came up to him. By his account, as well as that of others, the first motion of the earth was what may be called a pulse, or rather an undulation; and resembled (to use his own comparison) that of a long rolling, swelling sea; and the swell was so great, that he was obliged to run and catch hold of something, to prevent being thrown down. The tops of two trees close by him, one of which is 25, the other 30 feet high, he thinks waved at least ten feet (and I depend on his judgment in this particular, because he judged right of the height of the trees, as I found by actual mensuration); and there were two of these great wavings, succeeded by one, which was smaller. This sort of motion, after having continued, as has been conjectured, about a minute, abated a little; so that I, who was just then waked, and, I suppose, most others, imagined, that the height of the shock was past. But instantly, without a moment's intermission, the shock came on with redoubled noise and violence; though the species of it was altered to a tremor, or quick horizontal vibratory motion, with sudden jerks and wrenches. The bed, on which I lay, was now tossed from side to side; the whole house was prodigiously agitated; the windows rattled, the beams cracked, as if all would presently be shaken to pieces. When this had continued about 2′ it began to abate, and gradually kept decreasing, as if it would be soon over: however, before it had quite ceased, there was a little revival of the trembling and noise, though no-ways comparable to what had been before: but this presently decreased, till all, by degrees, became still and quiet . . .*

The earthquake was felt as far away as Halifax, Nova Scotia, to the north, the Eastern Shore of Maryland to the south, Lake George in eastern New York on the west, and on outer Georges Bank about 250 miles east of Boston. In this last-mentioned place, a ship in 250 feet (80 m) of water felt as though it had struck bottom. It was fortunate that the buildings in Boston in 1755 were low and mostly of wooden frame construction. The principal damage in the city of Boston and surrounding areas, besides the overturning of objects on shelves and tables, was the tumbling of chimneys and some brick walls. Many stone field fences were destroyed. Spindles of weathervanes were snapped off or bent, including the spindle holding the famous gilded copper grasshopper weathervane on Faneuil Hall. The spindle was a 5-inch wooden shaft. (Winthrop described this as the weathervane and spindle

on the "public-market house in Boston." In all likelihood, this was Faneuil Hall—the original hall, that is, before the enlargement and renovation of the building in 1805.) It is interesting to note that Faneuil Hall is built on reclaimed or made-land—that is, sand and gravel fill, dumped on harbor muds in the tidal zone—because one of the lessons learned from the famous San Francisco earthquake of 1906 is that buildings on made-land of this type fare the worst in earthquakes.

Brick buildings fared less well, losing walls as well as some chimneys. Buildings constructed during the great expansion of the city that took place in the 19th century, when the Back Bay and other tidal areas were filled, would fare badly in an earthquake like that of 1755.

THE GATHERING STORM

The revolution was long in coming. The basic cause—if such a passionate and complex chain of events can be described in a few words—was that the British Crown and successive governments chose to consider the colonists as second-class citizens, to use a modern term. The colonists, on the other hand, thought of themselves as British first and colonials second, and, as such, entitled to all the rights, liberties, and privileges of their fellow countrymen living in the homeland. Perhaps they were sensitive, if not touchy, on this matter, isolated as they were, and therefore quick to sense abandonment. Nevertheless, successive reminders were sent from London that the colonists were mistaken as to the nature of their citizenship. The situation grew progressively worse in 1763 after Britain signed the Treaty of Paris, ending the costly Seven Years' War with France. Although Britain was the victor, she was broke, in debt, and badly in need of extra revenues. With the rationalization that part of the war had been fought in America (the French and Indian War), young King George III and his ministers thought it only fair to tax the colonies disproportionately in order to increase revenues and fill once again the empty exchequer. The list of acts passed by Parliament or promulgated by Crown representatives with this in mind, or as punitive measures because of noncompliance, reads like a litany of authoritarian stupidity: Writs of Assistance, the Navigation Acts, the Sugar Act, the infamous Stamp Act (later repealed), the Townshend Acts (later repealed except for tea), the repressive stationing of troops and ships-of-war in Boston, the dissolution of colonial assemblies, and the declaration of martial law.

By 1765, Boston was already in a state of rebellion. The next 10 years were spent as though the community were suffering from

tropical fever—one great crisis after another. Each objection by townspeople to arbitrary acts by the authorities created additional arbitrary regulations. It was as though both parties were caught in a narrow passageway leading ever downward.

Among the many riotous events that took place during the decade 1765–1775, the Boston Massacre of March 5, 1770 (fig. 5), and the Boston Tea Party of December 16, 1773, are undoubtedly the best known. Porter (1881, p. 30–32) described the scene and mood of the Boston Massacre:

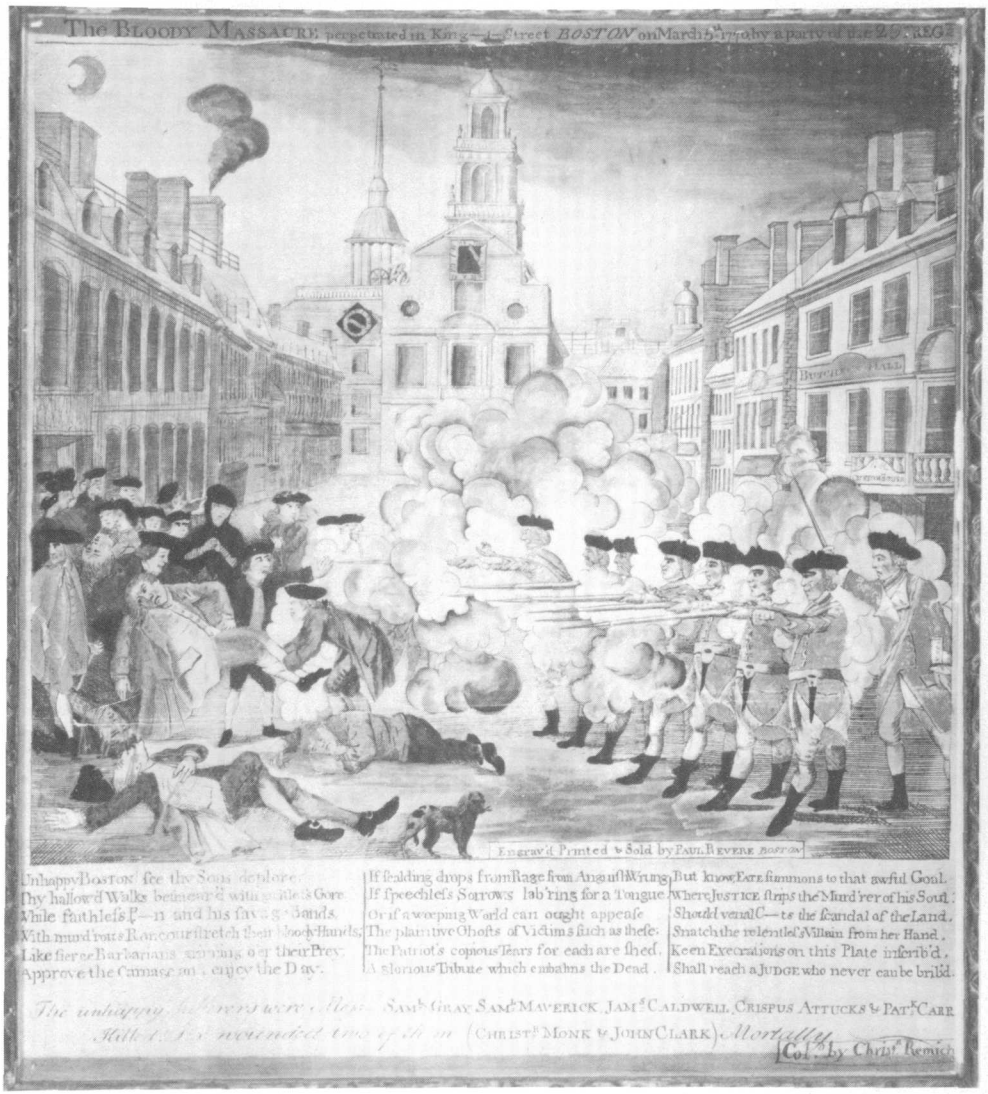


FIGURE 5.—A copper-plate engraving by Paul Revere, 1770, of the Boston Massacre, from a drawing by Henry Pelham. Courtesy, Museum of Fine Arts, Boston.

It was now nearly a year and a half since the troops had come to Boston, and their presence was a continual source of irritation to the inhabitants. Their services were not wanted; their parades were offensive; their bearing often insulting. Quarrels would occasionally arise between individual soldiers and citizens. 'The troops greatly corrupt our morals,' said Dr. Cooper, 'and are in every sense an oppression. May Heaven soon deliver us from this great evil!'

In this state of things, any unusual excitement might at any time occasion disastrous results. Towards the end of February an event occurred which threw the public mind into a ferment, and prepared the way for the tragic scenes of the fifth of March. A few of the merchants had rendered themselves unpopular by continuing to sell articles which had been proscribed. One of them in particular had incurred such displeasure that his store was marked by the crowd with a wooden image as one to be shunned. One of his friends, a well known informer, attempted to remove the image, but was driven back by the mob. Greatly exasperated, he fired a random shot among them and mortally wounded a young lad, who died the following evening. The funeral was attended by five hundred children, walking in front of the bier; six of his schoolmates held the pall, followed by thirteen hundred of the inhabitants. The bells of the town were tolled, and the whole community partook of the feeling of sadness and indignation that innocent blood had been shed in the streets of Boston.

A few days later, a still more serious occurrence took place. On Friday, March 2, two soldiers, belonging to the Twenty-ninth Regiment, were passing Gray's rope-walk, near the present Pearl Street, and got into a quarrel with one of the workmen. Insults and threats were freely exchanged, and the soldiers then went off and found some of their comrades, who returned with them and challenged the ropemakers to a boxing-match. A fight ensued, in which sticks and cutlasses were freely used. Several were wounded on both sides, but none were killed. The proprietor and others interposed, and prevented further disturbance. The next day it was reported that the fight would be resumed on Monday. Colonel Carr, commander of the Twenty-ninth, complained to the Governor of the conduct of the rope-makers. Hutchinson laid the matter before the council, some of whom freely expressed the opinion that the only way to prevent such collisions was to withdraw the troops to the Castle; but no precautionary measures were taken. At an early hour on Monday evening, March 5, numerous parties of men and boys were strolling through the streets, and whenever they met any of the soldiers a sharp altercation took place. The ground was frozen and covered with a slight fall of snow, and

a young moon shed its mild light upon the scene. Small bands of soldiers were seen passing between the main guard and Murray's barracks in Brattle Street, armed with clubs and cutlasses. They were met by a crowd of citizens carrying canes and sticks. Taunts and insults soon led to blows. Some of the soldiers levelled their firelocks, and threatened to 'make a lane' through the crowd. Just then an officer on his way to the barracks, finding the passage obstructed by the affray, ordered the men into the yard and had the gate shut. The alarm-bell, however, had called out the people from their homes, and many came down towards King Street, supposing there was a fire there. When the occasion of the disturbance was known, the well disposed among them advised the crowd to return home; but others shouted: 'To the main guard! To the main guard! That's the nest!' Upon this they moved off towards King Street, some going up Cornhill, some through Wilson's Lane, and others through Royal Exchange Lane. Shortly after nine o'clock an excited party approached the Custom House, which stood on the north side of King Street, at the lower corner of Exchange Lane, where a sentinel was standing at his post. 'There's the soldier who knocked me down!' said a boy whom the sentinel, a few minutes before, had hit with the but-end of his musket. 'Kill him! Knock him down!' cried several voices. The sentinel retreated up the steps and loaded his gun. 'The lobster is going to fire,' exclaimed a boy who stood by. 'If you fire you must die for it,' said Henry Knox, who was passing. 'I don't care,' replied the sentry; 'if they touch me, I'll fire.' While he was saying this, snowballs and other missiles were thrown at him, whereupon he levelled his gun, warned the crowd to keep off, and then shouted to the main guard across the street, at the top of his voice, for help. A sergeant, with a file of seven men, was sent over at once, through the crowd, to protect him. The sentinel then came down the steps and fell in with the file, when the order was given to prime and load. Captain Thomas Preston of the Twenty-ninth soon joined his men, making the whole number in arms ten. About fifty or sixty people had now gathered before the Custom House. When they saw the soldiers loading, some of them stepped forward, shouting, whistling, and daring them to fire. 'You are cowardly rascals,' they said; 'lay aside your guns and we are ready for you.' 'Are the soldiers loaded?' inquired a bystander. 'Yes,' answered the Captain, 'with powder and ball.' 'Are they going to fire on the inhabitants?' asked another. 'They cannot,' said the Captain, 'without my orders.' 'For God's sake,' said Knox, seizing Preston by the coat, 'take your men back again. If they fire, your life must answer for the consequences.' 'I know what I'm about,' said he, hastily; and then, seeing his men pressing the people with their bayonets, while clubs were being

freely used, he rushed in among them. The confusion was now so great, some calling out, 'Fire, fire if you dare!' and others, 'Why don't you fire?' that no one could tell whether Captain Preston ordered the men to fire or not; but with or without orders, and certainly without any legal warning, seven of the soldiers, one after another, fired upon the citizens, three of whom were killed outright: Crispus Attucks, Samuel Gray, and James Caldwell; and two others, Samuel Maverick and Patrick Carr, died soon after from their wounds. Six others were badly wounded. It is not known that any of the eleven took part in the disturbance except Attucks, who had been a conspicuous leader of the mob.

When the firing began the people instinctively fell back, but soon after returned for the killed and wounded. Captain Preston restrained his men from a second discharge, and ordered them back to the main guard. The drums beat to arms, and several companies of the Twenty-ninth formed, under Colonel Carr, in three divisions, in the neighborhood of the Town House. And now the alarm was everywhere given. The church bells were rung, the town drums beat to arms, and King Street was soon thronged with citizens who poured in from all directions. The sight of the mangled bodies of the slain sent terror and indignation through their ranks. The excitement surpassed anything which Boston had ever known before. It was indeed a 'night of consternation.' No one knew what would happen next; but in that awful hour the people were guided by wise and prudent leaders, who restrained their passions and turned to the law for justice.

If we may pause a moment and put aside this high drama to consider geology, it is interesting to note that the site of the Boston Massacre, the intersection of State and Congress Streets (incidentally, not quite where a circle of paving stones in a small triangular island in the center of State Street now shows it to have been), is just about where the Beacon Hill deformation makes its appearance. As alluded to earlier, Beacon Hill is composed of a complicated arrangement of layers of sand, clay, gravel, and till, which has been folded, faulted, and arched up, undoubtedly by glacial ice. We know from excavations that all deposits uphill from the site of the Boston Massacre are severely deformed as though they too had undergone revolutionary turmoil. On the other hand, the layers of clay in the opposite direction (towards the harbor) seem undisturbed. One need not look for a connection between this fact and the event of March 5, 1770, however.

To better understand Rev. Porter's description of the Boston Tea Party (below), it should be understood that with the levying of a high import duty on tea as a provision of the Townshend Act in 1768, the colonists, and particularly Bostonians, foreswore drink-

ing tea and, in general, foreswore importing from Britain any of the commodities covered by that act. This produced an era of self-denial and of self-reliance. Things now were manufactured in the colonies that had hardly been bothered with before. Woolens, linens, and textiles of all kinds that had been imported and that had once kept many English mills busy were now being turned out on home looms. For example, the Harvard College graduating class of 1770 was proud to present themselves at their commencement ceremony dressed to the man in homespun. By 1773, therefore, many Americans, though longing for the tea they had long denied themselves, were not so parched that they could not turn back a new shipment that the East India Company and the British Government thought they would be happy to accept, this time because it was at a bargain price. The tea, transhipped from Britain, was for the first time excused from paying English port duty though it still carried colonial duty (to be collected in Boston). It was the principle of the tax that rankled the Bostonians. Indeed, this had all become a great struggle for an overriding principle: Are we free-born British citizens or are we slaves? The issues had become clearly defined. Porter's (1881, p. 46–51) account follows:

On Sunday, November 28, the ship 'Dartmouth,' Captain Hall, after a sixty days' passage, appeared in the harbor, with one hundred and fourteen chests of tea. There was no time to be lost. Sunday though it was, the selectmen and the committee of correspondence held meetings to take immediate action against the entry of the tea. The consignees had gone to the Castle; but a promise was obtained from Francis Rotch, the owner of the vessel, that it should not be entered until Tuesday. The towns around Boston were then invited to attend a mass meeting in Faneuil Hall the next morning. Thousands were ready to respond to this summons, and the meeting was obliged to adjourn to the Old South. Boston, it was said, had never seen so large a gathering. It was unanimously resolved, upon the motion of Samuel Adams, that the tea should be sent back, and that no duty should be paid on it. 'The only way to get rid of it,' said Young, 'is to throw it overboard.' At an adjourned meeting in the afternoon, Mr. Rotch entered his protest against the proceedings; but the meeting, without a dissenting voice, passed the significant vote that if Mr. Rotch entered the tea he would do so at his peril. Captain Hall was also cautioned not to allow any of the tea to be landed. To guard the ship during the night, a volunteer watch of twenty-five persons was appointed, under Captain Edward Proctor. 'Out of great tenderness' to the consignees, the meeting adjourned to Tuesday morning, to allow further time for consultation. The answer, which was given jointly, then was that it was not in the power of the consignees to send the

tea back; but they were ready to store it till they could hear from their constituents. Before action could be taken on this reply, Greenleaf, the Sheriff of Suffolk, entered with a proclamation from the Governor, charging the inhabitants with violating the good and wholesome laws of the province, and 'warning, exhorting, and requiring them, and each of them there unlawfully assembled, forthwith to disperse.' This communication was received with hisses and a unanimous vote not to disperse. At this juncture, Copley the artist, son-in-law of Clarke, tendered his services as mediator between the people and the consignees, and was allowed two hours for the purpose; but after going to the Castle he returned with a report which was voted to be 'not in the least degree satisfactory.' In the afternoon, Rotch and Hall, yielding to the demands of the hour, agreed that the tea should return, without touching land or paying duty. A similar promise was obtained from the owners of two other tea-ships, which were daily expected; and resolutions were passed against such merchants as had even 'inadvertently' imported tea while subject to duty. Armed patrols were appointed for the night; and six post-riders were selected to alarm the neighboring towns, if necessary. A report of the proceedings of the meeting was officially transmitted to every seaport in Massachusetts; also to New York and Philadelphia, and to England.

In a short time the other tea-ships, the 'Eleanor' and the 'Beaver,' arrived and, by order of the committee, were moored near the 'Dartmouth' at Griffin's Wharf, that one guard might answer for all. Under the revenue laws the ships could not be cleared in Boston with the tea on board, nor could they be entered in England; and, moreover, on the twentieth day from their arrival they would be liable to seizure. Whatever was done, therefore, must be done soon. The Patriot leaders were all sincerely anxious to have the tea returned to London peaceably, and they left nothing undone to accomplish this object. On the eleventh of December the owner of the 'Dartmouth' was summoned before the committee, and asked why he had not kept his agreement to send his ship back with the tea. He replied that it was out of his power to do so. 'The ship must go,' was the answer. 'The people of Boston and the neighboring towns absolutely require and expect it.' Hutchinson, in the meantime, had taken measures to prevent her sailing. No vessel was allowed to put to sea without his permit; the guns at the Castle were loaded, and Admiral Montagu had sent two warships to guard the passages out of the harbor.

The committees of the towns were in session on the thirteenth. On the fourteenth, two days before the time would expire, a meeting at the Old South again summoned Rotch and enjoined upon

him, at his peril, to apply for a clearance. He did so, accompanied by several witnesses. The collector refused to give his answer until the next day, and the meeting adjourned to Thursday, the sixteenth, the last day of the twenty before confiscation would be legal. For two days the Boston committee of correspondence had been holding consultations of the greatest importance.

On Wednesday Rotch was again escorted to the Custom House, where both the collector and the comptroller 'unequivocally and finally' refused to grant the 'Dartmouth' a clearance unless her teas were discharged.

Thursday, December 16, came at last,—dies irae, dies illa!—*and Boston calmly prepared to meet the issue. At ten o'clock the Old South was filled from an outside assemblage that included two thousand people from the surrounding country. Rotch appeared and reported that a clearance had been denied him. He was then directed as a last resort to protest at once against the decision of the Custom House, and apply to the Governor for a passport to go by the Castle. Hutchinson, evidently anticipating such an emergency, had found it convenient to be at his country-seat on Milton Hill, where it would require considerable time to reach him. Rotch was instructed to make all haste, and report to the meeting in the afternoon. At three o'clock the number of people in and around the Old South was estimated at seven thousand,—by far the largest gathering ever seen in Boston. Addresses were made by Samuel Adams, Young, Rowe, Quincy, and others. 'Who knows,' said Rowe, 'how tea will mingle with salt water?' a suggestion which was received with loud applause. When the question was finally put to the vast assembly it was unanimously resolved that the tea should not be landed. It was now getting darker and darker, and the meeting-house could only be dimly lighted with a few candles; yet the people all remained, knowing that the great question must soon be decided. About six o'clock Rotch appeared and reported that he had waited on the Governor, but could not obtain a pass, as his vessel was not duly qualified. No sooner had he concluded than Samuel Adams arose and said: 'This meeting can do nothing more to save the country.'*

Instantly a shout was heard at the porch; the war-whoop resounded, and a band of forty or fifty men, disguised as Indians, rushed by the door and hurried down toward the harbor, followed by a throng of people; guards were carefully posted, according to previous arrangements, around Griffin's wharf to prevent the intrusion of spies. The 'Mohawks,' and some others accompanying them, sprang aboard the three tea-ships and emptied the contents of three hundred and forty-two chests of tea into the bay, 'without the least injury to the vessels or any other property.' No one inter-

fered with them; no person was harmed; no tea was allowed to be carried away. There was no confusion, no noisy riot, no infuriated mob. The multitude stood by and looked on in solemn silence while the weird-looking figures, made distinctly visible in the moon-light, removed the hatches, tore open the chests, and threw the entire cargo overboard. This strange spectacle lasted about three hours, and then the people all went home and the town was as quiet as if nothing had happened. The next day fragments of the tea were seen strewn along the Dorchester shore, carried thither by the wind and tide. A formal declaration of the transaction was drawn up by the Boston committee; and Paul Revere was sent with despatches to New York and Philadelphia, where the news was received with the greatest demonstrations of joy. In Boston the feeling was that of intense satisfaction proceeding from the consciousness of having exhausted every possible measure of legal redress before undertaking this bold and novel mode of asserting the rights of the people. 'We do console ourselves,' said John Scollay, one of the selectmen, and an actor in the scene, 'that we have acted constitutionally.' 'This is the most magnificent movement of all,' said John Adams. 'There is a dignity, a majesty, a sublimity, in this last effort of the Patriots that I greatly admire.'

The blow was now struck; the deed was done; and there was no retreat. The enemies of liberty talked of treason, arrests, and executions; but the Patriots almost everywhere rejoiced, and pledged themselves to support the common cause. Independence was now openly advocated; a congress was called for; and 'Union' was the cry from New England to Carolina.

The site of the Tea Party was Griffin's Wharf, which in terms of today's geography was on Atlantic Avenue approximately 75 yards north of Congress Street. If we attempt to relate the Tea Party to the earth, we can as geologists consider the harbor mud and how the tea thrown overboard would have became waterlogged and would have fallen to the bottom to be preserved, as so many things are. The organic mud of the river and harbor bottom underlies most of the made-land of the city; in fact, the distribution of this material is the basis for delineating the original shoreline on figure 6. Dig down 6–12 feet anywhere in the manmade part of Boston, and the chances are you will find organic mud and/or salt-marsh peat. Part of the mud of Griffin's Wharf area that would be of interest to us was dug away in constructing the sunken section of the Central Artery here, and some of it may have been removed in digging the foundation for buildings erected on the east side of Atlantic Avenue. Nevertheless, much of the harbor mud is still there, as was shown by the recent excavation for the new Federal Reserve Bank Building, just south of

Congress Street. There is yet the possibility of finding some of that famous shipment of tea, duty free, buried and preserved in the harbor mud. The sticky black mud which inevitably gives off a strong odor of rotten eggs when exposed, is a rich, though dirty, collecting ground of artifacts. In it the writer has found pottery, shoes, a cannon ball, buttons, and even an uncorked wine bottle.

PAUL REVERE'S RIDE

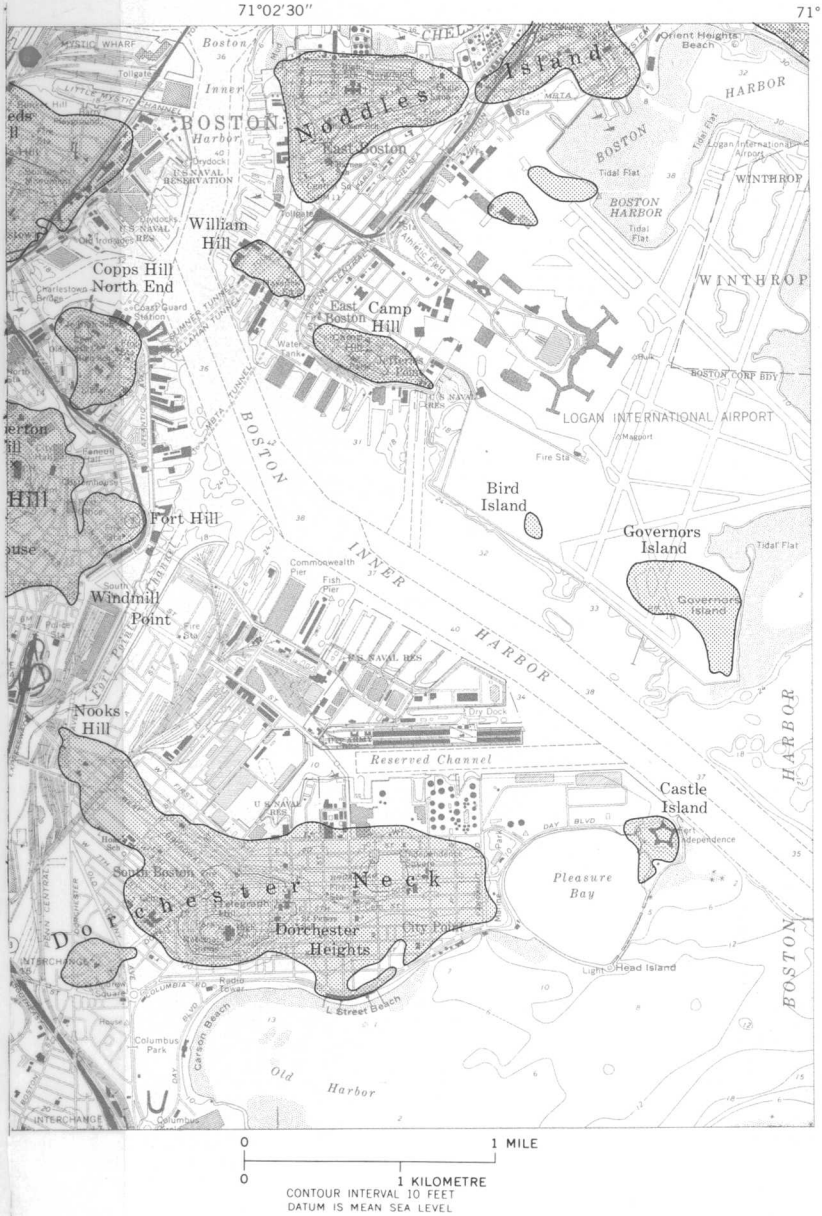
General Thomas Gage, commander-in-chief of British forces in North America and also Military Governor of Massachusetts, discovered that the colonists were stockpiling arms, ammunition, and other military stores in Concord. On the night of April 18, 1775, he sent about 700 soldiers across the Charles River in boats, landing at Lechmere Point, to begin their march to destroy these supplies (fig. 7). Because of an elaborate intelligence network, however, Gage's intentions were no secret to the patriots, and two lights suddenly shone from the belfrey of Old North Church. To alert the citizenry, William Dawes rode south down Boston Neck and then up through Brookline. Paul Revere began his ride in Charlestown, across the river from the Old North Church.

Paul Revere had many talents and an unusually lively mind. It is doubtful, however, that he thought much about geology as he made his famous ride that night. If he had been a geologist, he would have found much to distract him and take his mind off impending events. For example, as he mounted his very good horse at 11 o'clock on that pleasant moonlit night (as detailed in his letter to Jeremy Belknap (O'Brien, 1929, p. 4)) and took off from Charlestown, he might have speculated about two drumlins that rose steeply on his right—Breeds Hill and Bunker Hill. These drumlins are elongated parallel to each other, showing that they were fashioned by glacial ice flowing in an easterly direction. This is unusual, considering that the great glacial terminal moraines on the south side of Massachusetts indicated that ice flowed almost due south.

Shortly thereafter, Revere galloped over the narrow causeway of Charlestown Neck. At one time the Charles River might have flowed into the Mystic River through this gap. He then bore left at the fork in the road just beyond, onto today's Washington Street, Somerville, where two British officers jumped out of the bushes across the road and nearly captured him. A hundred yards up the hill on the right is one of the best of the rare outcrops of argillite in the Boston Basin. Revere had to turn back and scramble fast to get away from the officers, losing one of his would-be captors in a clay pit as he turned left up the Medford

Base from U.S. Geological Survey, 1:24,000
Boston North, 1971 and Boston South, 1970

FIGURE 6.—Central Greater Boston, showing the mean-high-tide shoreline as it



probably existed in 1630, on the basis of subsurface, surface, and historical data.

Base from U.S. Geological Survey, 1:24,000
Boston South and Newton, 1970

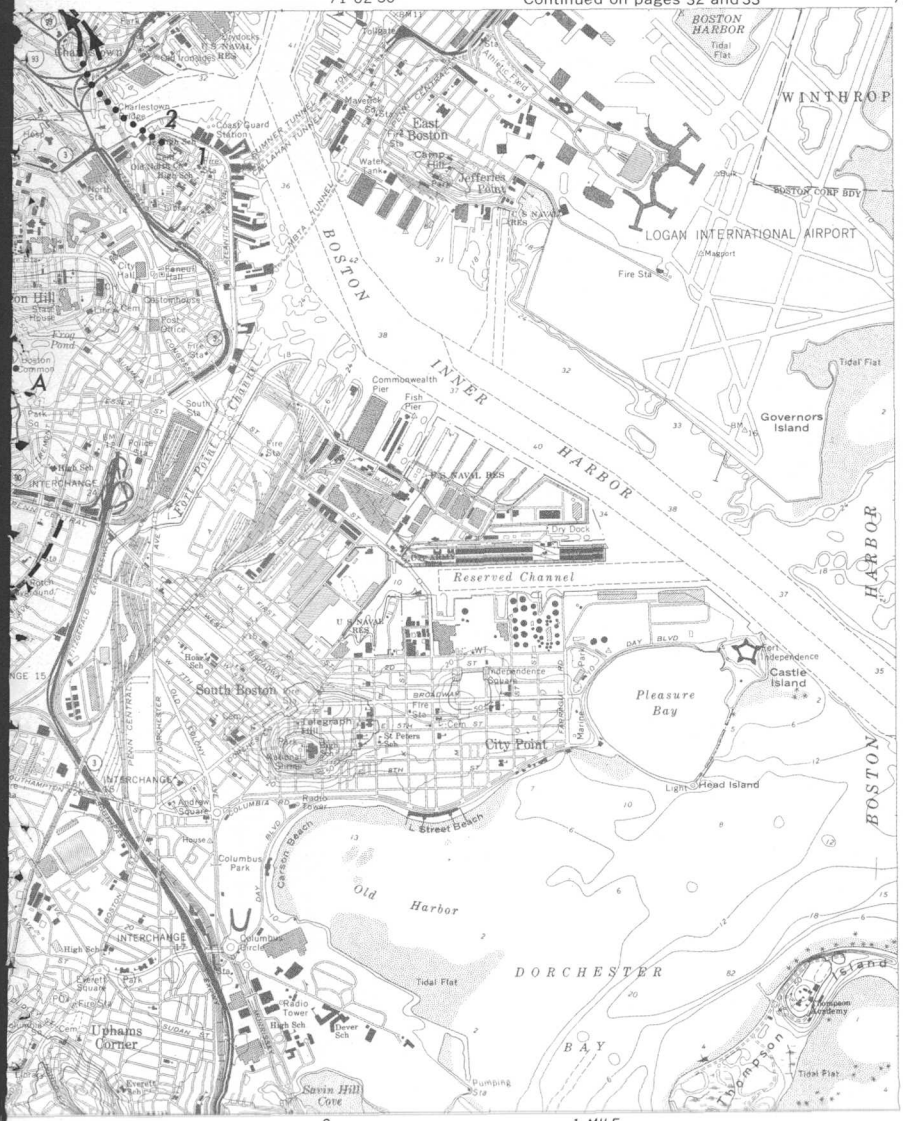
EXPLANATION

ROUTE OF PAUL REVERE'S MIDNIGHT RIDE (arrows show direction)

- By boat
- By horse
- 1 Christ Church (Old North Church)
- 2 Approximate place from where Revere was rowed across the Charles River to pick up a horse in Charlestown

ROUTE OF CHARLES DAWES' MIDNIGHT RIDE (arrows show direction)

FIGURE 7.—Maps of the present-day Boston area showing the routes taken by



0 1 MILE

0 1 KILOMETRE

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

ROUTE TAKEN BY BRITISH REGULARS (arrows show direction)

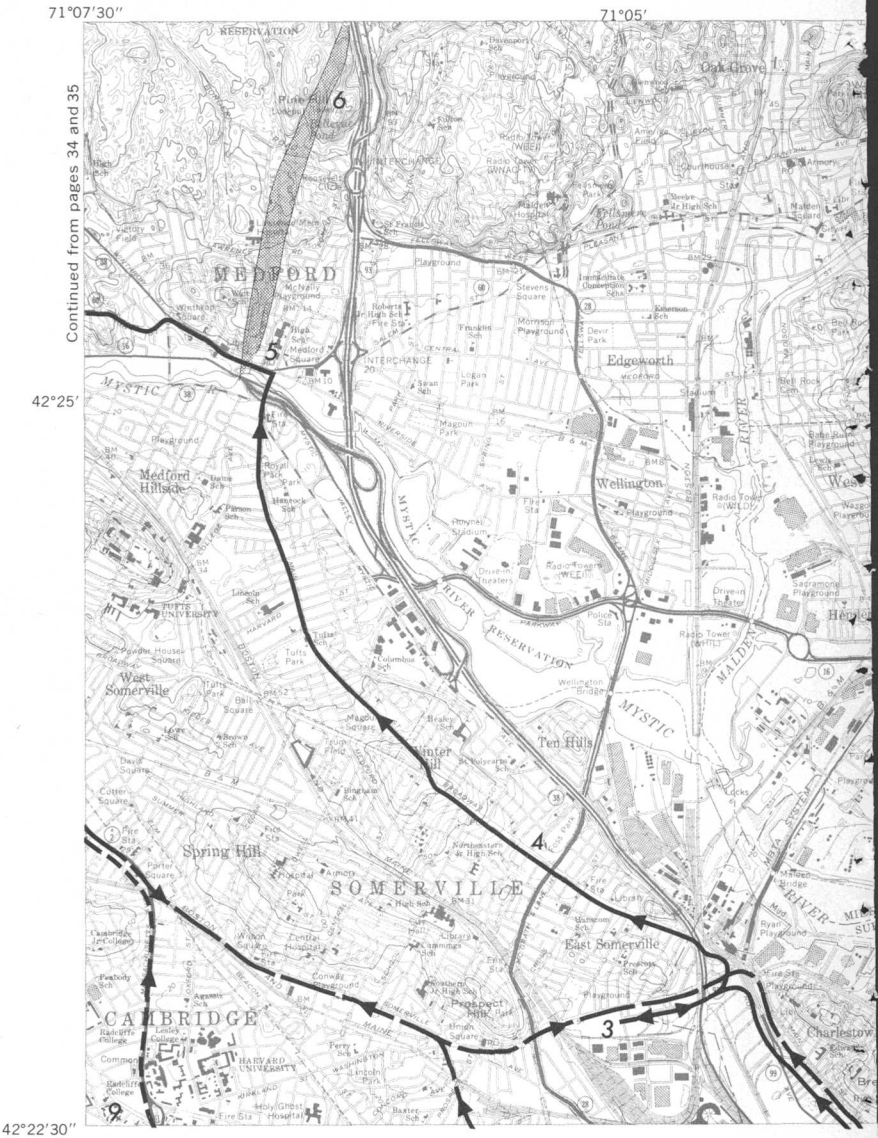
●●●●●●●●●● By boat

On foot

A Point of embarkation; foot of Boston Common

B Approximate point of debarkation

Paul Revere, Charles Dawes, and British regulars on the night of April 18, 1775.



Base from U.S. Geological Survey, 1:24,000
Boston North, 1971

EXPLANATION

ROUTE OF PAUL REVERE'S MIDNIGHT RIDE (arrows show direction)

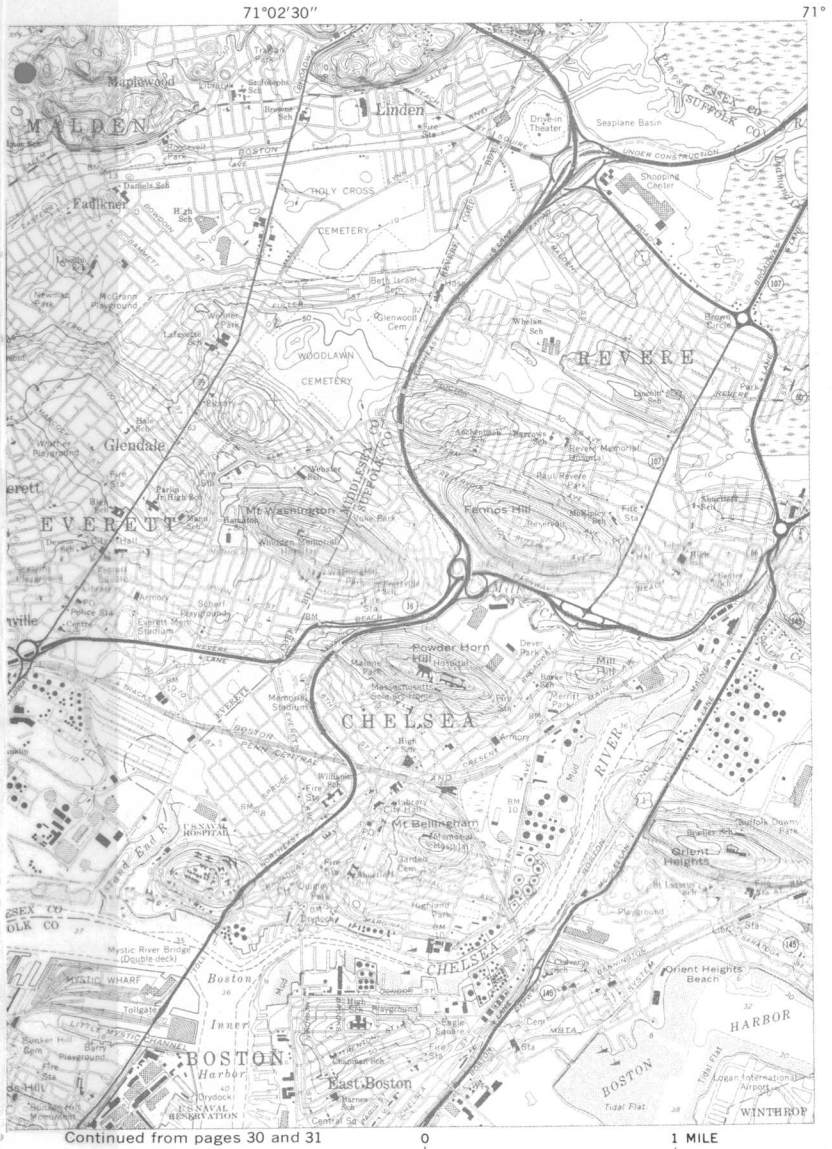
3 Surprised and turned back by two British officers

4 Possible location of clay pit

5 Medford

6 Pine Hill

FIGURE 7.—Maps of the present-day Boston area showing the routes taken by Paul



Revere, Charles Dawes, and British regulars on the night of April 18, 1775—Con.

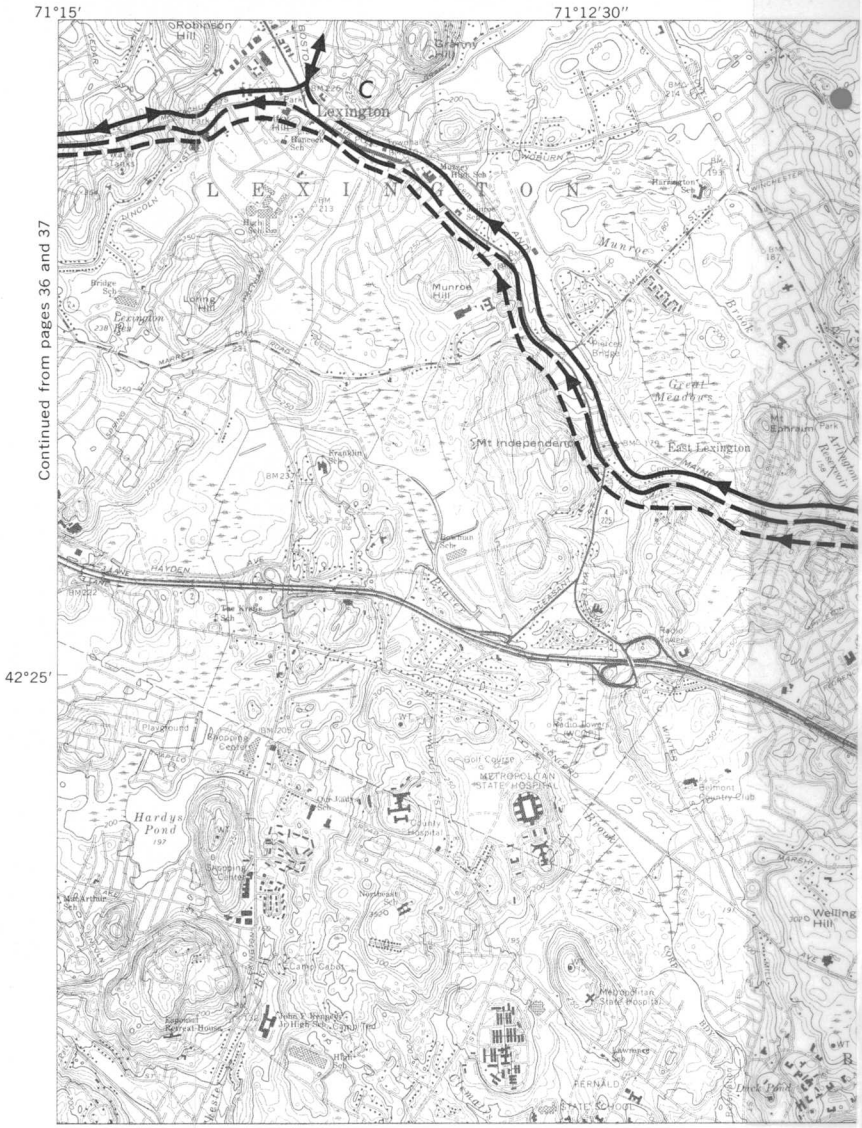
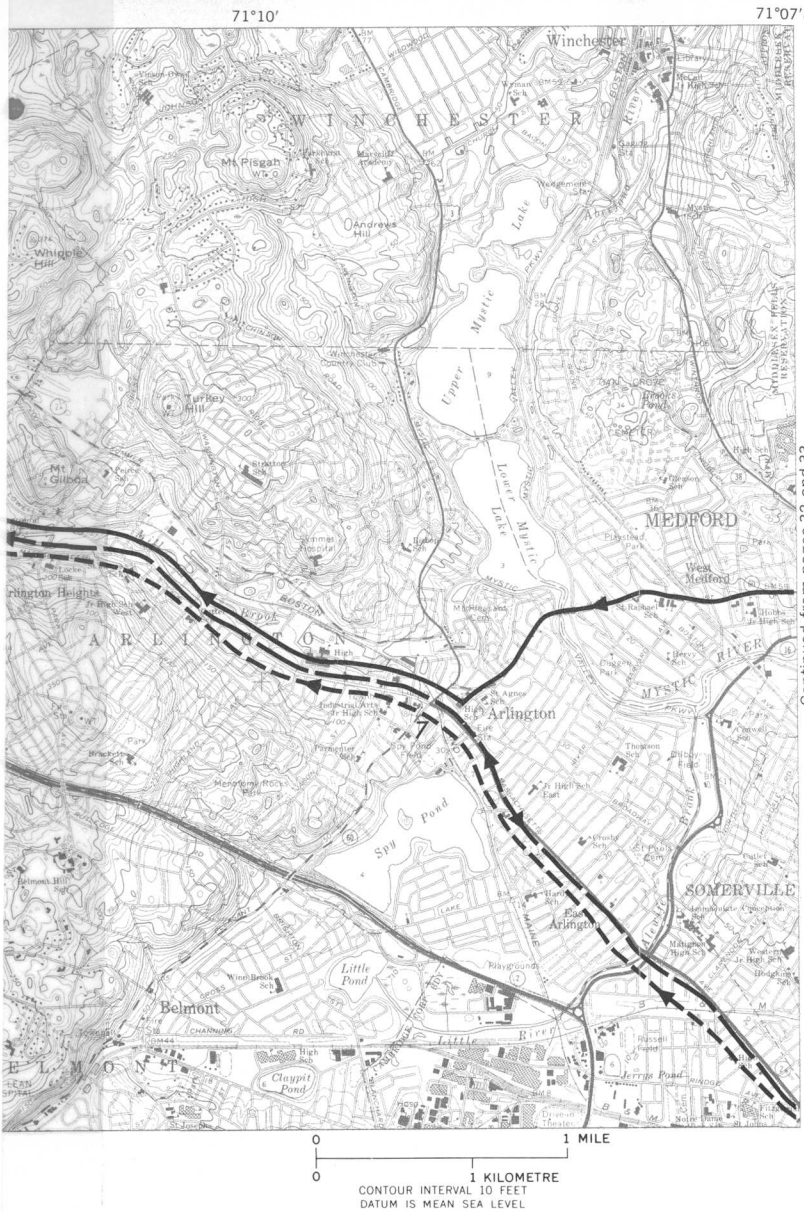


FIGURE 7.—Maps of the present-day Boston area showing the routes taken by Paul



Revere, Charles Dawes, and British regulars on the night of April 18, 1775—Con.

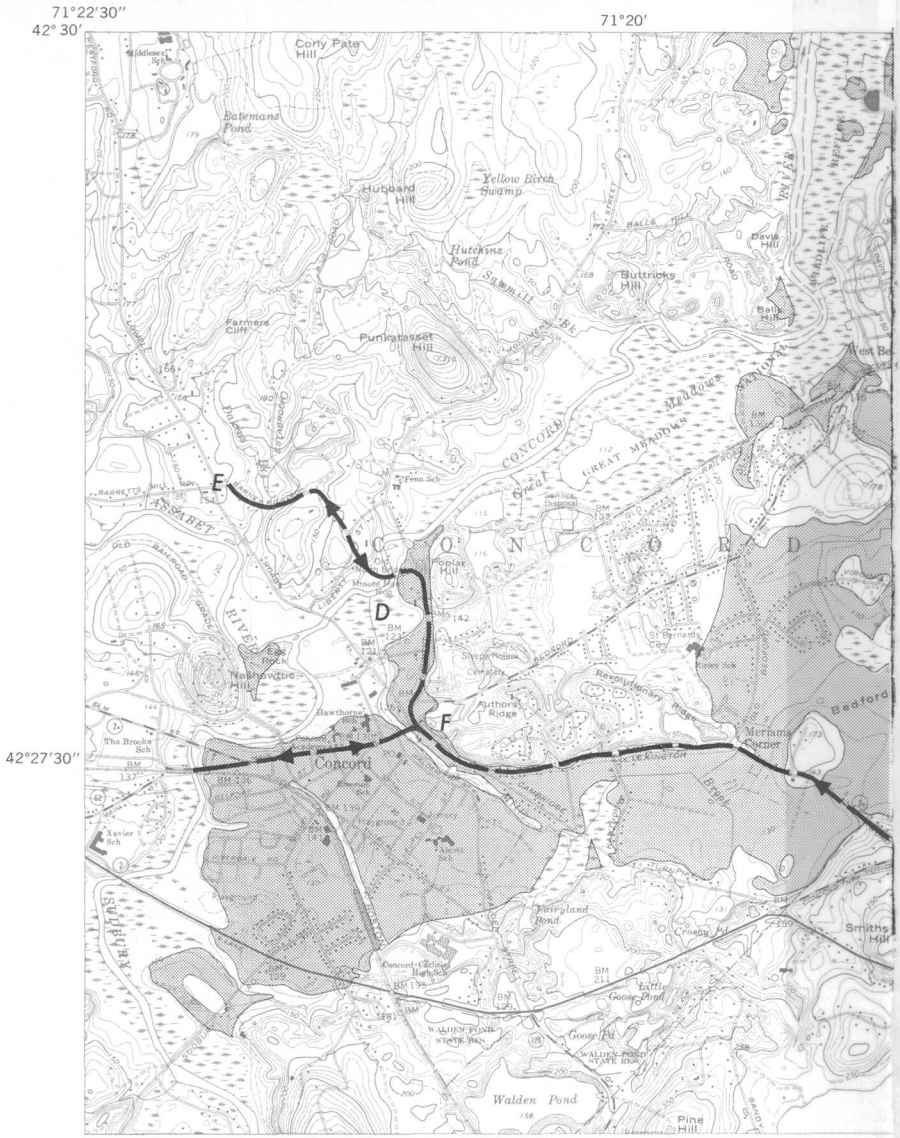


FIGURE 7.—Maps of the present-day Boston area showing the routes taken by Paul

Continued from pages 34 and 35

D North Bridge, scene of skirmish
E Farthest point reached in search for arms
F Center of Concord (see Doolittle engraving fig. 8)

Revere, Charles Dawes, and British regulars on the night of April 18, 1775—Continued.

Road (Broadway of today) at the same fork that he had previously passed. The location of the clay pit is conjectural, but the pit possibly was where Foss Park is now, almost a mile from the crossroads at Charlestown Neck (today's Sullivan Square). The pit hints at the widespread use of the local upper Pleistocene clay for bricks and pottery in the 18th century (see p. 71).

Revere rode on to Medford, awaking the citizenry to the British march on Concord. In his letter to Belknap, he makes no mention of having stayed to examine the remarkable outcrop of rock on Pine Hill, north of the town, where a thick biotite-bearing diabase dike is exposed and where volcanic rocks in contact with older quartzite and colorful porphyritic granite can be seen. Instead, he galloped along High Street, crossed over the Mystic River just below Lower Mystic Lake and then up the narrow rockbound valley in which lies the town of Arlington (fig. 1; fig. 7).

If he had stopped long enough to dismount and examine the rocks exposed on both sides of the valley, he might have concluded that the rocks were different and that the valley probably marked a fault (fig. 1), one of those ruptures in the Earth's crust caused by forces of great magnitude.

Out of the Arlington valley and onto the meadowland leading to Lexington rode Revere. The flat marshy meadowlands about Lexington interconnect. They mark the bottom of a short-lived late-glacial lake. The surrounding hills are mostly bedrock covered with glacial till. Lexington Common, on which the first skirmish of the Revolution took place, is underlain by gravel and sand that may have been deposited by a glacially fed stream after the draining of the lake.

Revere rode towards Concord, accompanied now by William Dawes, the other nightrider, and Dr. Prescott. Shortly thereafter, they were stopped by a detachment of British, taken into custody, and turned back to Lexington. Revere was at Lexington when the British regulars marched into town later in the morning, and shots were fired on the green.

BATTLE OF CONCORD

The Concord River meanders lazily through a flat marshy plain amid rounded hills. The flat plain widens at the town of Concord; to the northwest, at Bedford, it is nearly 4 miles across. This is the bottom of Glacial Lake Concord, a lake that formed during the melting of the last glacier, at a time when detached blocks of glacial ice, large and small, dotted the landscape and blocked the natural drainage of the area. At its greatest extent, the lake was

at least 100 feet deep and extended 10 miles in an easterly direction. The lake drained slowly as the various ice-block dams melted, and it probably was entirely drained about 12,000 years ago.

The Battle of Concord, April 19, 1775, was fought at close quarters on the flat floor of this former lake, at a place where the floor is constricted to a width of about 500 yards between a bedrock knob thinly covered with lake sands on the left bank and a small drumlin on the right bank. Because the low flood plain was so close to the normal level of the river, the colonial designers arched the famous bridge, not only to give it strength to surmount the modest width of river but also to raise the center of the structure well above flood level in order to protect it from damage by floating branches and other flotsam.

The British regulars marched the morning of that fateful day along several miles of the lake bottom as they approached Concord from the east (fig. 7). On arriving, they lined up in neat regimental formation in the main street of the village, while their commanding officer, Lieutenant Colonel Francis Smith, climbed to the flat-topped sand ridge, immediately to the north (now called Authors Ridge), and standing among the old slate headstones in the cemetery, surveyed the area through his spy glass to locate the rebellious colonists. The Boston artist and engraver, Amos Doolittle, has given us a fine picture of this moment in the only on-the-spot illustration of the events of that day (fig. 8).

Authors Ridge consists of sand deposited by glacial melt water in the very earliest stages of Glacial Lake Concord, at a time when the ice was just beginning to break up into isolated blocks.

After the British troops met the American farmers at North Bridge, they beat a retreat to Boston and once again crossed the lakebed. Now, however, they were continually harrassed by the Continentals, who sniped at them along the entire route from behind the stone walls that lined the road and separated the adjoining fields and from windows of farmhouses that dotted the road. The British ran a gauntlet of musket fire the 16 miles back to Boston. Thus, the stones that "grew" in the farmers' fields (in the winter, frost action pushes shallow buried stones to the surface) and that the farmers regularly collected at spring planting and lugged to the side of the field, paid an unanticipated dividend of protection. Surely the stone walls were not as high and formidable as the hedgerows that divided the fields of Normandy and that gave our troops much trouble 160 years later, but they proved a good deal more effective to the national interest. The commanding officer of the British party later revealed that he would have surrendered then and there if there had been somebody to surrender to.

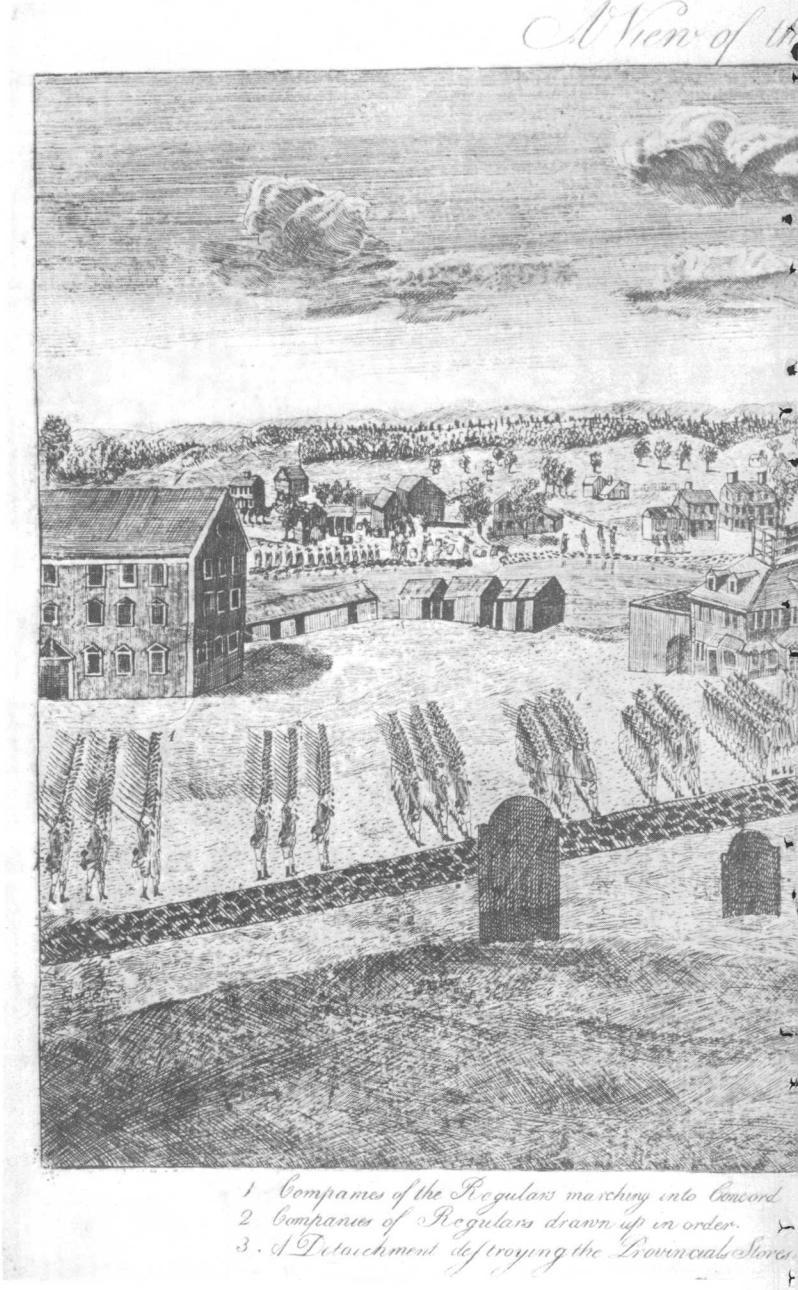
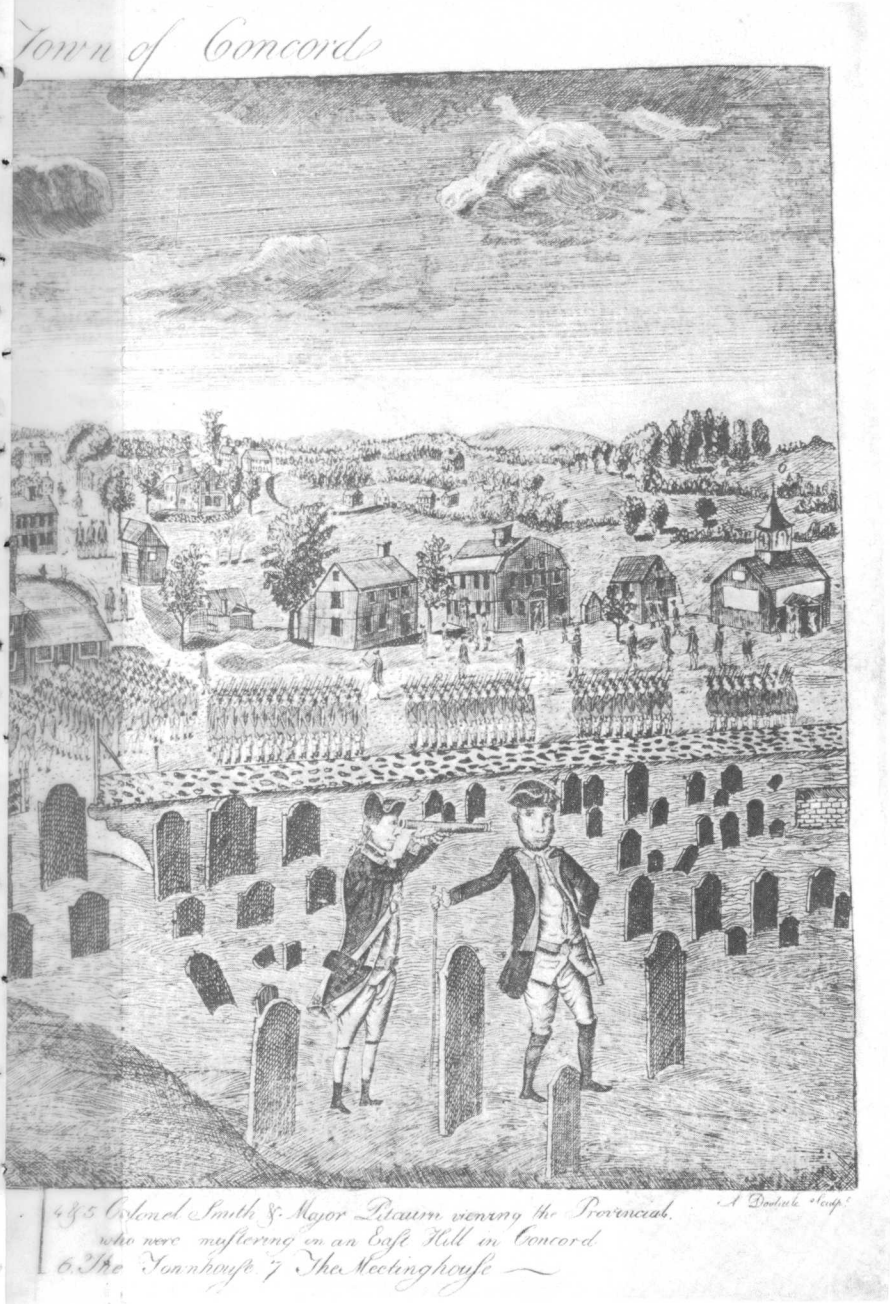


FIGURE 8.—A view of the town of Concord from Burying Ground on Revolu-
Boston, 1775. Courtesy



tionary Ridge just before the battle at North Bridge; engraving by Amos Doolittle, Chicago Historical Society.

After reaching Boston, the British were bottled up by the colonial militia and minutemen for 2 months. In June, General Gage decided to sally out of Boston with the reinforcements that had arrived under the commands of Generals Howe, Clinton, and Burgoyne. The end result of Gage's decision was the Battle of Bunker Hill which took place on June 17, 1775.

BUNKER HILL

The first real battle of the Revolutionary War took place on two large drumlins—Bunker Hill and Breeds Hill. The bulk of the fighting was on Breeds Hill, and it is something of an historical accident that the battle has never been properly named. The battle turned out to be the bloodiest, fiercest, and one of the most heroic of the entire war and, in many respects, the most sobering of any the British were to face. About 4,000 well-trained British regulars, in full crimson regalia, marched up Breeds Hill under a hot afternoon sun to face withering musket fire at point-blank range from about 800 farmers entrenched behind a 6-foot wall of earth that they had heaped up on the crest of the hill the night before. Two times the British climbed the hill in tight lines only to be turned back with very heavy losses. On their third courageous assault, they found to their surprise that the defenders had run out of ammunition. The Americans were forced to retreat down Breeds Hill and up over Bunker Hill to safety over Charlestown Neck, all the while taking heavy losses from British fire and bayonets. The British did not pursue farther than the Neck, and for the remaining 11 months of occupation of this part of New England, they clung to Charlestown and Boston peninsula.

The redoubt that was constructed during the early hours of June 17 by the newly recruited American troops probably involved digging only 2 or 3 feet off the top of the drumlin in a rectangular area. The soil was piled to form a parapet 6 feet high around the perimeter in a plan laid out by the engineering officer-in-charge, Colonel Gridley. The digging appears to have been largely confined to the surface silt zone, and the stony till beneath was barely scratched. Support for this view is given by the fact that the digging went on in silence and was not noticed by the watches on board the British naval ships that were anchored in the river less than a half a mile away. Not until daybreak did the British on the ships discover the freshly made entrenchments. Eight hundred men digging glacial till under a clear sky would most certainly have made a din as their picks and shovels hit pebbles and rocks.

Bunker Hill Monument

The Bunker Hill Monument (fig. 9) was innovative on two counts. It was the first use of a large obelisk in the architecture of the country, preceding the Washington Monument in the District of Columbia both in design (1825) and construction; it also established the use of Quincy Granite, thereby inaugurating a fashion in granite construction in Boston that would last many decades and starting the large-scale quarrying industry of the city of Quincy.

The monument also is responsible for another notable innovation; the first railroad in the United States was built expressly to transport the blocks of granite for the monument from the quarry to a shipping point. Three miles of horse-operated railroad were built in 1826 to transport the large dressed granite blocks to tidewater on the Neponset River. The blocks then were shipped by water to Charlestown. The railroad, both tracks and cars, was designed and built by Gridley Bryant, a young engineer later to invent many pieces of railroad equipment that played a major part in the development of the American railroad system. The ties consisted of granite sleepers spaced 8 feet apart. The rails were of wood, 6 inches thick and 12 inches high. Spiked on top of these were iron plates, 3 inches wide by $\frac{1}{4}$ inch thick. After a few years, the wooden rails were replaced by granite rails. The cars were worked downslope by a gravity-brake system and hauled upslope by horses (Cameron, 1953).

FORTIFIED HILLS OF BOSTON

Most of the hills of Boston were fortified by 1776. Some had long been fortified for the protection of the colonial city, but some fortifications were the work of the British in the opening year of the war.

A fort built on Fort Hill in 1632, along with a large fort on Castle Island in the harbor, provided the main defense of the town throughout colonial times. The fortifications on Fort Hill were strengthened later by the British, but after the war, the guns were removed, and the fortifications fell into ruins. During the 19th century, the hill was blanketed by houses except for a small circular park at the top to mark the site of the old fort. The hill, a small rotund drumlin, was leveled during the period 1869–1872, and the fill used mainly to build the causeway for Atlantic Avenue. Photographs of the hill being leveled (Whitehill, 1968, p. 176) show that Fort Hill consisted of both till and clay.

FIGURE 9.—Bunker Hill Monument. Statue at base is of Col. William Prescott, hero of the battle, by the American sculptor W. W. Story.

Copps Hill, in the North End, supported the British battery that set Charlestown afire during the Battle of Bunker Hill. The hill has been important throughout Boston's history. At first it was called Windmill Hill because the town's first windmill was built on it in 1653. In 1660, the burial ground that still exists was established. On the gentle south slope of the hill, Christ Church (Old North) was built in 1723. Copps Hill is probably a drumlin, much like Fort Hill. Before the 19th century, it terminated at the shore in a steep sea cliff. In 1807, the summit of the hill was lowered by 8 feet, and part of the cliff was removed to build Atlantic Avenue at its foot.

Another fortified site in the city was West Hill, the westernmost tip of Beacon Hill, where a small artillery battery was set up by the British. West Hill was a small elevated area that terminated in a steep sea cliff facing the Charles River. In 1797, the cliff was cut back, and the top of West Hill, along with adjoining Mt. Vernon, was leveled to the general slope of Beacon Hill as we know it today. Again, the purpose was to provide fill, this time for the Charles Street embankment.

Fox Hill, a small hill on the shore of Back Bay at the foot of the Common, was the site of a battery set up in 1775. The exact site of the hill became lost because its location and shape changed from one 18th century map to another. Some maps, for example, showed Fox Hill as an island (fig. 10). In 1960, the roots of the hill were exposed in the deep excavation for the underground garage at the foot of the Common, and its location was pinpointed. Its height is estimated to have been about 20 feet above tide level (fig. 11). Clearly, Fox Hill had not been an island, but from the earliest time it appears to have been a source of sand for anyone wanting a small quantity for fill, mortar, or whatever purpose. The selectmen of Boston repeatedly inveighed against raiding the hill, which was town commonland. The practice of digging away at the hill persisted, nevertheless, and generally at night. Strangers from Cambridge across the river are repeatedly mentioned in minutes of the meetings of the Board of Selectmen as stealing skiff-loads of sand. The reduced state of the hill by 1764 is clearly visible in the drawing by Lt. Byron made from the top of West Hill (fig. 12).

The location of Round Marsh (fig. 11), or Round Pond as it was called in colonial times, was also deciphered from exposures in the garage excavation. It nestled between Fox Hill and Powder House Hill in the center of the Common.

Powder House Hill (fig. 11) is a few hundred yards east of Fox Hill. Today it is a low mound that features the Soldiers and Sailors Monument, but in 1775 it supported a six-gun artillery

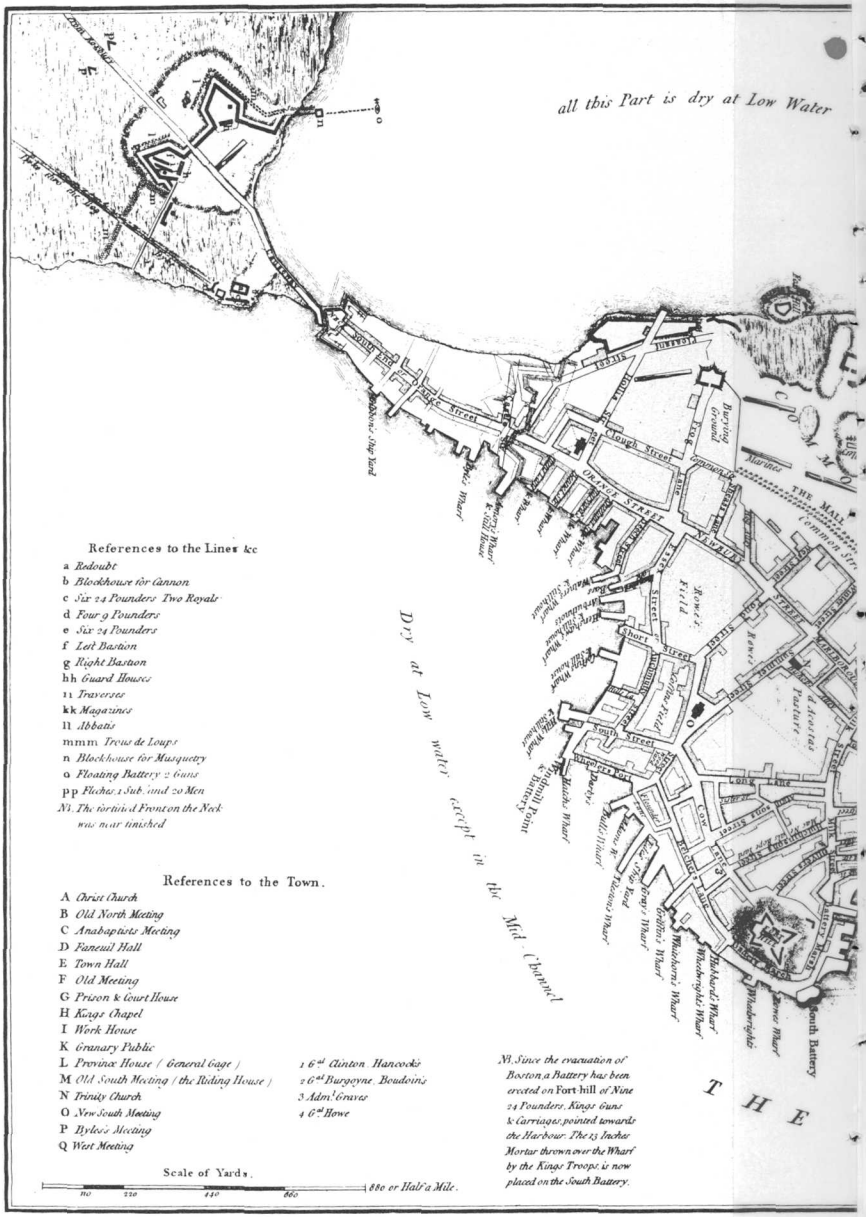
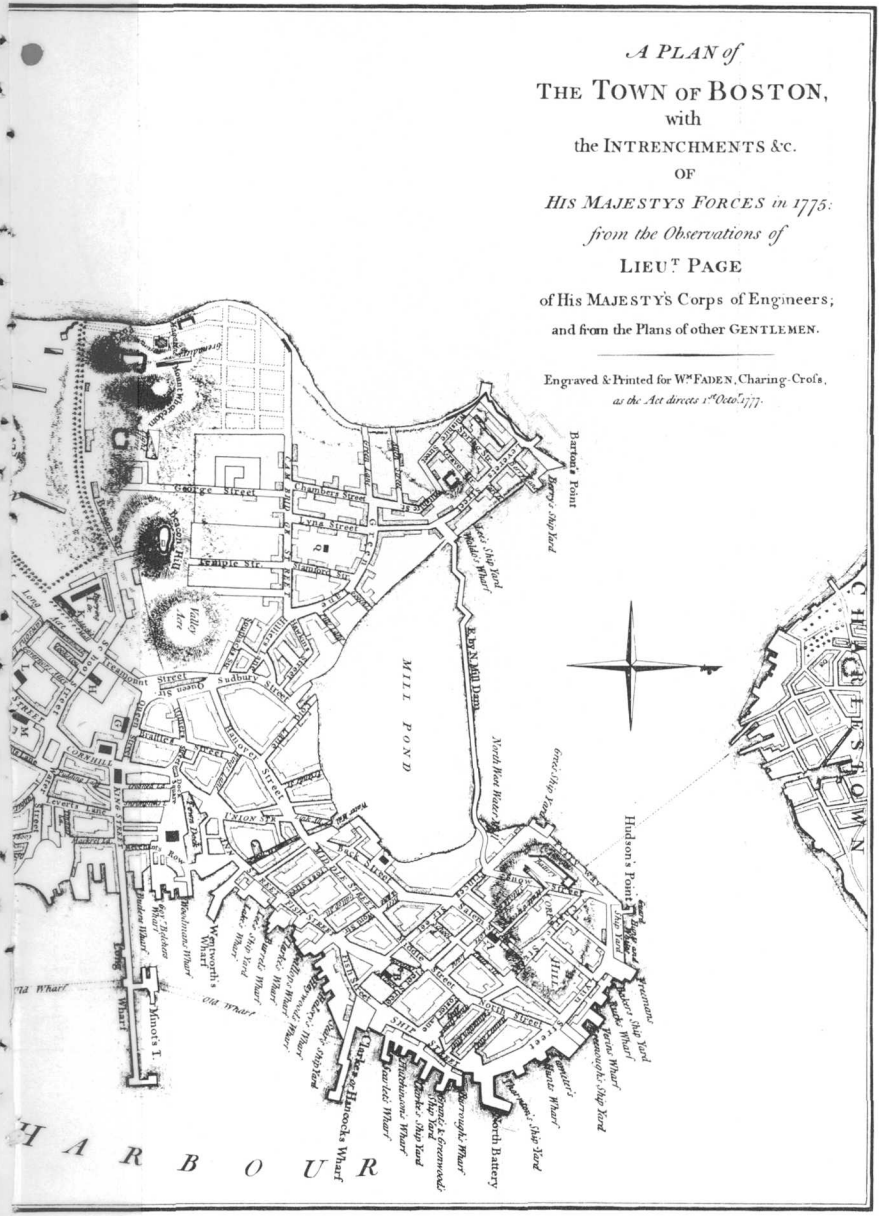


FIGURE 10.—Map of Boston by Lieutenant Page, 1775, showing fortifications



and erroneous position of Fox Hill. Compass rose points to magnetic north.

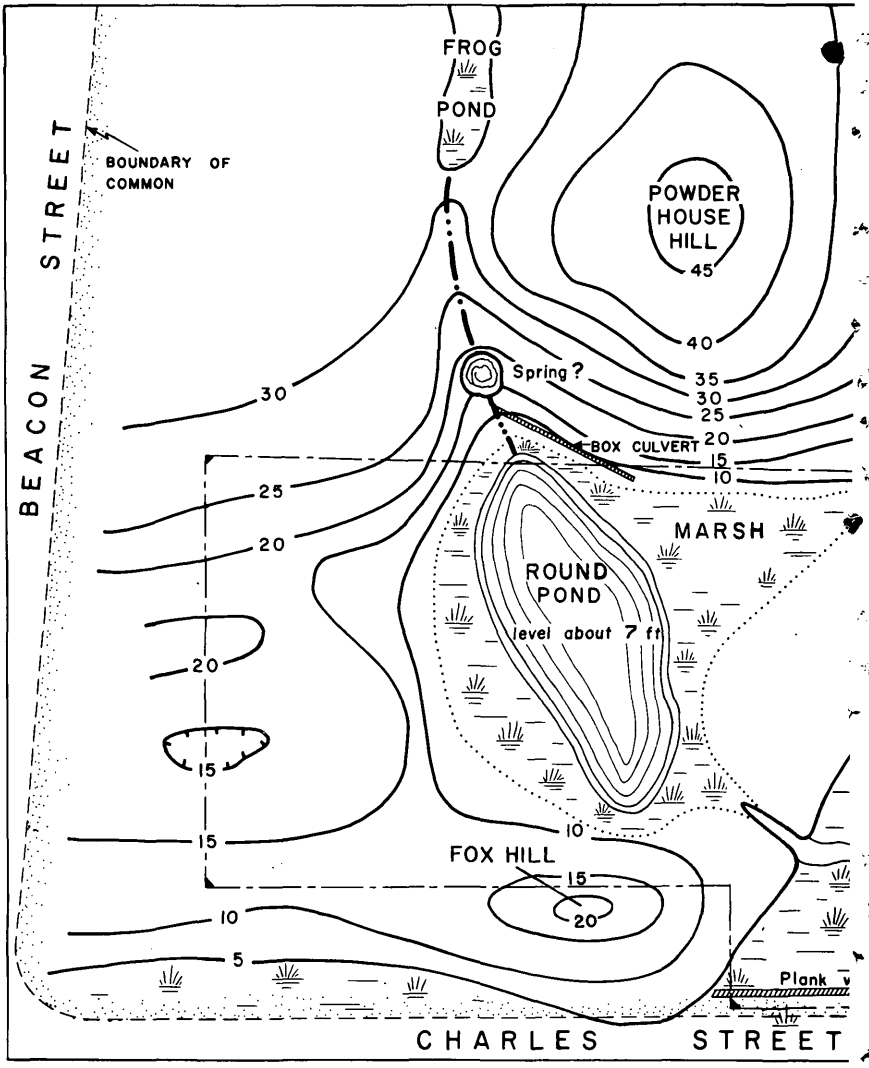
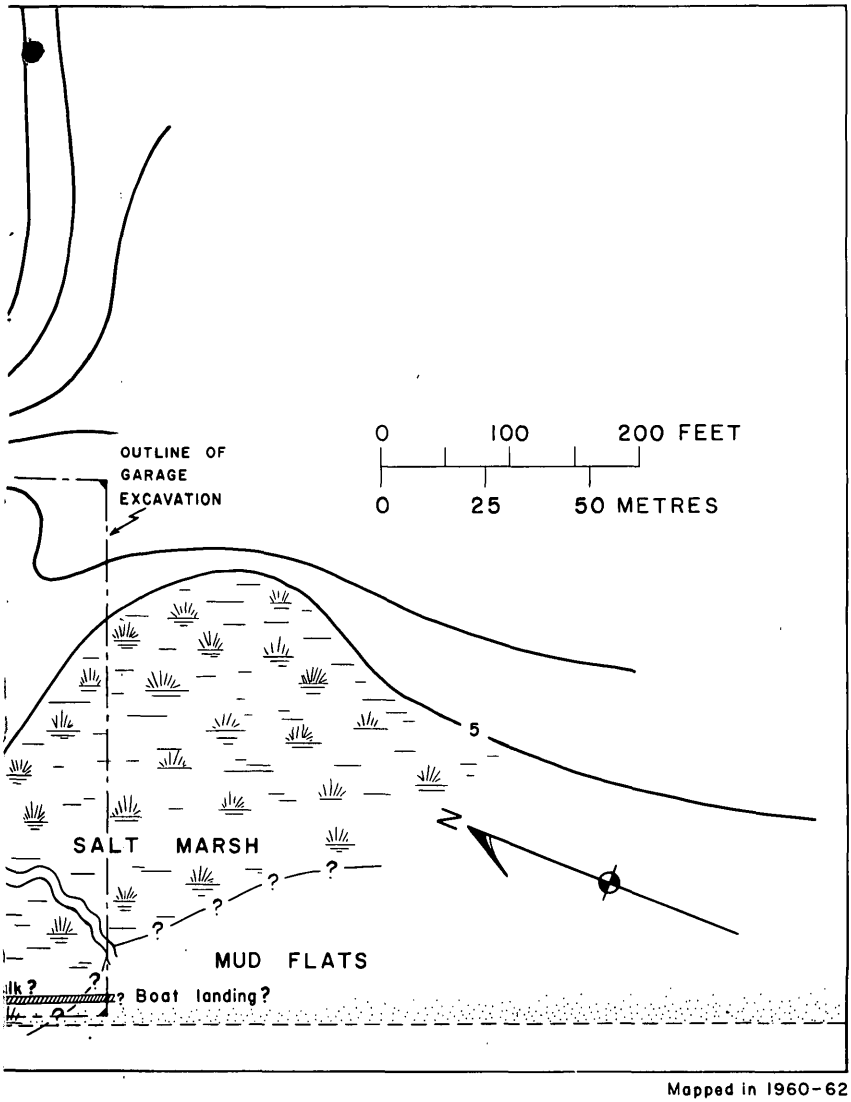


FIGURE 11.—Topography of lower Boston Common in colonial times, as re-

battery. Boston's powder magazine had been here, hence the name Powder House Hill. The powder house, a small six-sided building with an onion-shaped roof, is clearly visible on Lt. Byron's watercolor. At the outset of hostilities, the magazine was moved to a safer location on the lower flank of West Hill, approximately at the present intersection of West Cedar and Pinckney Streets. As far as is known, Powder House Hill appears to consist of hard yellow clay.



constructed from observations made in excavation for underground garage.

BEACON HILL AND THE COMMON

William Blackstone, the first settler on Shawmut Peninsula, who in August 1630 invited the Puritans to join him, must have regretted his generosity. Within 4 years (1634) he sold the town all but six of his acres and left Boston. The acreage he sold encompassed the Common and Beacon Hill—or Trimountain, as it was called throughout colonial time (Whitehill, 1968). By 1640, the town fathers had designated the bounds of the Common as we

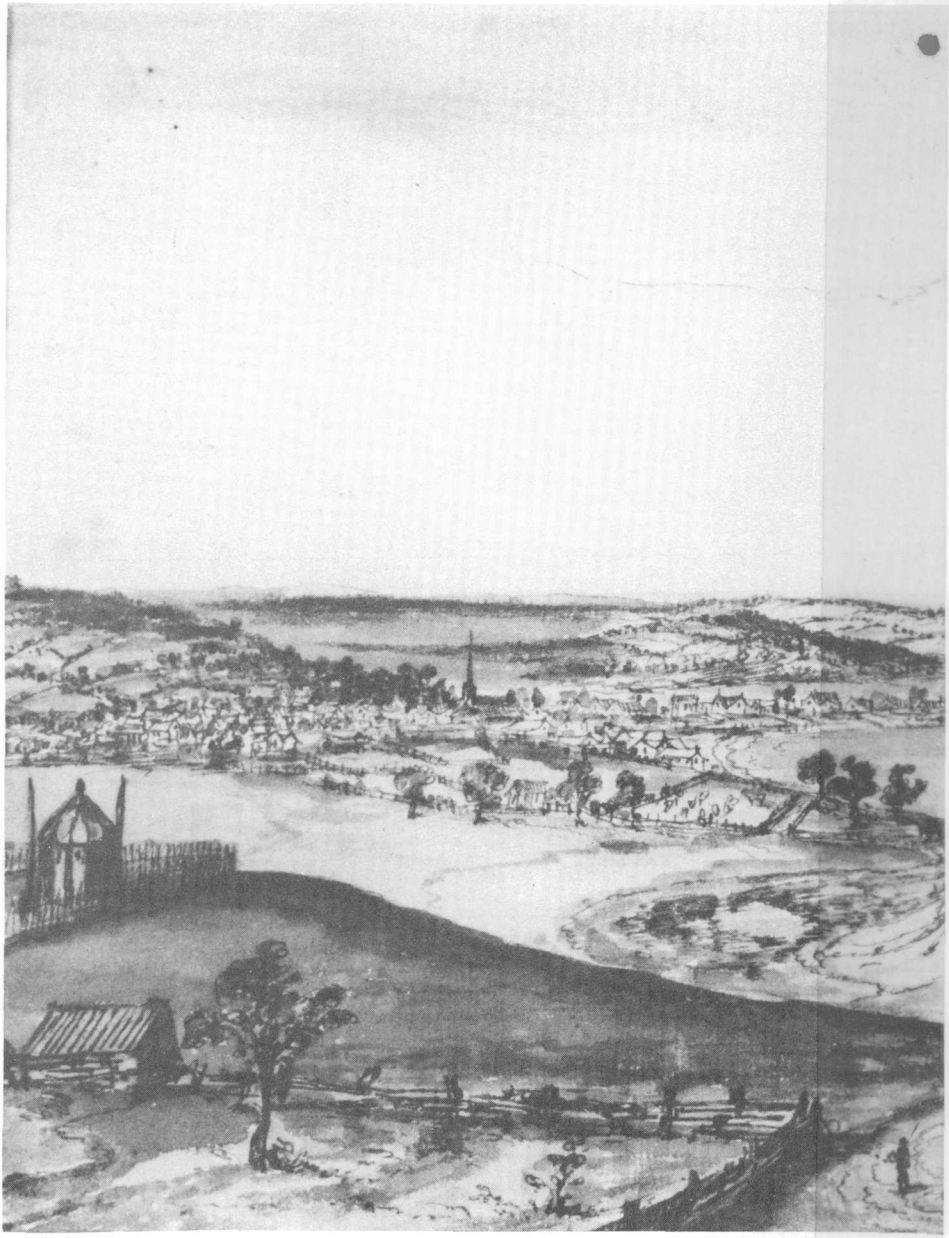


FIGURE 12.—Watercolor drawing by Lt. R. Byron, about 1764, from West Hill (Beacon Hill) is in the middle distance. Published by permission

looking south. Fox Hill is the small hill in foreground, Round Pond is to its left. Boston Neck of The Bostonian Society, Old State House.

know it today, reserving it as a parade ground for the militia and a place where all citizens could pasture their livestock. Trimountain's fate was left to private landowners.

The highly irregular shape of Beacon Hill in colonial time was very different from the smooth drumlinlike profile we see today and amply justified the name Trimountain (later shortened to Tremont, as in Tremont Street). The crestline of the hill was very irregular and was dominated by three peaks, all of which have since been removed.

Throughout the 17th century, most of Beacon Hill was brushland. In the 18th century, a few people realized the residential possibilities of Beacon Hill and bought up much of it. The largest landowners were the artist John Singleton Copley and Thomas Hancock, uncle of Governor John Hancock. Both built houses on Beacon Street facing the Common (see p. 72).

The cornerstone of Charles Bullfinch's splended golden-domed State House was laid in 1795 on the site of John Hancock's pasture adjoining his house. The building, completed in 1797, backed up onto the foot of Sentry Hill, the central and highest of the three peaks on Beacon Hill. This steeply conical hill rose to an altitude of 138 feet and projected about 40 feet above the general level of the hill as it is today. In 1634, this highest point in Boston was designated as the site of a beacon, whose purpose was to provide a danger signal to surrounding communities in case of invasion by land or sea. A kettle of tallow or pitch was hung from the top of a tall wooden pole; when lighted, it was visible for miles around. The beacon, never used in an emergency, was blown over in 1789 and never rebuilt. The conical hill was then used as a source of fill. By the second decade of the 19th century it had been entirely leveled to the general crestline of Beacon Hill. A set of lithographic prints shows Sentry Hill being dug away and large angular blocks of rock scattered about (see Whitehill, 1968, fig. 42). The geologist would conclude from this that these are boulders and that till was the material being hauled away. However, these boulders were embellishments put in by the lithographer, for they do not appear on J. R. Smith's original watercolor drawing done in 1811 and now in the Print and Drawing Room, Boston Public Library.

West Hill, or Mt. Vernon, the westernmost peak on Beacon Hill, was leveled as a real estate venture by the Mt. Vernon Proprietors in 1795 with the aim of developing a neighborhood of elegant townhouses that centered on Louisburg Square. The soil dug from the hill was carried downslope in small wheeled trucks that rode on crude wooden rails. At the base of the hill, the fill was spread over the tideflat to make the causeway for Charles

Street. The tracked-way for the carts has been claimed by some to have been America's first railway, but the granite railway at Quincy seems to have been better qualified for this distinction.

The third small hill, Pemberton, or Cotton Hill, at the eastern end of Beacon Hill, was leveled in 1835 by a land developer, P. T. Jackson, who had 65 feet of the hill dug away in order to lay out Pemberton Square, another fine townhouse development (Whitehill, 1968). The Court Houses now occupy the site.

Beacon Hill is important and interesting geologically, as well as historically. The hill appears to be a fragment of a glacial moraine, formed in very late glacial time. The wasting ice sheet, which had melted north back of Boston, must have been resupplied with ice from the north and in consequence surged forward to about the central part of the Boston Basin. Some time later, the ice front melted back once again, leaving a moraine to mark the position of maximum advance. This was not, however, the last glacial act. Subsequently, a final glacial readvance refilled Boston Basin with ice. This time, the ice appears to have flowed into the basin from the west and spread in bulbous lobes that pushed against the surrounding topographic highs. It overrode and destroyed the earlier moraine except for the Beacon Hill section. Perhaps Beacon Hill was spared because it was the high point of the moraine, and the last ice was not thick enough to engulf it.

The reader will wonder how we know all this. For one thing, excavations in Beacon Hill reveal the kind of deposits and structural disarray that are characteristic of glacial thrust-moraines. Secondly, when Beacon Hill is examined in its original Trimountain shape, it becomes apparent that the hill was U-shaped in ground plan, Pemberton Hill making up the right arm, elongated Mt. Vernon making up the left arm, and Sentry Hill rising from the center of the cross arm. The deposits in the hill were thrust from the north and bent to conform to the same U shape as the hill. From this it becomes apparent that this is a lobate section of a moraine, probably part of a once longer moraine. When we seek the reason for the rest of the moraine having been destroyed, we discover that Beacon Hill is ringed in by glacially deformed deposits in the lower surrounding slopes, including those in Boston Common, and that this glacial deformation clearly cuts across and, therefore, is later than the structural alinement of Beacon Hill. The ice appears to have spread around Beacon Hill and pushed up small mounds, or ridges, at its margin. This push-ridge and intervening swale topography characterizes much of Boston Common. The ridges are represented by Fox Hill, Powder House Hill (now surmounted by the Soldiers and Sailors Monument), and the low knoll at the southwest corner of the Common

on which the old burying ground is located; the swales are represented by the depression containing the Frog Pond and former Round Marsh, or Round Pond (fig. 11).

One more noteworthy result of this last ice readvance was Boston Neck. This is a clay ridge, pushed up at the margin of the bulbous ice lobe that had also pushed up against the south side of Beacon Hill. The Back Bay ice lobe (this name seems appropriate, for its outline was pretty much that of the original Back Bay) also contributed to other topographic features rimming the Back Bay, including the terracelike area of the Harvard Medical School hospital complex. The terrace is actually a sheet of glacially deformed clay thrust up over sand and gravel.

THE WASHINGTON ELM AND THE CAMBRIDGE FLOOD

The Continental Congress appointed Col. George Washington Commander-in-Chief of the newly organized Continental Army on June 15, 1775. The colonial army centered around Boston where hostilities had already begun and where the Battle of Bunker Hill was about to take place. Washington traveled from Philadelphia overland to Cambridge, the small college town across the Charles River from the besieged city of Boston, where army headquarters had been established. He arrived on July 2, and on July 3, 1775, he took command, in a simple ceremony beneath the shade of a large elm tree at the edge of Cambridge Common. A few hundred yards to the south stood the small cluster of red brick buildings of Harvard College. Christ Church, a modest structure faced with wide wooden boards laid vertically—where Washington was to worship during the cold days of the ensuing winter—was a stone's throw away. These buildings are still standing, performing the same functions as they did then. Only the great elm has disappeared. We know, however, from old photographs that the tree grew in the middle of Garden Street, at the intersection of Mason Street. This is not (visitors please note) where a large granite monument in the Common says it stood.

Cambridge Common, Harvard Yard, and, in fact, much of this part of Cambridge is a flat plain at an altitude of about 20 feet above mean sea level. Excavations on and around Harvard Yard for new buildings have revealed something about the origin of the plain. The sides of these excavations show a sequence of deposits that has glacial till at the bottom, then clay plus till, a layer of boulders, thinly stratified silts and fine sands, and finally 10 feet or more of sand and gravel at the top, and here and there

patches of the original layer of windblown silt. From the bedding or stratification of these deposits, the geologist can tell something about the velocities and direction of the water currents that transported and deposited them. The sand and gravel were laid down on a flood plain by a glacial melt-water river that flowed north.

When we compare these data with geological observations taken elsewhere, an interesting picture emerges of how things must have been around Boston about 12,000 years ago.

The landscape was still glacial. There were many large masses of partially melted glacial ice, and patches of bare ground showed only here and there. Much of the landscape consisted of a network of lakes, frozen during most of the year. A few outwash streams flowed on gravelly flood plains. More ice was present than met the eye, for much of it was buried beneath thin deposits of clay, sand, gravel, and till, and it included frozen ground (permafrost). Trees were absent; only very low, barely noticeable tundra-type plants were present. The desolate landscape resembled, in part, the tundra land that still exists in northern Canada, Alaska, and Siberia. The course of the lower Charles River, including the Back Bay, was blocked with large stagnant masses of glacial ice.

During this interval of gradual ice melting, an ice dam across the valley of the upper Charles River in the vicinity of Newton Upper Falls gave way. Behind this dam a large lake had backed up which had filled the valley to the south. When the ice dam broke, the great flood of water carved the gorge in a bedrock ridge at Newton Upper Falls, then coursed down the valley of the Charles River as far as Cambridge where it was deflected northward by the thick ice still occupying the basin of the lower Charles. Waters of the Cambridge flood spilled down both the Mystic Valley and the valley of Willis Creek in Somerville (now occupied by the tracks of the Boston and Maine Railroad). The flood tore up blocks of ice in its path, and in a short time, new channels were opened, including that of the lower Charles valley.

POLLUTION OF THE CHARLES RIVER

The rivers of Massachusetts, including the Charles, were an important source of food in colonial times. Fish, including salmon, were plentiful, and shellfish were abundant in the tidal estuaries. The estuary of the Charles, up as far as Watertown, contained extensive oyster beds, and the muds exposed at mean and low tides were jammed with large soft-shell clams (*Mya arenaria*). We know this both from the historic record and from excavations

for buildings. Since the great landfill era of the 19th century covered them over, the oyster reefs in Boston's Back Bay and in the Mystic River estuary have been exposed from time to time in foundation excavations. The reefs have been uncovered in excavations along Boylston Street, first for the construction of the Boston Society of Natural History building (now Bonwit Teller's store) on Berkeley Street, then in the late 19th century for the deep subway trench in this same area, and later for the New England Mutual Life Insurance Building on Clarendon Street (an occurrence that has been extensively investigated and discussed in reports on the Boylston Street Fish Weir; see Johnson and others, 1942, 1949). The writer has seen the shells in excavations for the IBM building (Boylston and Clarendon Streets) and under several buildings in the central part of the MIT campus.

The oysters grew solidly packed together, and because of this had very elongate shells 10 inches or more long. Annual growth rings show that many oysters lived 25 years or longer. The clam shells found in these estuarine deposits are commonly 3 inches high and 4–5 inches long, twice the size of average clams dug today.

At least by the early 19th century, when the Industrial Revolution got underway, not only the salmon, but even the lowly herring (the alewife) and the smelt had disappeared from the rivers of Massachusetts. Mills of every kind were then being constructed along streams and rivers, wherever there was a rapid, waterfall, or a site for a mill dam. Towns sprang up around the mills. Population burgeoned, and, in consequence, industrial and human wastes rapidly changed the nature of the rivers and drove away the fish.

An intensive study of pollution of the Charles River estuary was conducted at the beginning of the 20th century as part of the study for the construction of the Charles River dam (G. W. Field, *in* Massachusetts Comm. Charles River Dam, 1903, appendix 6, p. 315–343). The clams in the badly polluted mudflats at that time are described as being "rather small and black" (p. 336). Oysters seem to have disappeared from the river by the early 19th century.

HARBOR ISLANDS

The entrance to Boston from the sea is via a broad bay dotted with many islands. Some of these islands are barren bedrock outcrops, but most are drumlins (fig. 13). All the drumlin islands of the harbor were well wooded at the time of the first settlement, but they were soon cleared and converted to farmland.

The approach to Boston by large vessels was hazardous because of these islands and shoals, particularly so at low tide (the mean tidal range at Boston is almost 10 feet). Nevertheless, it was not until 1716 that the community built a lighthouse on one of the rocky outermost islands, Little Brewster Island (Lighthouse Island) (fig. 1). Although this lighthouse guided shipping to the entry of the harbor, it did little to help navigation through the tangle of natural obstructions.

Little Brewster Island is a narrow elongated outcrop of rock consisting of both argillite (the rock that underlies much of the harbor, Boston, and Cambridge) and diabase, a hard, resistant igneous rock. It is precisely because of the outcropping of the more resistant diabase that the island is there.

The original brick lighthouse received rough treatment in 1775–1776 from both sides in the conflict. First the Americans, in an attempt to hamper British shipping during the seige of Boston, raided the island several times and set fire to the tower. The British, during the evacuation of Boston, sent a party to Little Brewster, mined the battle-scarred tower with powder, and blew it up as their fleet sailed out of the harbor.

A new stone lighthouse was built on the same site in 1783 (fig. 14), and this, still flashing, is the oldest active lighthouse in the United States.

Benjamin Franklin's name comes up in two ways whenever the first Boston Lighthouse is discussed. His first literary work was a doleful poem entitled "The Lighthouse Tragedy," which told of the death by drowning in November 1718 of the first lighthouse keeper, Mr. Worthylake, and his wife and daughter. The poem was printed on his brother's press in Boston.

Although the first lighthouse was damaged by lightning several times, no move was made to erect a lightning rod, in spite of Franklin's experiments and writings, which had established the effectiveness of such rods. It is said that the local folk were prejudiced against lightning rods. One might speculate that the iron-rich diabasic rock on which the lighthouse stood may have been a contributing factor in the frequency with which lightning hit the structure.

Castle Island, a drumlin, was utilized as early as 1632 for the main defense of the harbor (figs. 1, 13). In colonial times, it was separated from South Boston (Dorchester Neck) by a half mile of water but is now part of the mainland, connected by a broad strip of made-land. The original shape of the island has been changed by repeated earthwork construction. Its simple drumlin form and the steep sea cliff that originally formed the northeastern face have been obliterated. Earthworks were first constructed in

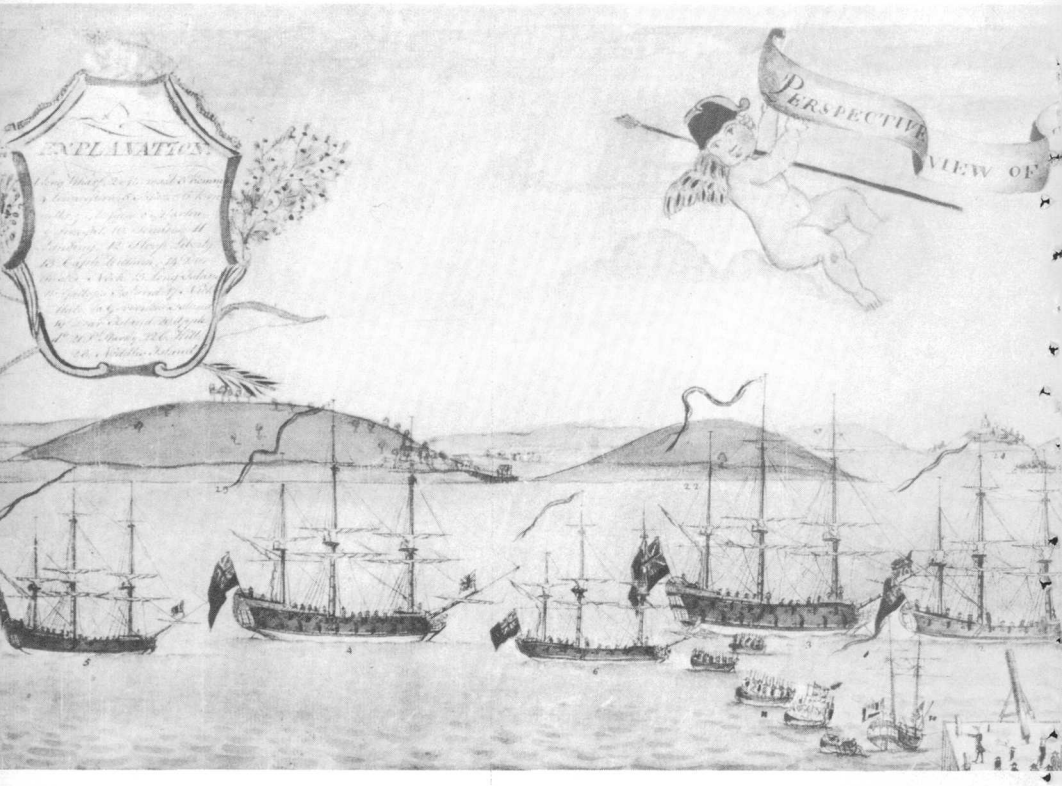
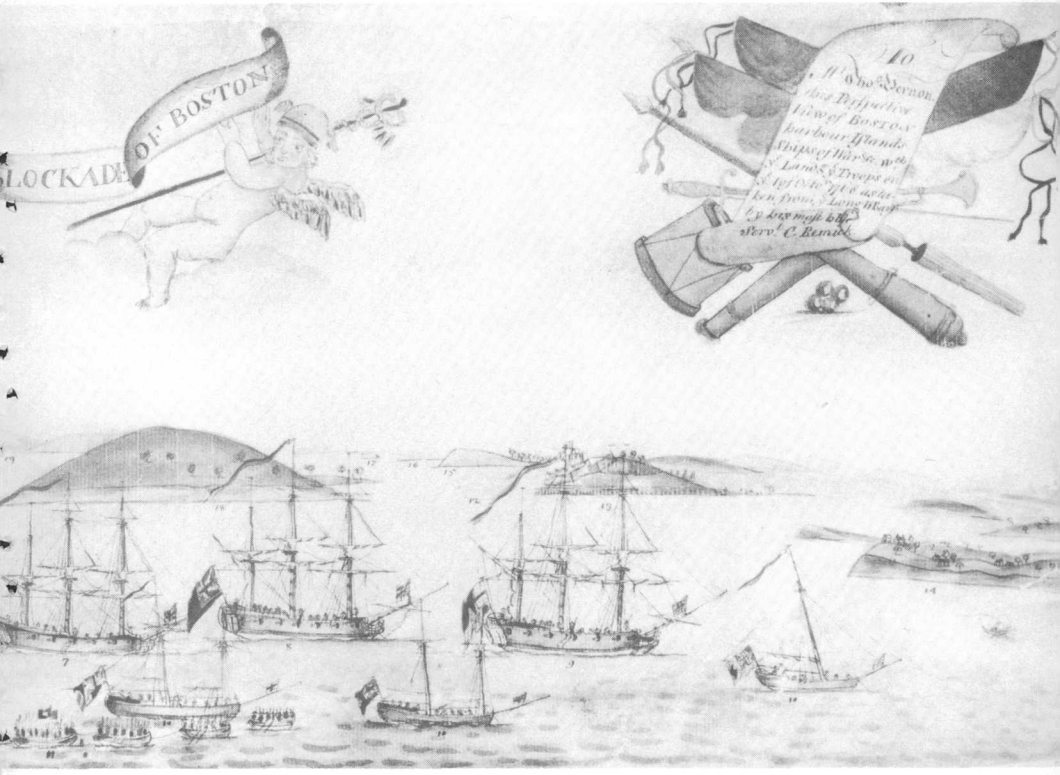


FIGURE 13.—Perspective view of the blockade of Boston. Watercolor drawing by Christian
many drumlin islands in Boston Harbor. Reproduced by

1632, and throughout the next two centuries the fortifications were strengthened. The present star-shaped granite fort dates from the mid-19th century. The fort was first called "Castle" and then "Castle William," after its rebuilding in the reign of William I; in the 19th century, it was named "Fort Independence." For awhile during part of the Revolutionary War, Paul Revere was commanding officer.

Ship ballast brought back from western Europe by U.S. troop and supply ships during World War I was used in constructing the fill that connects the island to South Boston. The ballast was largely gravel from the English Channel coast, and it contains many flint nodules peculiar to the chalks of that region. Such flints were in great demand in the time of flintlock rifles. Today they constitute a peculiarly exotic element among the suite of rocks and minerals of the Boston area.

One of the largest drumlin islands in the harbor was Governors Island (figs. 6, 13), about three-fourths of a mile due north of Castle Island. No attempt was made to fortify it on a large scale until 1808. This fort was greatly enlarged in the epoch 1850–



Remick, 1768, from the collection of the Massachusetts Historical Society. Drawing shows the
permission of the Massachusetts Historical Society, Boston.

1875. The island was entirely leveled in the 1940's to make way for the runways of Logan Airport.

The island was granted to Boston's first Governor, John Winthrop, in 1632 for his private use, and on it he planted a vineyard and the first apple and pear trees in New England. The original grant stipulated that a rent to the Commonwealth of a hogshead of wine and two bushels of the best apples be paid yearly. The Governor was reported to have taken great pride in his orchard, which had the reputation of being one of the first and finest in New England.

During the siege of Boston, the British controlled most of the harbor islands and used them as best they could to provide the town with agricultural produce, particularly meat. Continental troops, knowing this, made several forays against the islands, including Grape Island (fig. 1), raided for hay; Noddles and Hogg Islands (figs. 6, 13), from which hundreds of sheep and many cows and horses were driven; Long Island (figs. 1, 13), which yielded hay and horses; and Deer Island (figs. 1, 13), from which 800 sheep and some cattle were removed.

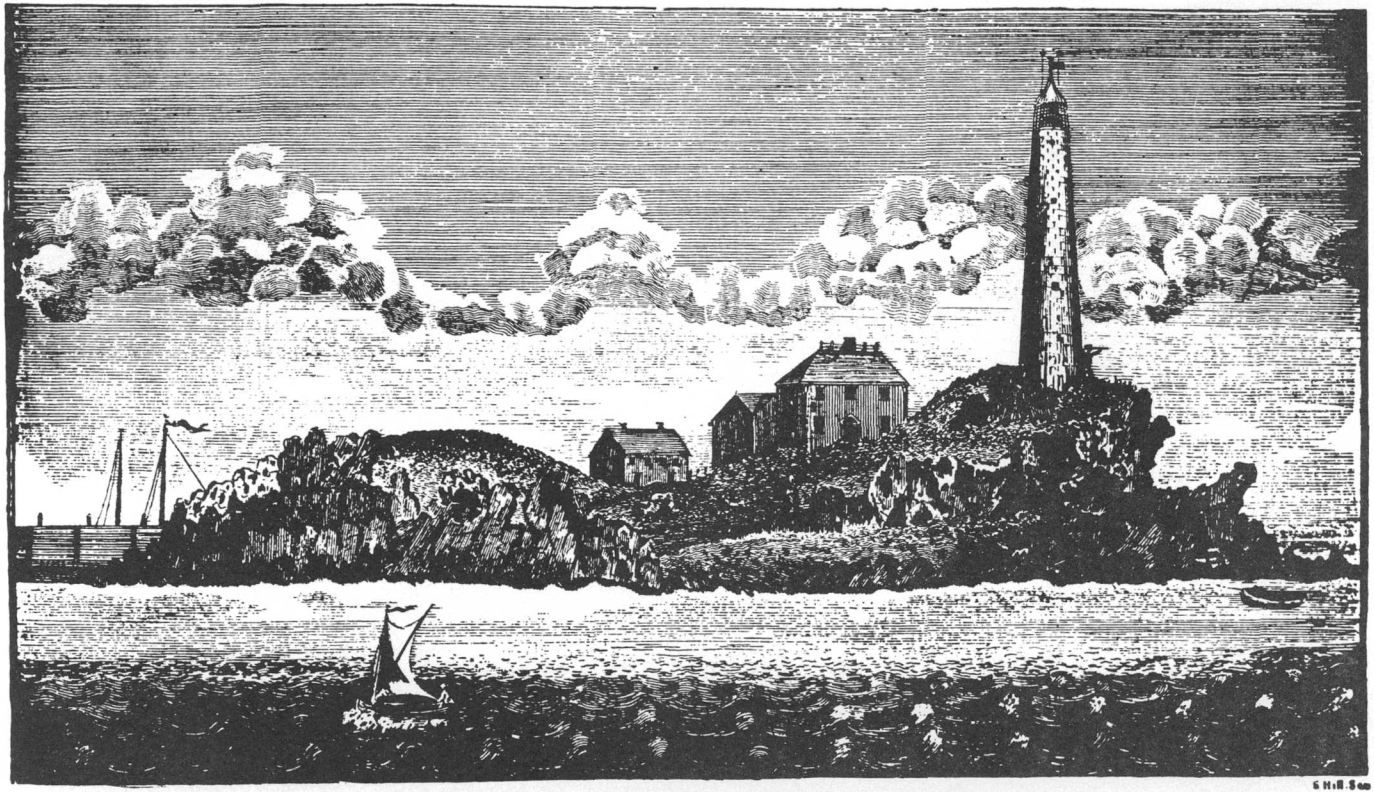


FIGURE 14.—Boston Lighthouse; from an engraving in the *Massachusetts Magazine*, 1789.

THE COMMON

The troops that marched to Lexington and Concord on April 19, 1775, embarked in boats from the foot of Boston Common and crossed the Charles River to Lechmere Point in Cambridge. Throughout 1775, and until the British evacuated Boston in 1776, the lower part of the Common was badly trampled. British troops were camped there and maintained several artillery batteries in the vicinity. At that time, the Lower Common consisted mostly of Fox Hill, the swampy polluted Round Pond, and an adjoining area of salt marsh (fig. 11). Later, in the early 19th century, the entire swampy area was filled to make the parade ground, now occupied by the underground garage and the adjoining playfield.

Excavations for the underground garage revealed the entire sequence of geologic events that took place since late-glacial time. The bottom of Round Pond was found to contain as much as 16 feet of clayey pond sediment and peat. Study of the pollen, leaves, cones, fruits, and wood preserved in this material give a record of the vegetation that existed in the vicinity from about 11,600 years ago to the 19th century. Subsequent layers of red-cinder fill separated by layers of topsoil attest to the fact that the level of the parade ground had to be periodically raised by the troops as the underlying peat slowly compacted beneath the weight of the fill.

There is evidence that an even older pond existed, at the same place or at least close by. Lumps of peat and branches of birch trees were found embedded in clay and glacial till that had been pushed up by the Back Bay ice lobe. These organic remains are about 12,200 years old, according to carbon–14 dating, and indicate that the glaciation of Back Bay took place after that date. What is particularly interesting is that pieces of this wood had been cut by beaver, because the unmistakable toothmarks of beaver are obvious on the faceted ends of the branches (Kaye, 1962) (fig. 15).

The bottom of the deposits of Round Pond consists of a mat of fibrous vegetable matter, which was radiocarbon dated at about 11,600 years of age. This material is overlain by 8 feet of highly organic mud having the consistency of butter, within which are leaves of white birch and alder, showing that these trees were growing in close proximity to the pond. About 11,000 years ago, forests dominated by black spruce became established. At this level, the organic mud is replaced by fibrous peat containing a mixture of forest debris, including spruce cones, needles, twigs, and logs. Most of this wood was also cut by beaver, showing that after a temporary absence of 1,000 years or so, beaver again entered

FIGURE 15.—Small logs that are dated as 12,200 years old that were cut by Canadian beaver (note teeth marks). From excavations for underground garage in lower Boston Common.

upon the scene. The surrounding spruce forest was then replaced by one of white pine, and the characteristic cones of this tree are found preserved in the peat. About 6,000 years ago, oak became abundant and pines disappeared. The beaver colony remained active; their unmistakable signs continue through the peat section. The last layer consists of the leaves and nuts of red and white oak, willow, and shagbark hickory. These trees must have been growing on Fox Hill and on the banks of Round Pond shortly before the Puritans arrived.

Early descriptions of Shawmut Peninsula tell of the absence of wood; for example, the description of William Wood in 1634:

. . . Their greatest wants be Wood, and Medowground, which never was in that place; being constrayned to fetch their building-timber and fire-wood from the Islands in Boats, and their Hay in Loyters; It being a necke and bare of wood: they are not troubled with three great annoyances, of Woolves, Rattle-snakes, and Muske-toes . . . (Shurtleff, 1891, p. 40–41).

One must conclude that the Indians had either only recently cleared the peninsula for purposes of planting corn or that trees were indeed growing in the lower Common in 1630 but that either the colonists had cut them by the time Wood made his observations or that the lower Common was an exception and that Wood may not have seen it. However, even if the colonists had cut all the wood in the first 2 or 3 years of their occupation of the peninsula, they certainly could not have succeeded in pulling all the stumps in that short period of time, and one would think that observant Wood would have noticed this and come to the proper conclusion. What happened to Boston's woods, therefore, becomes an unsolved mystery.

SOUTH BOSTON OR DORCHESTER HEIGHTS

There is a curious parallel between South Boston—known as Dorchester Neck in colonial times—and Charlestown. Both were islands at high tide separated by a narrow strip of water from Boston proper; both consist of a cluster of drumlins. Charlestown flanked Boston on the north; Dorchester Neck flanked it on the south. Charlestown was the site of the first battle of the conflict in Boston; Dorchester Neck was the site of the last or culminating confrontation as far as Boston was concerned, and this turned out to be as bloodless as Bunker Hill was bloody.

The high core of South Boston is two parallel drumlins, both trending east and joined to one another on the sides like Siamese twins. Today, the crest of the northern drumlin has been lowered

because of street grading in the last century, so that the southern of the two, Telegraph Hill, stands about 50 feet higher. In 1776, these drumlins were collectively called Dorchester Heights.

The American siege of Boston in 1775 and 1776 was complete except for the harbor. In Boston, the British army and the remaining civilian inhabitants led a precarious existence. Their only source of supply was by sea and such produce as the harbor islands afforded. With this in mind, General Washington decided to seal off the harbor by placing artillery in range of the ship channel. The high drumlins of Dorchester Heights, although a little more than a mile to the south, were still in cannon range and would serve his purpose well.

In February 1776, Col. Henry Knox (the same who played a role in the Tea Party) arrived at army headquarters in Cambridge with 8 brass mortars, 6 iron mortars, 2 iron howitzers, 13 brass cannon, 26 iron cannon, 2,300 pounds of lead, and 1 barrel of flint, all captured a few months before at Crown Point and Fort Ticonderoga on Lake Champlain in northeastern New York. Col. Knox and his men with teams of oxen had courageously pushed and dragged this weighty ordnance on sleds in the dead of a snowy winter over several hundred miles of wretched mountain trails to perform one of the great physical feats of the war.

Washington and 2,000 men, now supplied with artillery, moved onto Dorchester Heights on the night of March 4, 1776. Before the night was out, a strong redoubt had been built on the top of Telegraph Hill, and by the end of the week, several smaller batteries had been emplaced lower downslope almost reaching the water's edge. Meanwhile, preparations were made for an all-out attack on Boston from the north and west—to be launched if and when the British sailed out to attack the new American positions on Dorchester Neck. Bad weather, however, prevented the British from fully rising to the bait. A sudden violent storm struck, and the British assault boats were swept by wind and waves to the far shore of Governors Island. The attack was called off. The British, besieged now by sea as well as by land, decided to evacuate Boston. The matter came to a bureaucratic standstill as negotiating messages passed between the Commanders of the British and Continental armies. The matter was brought to a head on March 16, when the Americans placed a battery on Nooks Hill drumlin, the northwesternmost point of Dorchester Neck and within easy range of harbor and town. The following day, the British army embarked and set sail, never to return to Boston again.

The great masses of stony sandy clay left by the retreating glaciers and standing as drumlin hills above the surrounding peat- and clay-filled lowlands had, as we have seen, controlled the course

of the short war. The battles were all battles of drumlins. The terrain was the product of the Ice Age, and man's history has never escaped this heritage.

THE CHANGING SHORELINE OF BOSTON

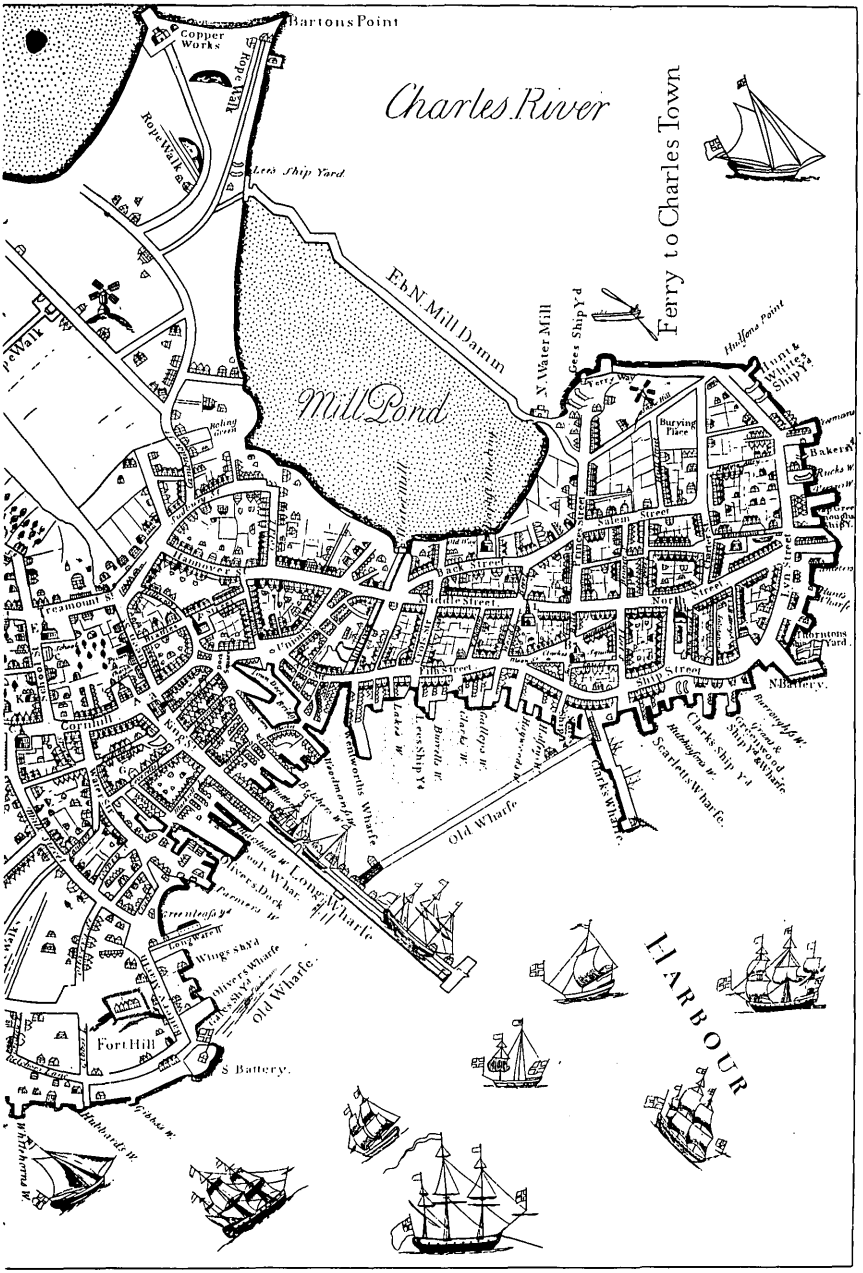
The shoreline of the Charles River estuary and the harbor at the time the Massachusetts Bay Company Puritans arrived in 1630 has never been precisely known. Early records offer only general descriptions and very small scale and poorly surveyed maps. Bonner's 1722 map of Boston (fig. 16) is the earliest large-scale map and shows the shoreline of the peninsula at that time accurately in most places. It is interesting to compare this map with one just prepared by the U.S. Geological Survey which shows the high-tide shoreline as it probably existed in the early centuries of this millenium and perhaps when the first settlers arrived (fig. 6). The principal basis for drawing this shoreline was the limits of organic harbor muds and salt-marsh deposits as revealed by records of more than 30,000 borings drilled for engineering purposes throughout the city and in excavations in and around the city. Where information was lacking, the shoreline was drawn on the basis of historic records and topographic interpretation.

The extraordinary growth of Boston by means of landfill at the expense of tidelands is evident from figure 6, and by comparing this map with Bonner's map, the changes wrought during the first 92 years of European occupation are evident. The earliest fill must have been used to build a causeway over the marsh that separated the North End from Boston proper. The filled area must have been extended rapidly, because early land titles show that much of the original marshland separating the two islands had been granted and occupied in the first few decades of the city's history.

A causeway over the marsh on Boston Neck must also have been a very early enterprise. Although town records tell of occasional flooding of stretches of Boston Neck, the record is vague about the extent of the Neck affected or the precise locations of the flooding. Undoubtedly, these early fills had to be replenished from time to time as they settled into the compressible peats of the marsh or were topped and eroded by high storm tides.

Bonner's map does not show the marshy slough that extended up Water Street and along Congress Street as far as Franklin Street (today's names), nor does it show the full extent of the marsh at the north side of Beacon Hill. Some early extension of the natural shore is indicated on Bonner's map in the area labeled

FIGURE 16.—Map of Boston, by Capt. John Bonner, 1722.



The first large-scale informative map of the town.

Barton's Point and Copper Works. We do not know who was responsible for this filling or when it was done.

Bonner's 1722 map shows other sections of shore that were altered during the first century of occupation. The shore between Boston Neck and Windmill Point (intersection of East Street and Atlantic Avenue today) had been built hundreds of feet seaward and smoothed to a gentle curve. So had the shore between Windmill Point and the South Battery at the foot of Fort Hill, as well as the shore between South Battery and Long Wharf (now mostly State Street) and the Town Dock (crowded in and much reduced in size by 1722). Beacon Hill, particularly the neglected north slope, may have been a source of the fill. Fox Hill, at the foot of the Common, was another possible source. In addition, indications are visible in some modern excavations in Boston that the very early landowners improved their property by judicious grading. Small swampy spots were filled and low knolls leveled by several feet. This is revealed by patches of original soil and surface oxidation or leaching, such as is characteristic of wet places that have been uncovered in recent excavation in central Boston.

The great era of landfilling in the Boston area was the second half of the 19th century. During this time, the entire Back Bay was filled, as was the northern half of South Boston, the area in Cambridge that fringes the Charles River and on which the Massachusetts Institute of Technology now stands, and the marshlands of East Boston that included several drumlin islands (Noddles Island, Camp Hill, Togg Island, etc.).

The last great landfill in Boston was made for the construction of Logan Airport. Governors Island was leveled and used for fill, and a second and smaller island, Apple Island, also within the airport site, was destroyed. Most of the site was filled in the early 1940's by dredging glacial clays from the bottom of the harbor and by pumping this thick mud slurry into settling basins where it formed a thick clay platform.

PAUL REVERE AND COPPER SMELTERS IN BOSTON

The Bonner map shows a prominent building labeled Copper Works, at the western end of Bartons Point, about the westernmost point of town. The building was adjacent to a small square wharf jutting out into the Charles River. The street in front of it was later called Copper Street, changed in the 19th century to Brighton Street.

During the early 1960's, the writer observed bright-green coloration of the usually dark-gray river silts exposed in the excavation

for Emerson Place. This color must have been stains from the many pieces of scrap copper that had fallen into the river or that had been buried in the ground beneath the floor of the foundry during the 18th century.

Except for several ropewalks and shipyards, this is the only industrial or manufacturing establishment shown on Bonner's map. It is curious, therefore, that little information about the copper works can be found. We may surmise, however, that the plant was a small foundry making copper and perhaps brass nails, spikes, and assorted fittings for the shipbuilding trade, which was Boston's principal industry at that time.

The plant undoubtedly was a foundry rather than a smelter and had to import pigs of refined copper. No copper mines existed in Massachusetts at that time. The nearest source of copper was the Sims mine in the Connecticut Valley, just south of the Massachusetts line in Connecticut; it is unlikely that ore from this small deposit reached Massachusetts Bay. In the 17th century, copper was found north of Boston between Danvers and Topsfield, on land owned by Governor Endicott; there are, however, no records of commercial production in this period (Toulmin, 1964, p. A74). On July 30, 1648, Governor John Winthrop wrote his son John *". . . Mr. Endicott hath found a copper mine in his own ground. Mr. Leader hath tried it and the furnace runs 8 tons per week and their bar iron is as good as Spanish . . ."* (Savage, 1826, v. 2, p. 356).

The next copper and brass foundry to be built in Boston was Paul Revere's. The famous patriot had been goldsmith, silversmith, copperplate engraver, political caricaturist, dentist, maker of false teeth *". . . that looks as well as the Natural and answers the End of Speaking to all Intents . . ."* (from an advertisement in the *Boston Gazette and Country Journal,* September 19, 1768), commanding officer of Castle Island (Castle William), manufacturer of gun powder, proprietor of a hardware store, health officer and coroner of the city of Boston, and founder of the first mutual fire insurance company in the city (Massachusetts Mutual Fire Insurance Company). The enterprise that stood his family in good stead for generations started with the establishment of a small copper and brass foundry in 1788 at No. 13 Lynn Street (now Commercial Street), where the narrow lanelike Foster Street drops down the side of Copps Hill. Some uncertainty exists as to the precise location of this shop; most biographies suggest that it was at the corner of Lynn and Foster Streets. This location is a steep slope, and it seems unlikely that a foundry that cast heavy brass church bells and cannon could have occupied such a restrictive site. The site of the foundry more likely was across Lynn Street,

on the wharf side. The location probably was just west of where the headquarters buildings of the 1st District, U.S. Coast Guard, now stand.

Revere did not smelt ore but worked with already refined copper, as did the earlier copper works. He cast more than 75 church bells, some of which are still hanging. His biggest trade, however, was directed to shipbuilding, where he provided much of the hardware. He made bolts, spikes, braces, cogs, pintles, sheaves, pumps, ship bells, and other metal parts for both merchant ships and warships (including the hardware for the U.S.S. *Constitution,* the U.S.S. *Essex,* and the U.S.S. *Boston*) that were then being built within a short walking distance of his foundry.

In 1801, he established a large mill in nearby Canton, on the headwaters of the Neponset River, in a powder mill of the Revolutionary War. Here, waterpower from the river was used to operate the first rolling mill for copper sheeting in New England, and Revere was successful in rolling the sheeting to cover the dome of Charles Bullfinch's State House, newly erected on Beacon Hill. In the next year, 1802, he rolled the copper-protective sheeting for the hull of the U.S.S. *Constitution* ("Old Ironsides") just before she sailed on her famous expedition against the Barbary pirates on the North African coast.

The great hurricane of October 9, 1804, blew the roof off Revere's Lynn Street foundry. After that, all his manufacturing was done in Canton. Through the 19th century the company prospered, combining with other growing copper companies. Until the discovery of the great copper deposits in Michigan in the middle of the century, when a large source of native ore was insured, almost all Revere's copper came from abroad or was resmelted from scraps. Revere imported copperplate from Sweden and Turkey, copper bars from Russia, and copper pigs from South America. In 1803, he suggested to the Secretary of the Navy that U.S. naval ships operating in the Mediterranean Sea return to the States with ballast consisting of copper ore from Smyrna.

BOSTON BUILDING STONES

Until this century, when easy rapid transportation has made materials from distant sources available, city buildings have always reflected the nature of local building materials.

Boston began as a town of wooden houses. Trees were abundant, if not on Shawmut Peninsula (see p. 63), then on the nearby mainland. The colonists cut the forests to clear farmland in Brookline, Roxbury, Dorchester, Cambridge, and in countless other small

communities that were springing up all over the eastern part of the Colony.

By the end of the 17th century, attention was being given to the abundant deposits of clay that underlay the coastal lowlands extending from Boston north along almost the entire coast. Although clay was dug for brickmaking earlier in the century, it was not until a series of disastrous fires had swept the young city that serious thought was given to replacing wooden construction with brick. This description by a French visitor to Boston in 1687 (Shurtleff, 1891, p. 47) reflects the feelings of the time: ". . . *The town is almost wholly built of wooden houses; but since there have been some ravages by fire, building of wood is no longer allowed so that at this present writing very handsome houses of brick are going up* . . . ." The ordinance prohibiting wood construction must not have been enforced, as almost 100 years later, in 1780, the Count de Rochambeau described in detail the construction of the many wooden houses in Boston (Shurtleff, 1891, p. 68). However, many of these had brick sidewalls, and much of the city by that time was of brick construction.

Clay for bricks and pottery was dug most commonly along the flats bordering the Mystic River, Willis Creek in Somerville, to a lesser extent the Charles River, and in the town of Lynn to the north, bordering the Saugus River. Brick kilns were small beehive-shaped ovens. A small kiln of this type existed on the lower northeast slope of Bunker (Breeds) Hill at the time of the battle.

The geology of these brick clays is interesting. There seem to be three separate clay beds, each deposited at a different time during the late Ice Age. The uppermost bed has provided most of the clay for bricks.

The upper clay is gray, varying from greenish to slightly bluish gray. The top 4–15 feet is generally buff or yellow. The clay is as much as 225 feet thick under parts of the Back Bay, Charles River, and the harbor. It is found at altitudes as high as 50 feet above mean sea level.

The clay consists of glacial rock flour, the very fine grained sediment carried by glacial melt water from the ice. The melt waters containing this fine silt and clay in late-glacial time must have been milky, as are glacial melt waters today.

The clay was deposited in salt water. We know this because at a few places it contains fossil marine shells. These shells have been dated by means of carbon-14 and are about 14,000 years old. Because these clays are found at altitudes of as much as 50 feet above sea level, we can conclude that about 14,000 years ago, sea level at Boston was at least 50 feet higher than it is today (Kaye and Barghoorn, 1964).

The use of stone for building purposes in Boston did not come into its own until the 19th century, despite the abundance of granite and other usable stone in the area. Apparently the skills required for stone quarrying and stone dressing (stone cutting and masonry) did not exist in the Colony.

The earliest recorded use of stone for house construction in Boston was Deacon John Phillip's Old Stone House, erected about 1650, on Cross Street and demolished in 1864, at which time it was the oldest building standing in Boston. A contemporary description states that the ". . . *foundation walls were four feet thick or more; the walls above ground were two feet in thickness, and built entirely of small quarried stones, unlike anything to be seen in this neighborhood and were probably brought as ballast from some part of Europe . . .*" (Drake, 1971, p. 155).

Soft red sandstone from the Connecticut Valley, called "freestone," was shipped in small quantities to Boston in the 17th and 18th centuries and was used for window and door lintels, corner quoins, and various other semistructural and decorative uses.

The first of two buildings to be constructed of locally dressed stone was the mansion of Thomas Hancock on Beacon Street facing the Common, on ground now occupied by the underground archives building of the State House. It was built in 1737 of Quincy Granite. The second building was Kings Chapel, begun in 1750 (fig. 17). This too was of Quincy Granite, even though the stone came from the North Common in Braintree, just south of the town of Quincy. The stone for both buildings was not quarried; the blocks were trimmed from loose boulders of granite scattered about on the surface. The boulders were hand split and hammered by a group of Germans who had settled in Braintree between 1725 and 1750 and who had brought with them from Europe a knowledge of stone dressing (Shaw, 1860).

The next stone building of note is St. Paul's Cathedral on Tremont Street, facing the Common; it was consecrated in 1820. The church building is of quarried Quincy Granite; the Doric portico, on the other hand, consists of light-tan sandstone from the Aquia Creek quarry, Stafford County, Va., the same quarry that provided stone for the United States Capitol and the White House in Washington, D.C. The building is the earliest example of Classical Revival architecture in the city and is the first major structure to use a building stone of distant origin.

Soon after the construction of St. Paul's Cathedral, Mayor Joseph Quincy of Boston built (1824–1826) his famous market building facing Faneuil Hall. The stone of white mica granite came from the West Chelmsford area, about 25 miles northwest of Boston. It is claimed that the stone was not quarried but was dressed from

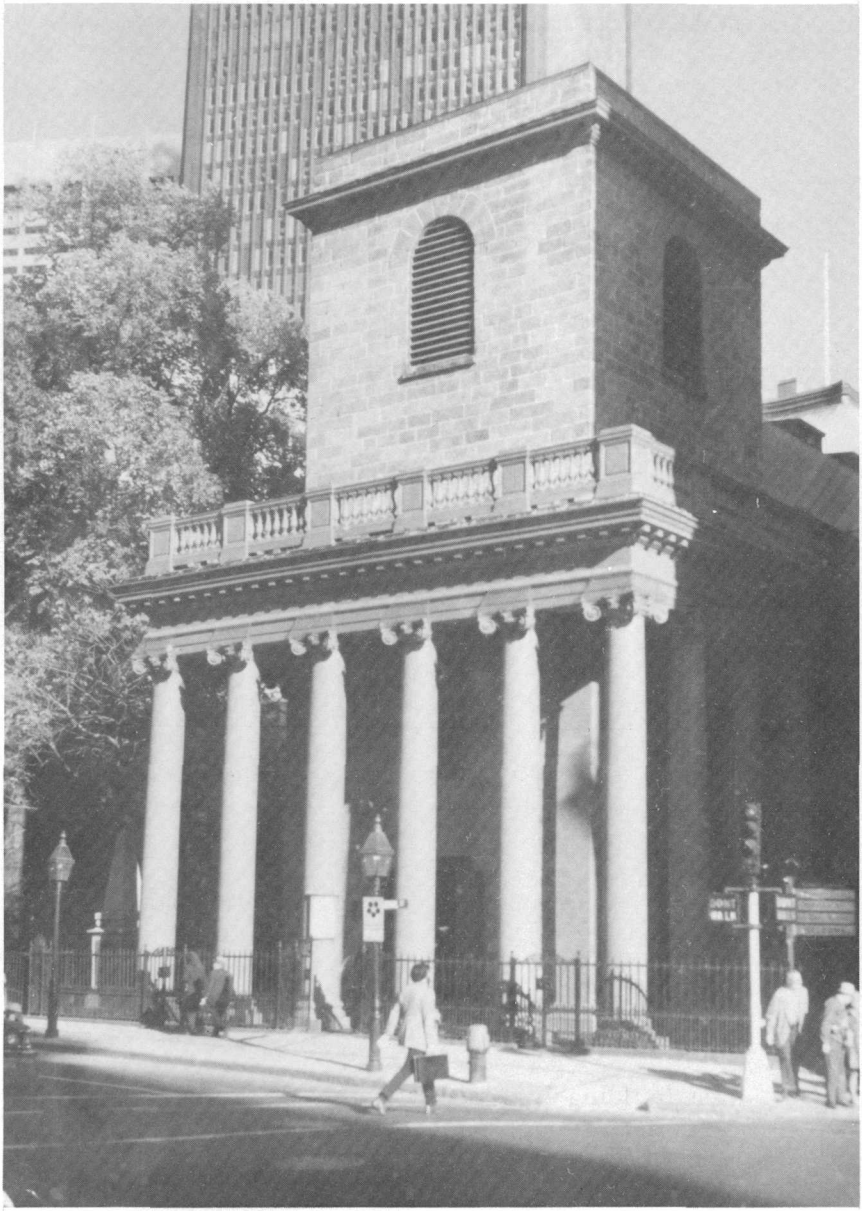


FIGURE 17.—King's Chapel, built in 1750, Boston's earliest extant stone structure. Stones in the tower are hand-dressed boulders of pink and gray Quincy Granite from Braintree Common. Columns and porch are of wood.

surface boulders. If this is so, it is noteworthy that the shafts of the eight Doric columns in the porticos at both ends are monoliths, 22 feet long, and would have required boulders of at least this length.

White marble, hauled from Vermont, was used for many buildings in the 19th century. In larger buildings it was generally mixed, in imitation of Italian architecture, with other stones, often verde antique (serpentinite), which also came from Vermont.

The great era of Quincy Granite construction in Boston began with the opening of the quarry for the Bunker Hill Monument, described elsewhere in this report. The era lasted until about 1855, during which time many elegantly designed buildings were constructed. Several of these gray buildings are still standing, particularly in the waterfront area (Custom House, Lewis Wharf, and Commercial Wharf).

The great growth of Boston in the second half of the 19th century, mostly the result of the filling of the Back Bay, brought with it the use of a heretofore neglected local stone, the Roxbury Conglomerate, or "puddingstone." It is a mottled brown and, because of the embedded round pebbles, has a rough appearance. The rock crops out in Brookline and Roxbury, and some quarries were opened immediately adjoining the Back Bay, as, for example, the quarry at the northeast end of Parker Hill. Most of the churches in the Back Bay were built of this stone.

By 1885, the railroad network of the country was so extensive that granite and other building stones from areas heretofore beyond the economic reach of the city had become accessible. Many large buildings constructed between 1875 and World War I are of stones quarried in New Hampshire, Vermont, Indiana, Minnesota, and other States.

The advent of curtainwall construction and reinforced concrete in this century changed building technology completely. Brick and stone are now used only as thin surface veneers. Concrete, however, is largely sand and gravel, and the sudden need for this aggregate produced a rush on the glacial-outwash deposits in the valleys surrounding Boston; almost overnight, sand and gravel pits were opened everywhere. What had seemed an inexhaustible resource a few decades ago is nearly gone at the time of this writing, and Boston today must import most of its sand and gravel from adjoining States. The future supply of sand and gravel is a matter of serious economic concern.

Until the first half of the 19th century, Boston streets were paved with rounded cobblestones. These naturally rounded cobbles, averaging about 7 inches in length, at first probably came mostly from nearby beaches, such as Cohasset, Nahant, and Cape

Ann. Later, however, they were carried by coastal schooners from the Maine coast in large quantities. To make a pavement, they were set, one against the other, in beds of sand, their long dimensions vertical. From time to time, more sand was added to fill the voids between the cobbles. Most streets lacked sidewalks, at least during colonial time, and these pebbly pavements served both pedestrian and vehicle traffic. The smooth rounded ends of the cobbles must have made treacherous footing for pedestrian, horse, and cart wheel alike on the steep streets of Boston, particularly in wet weather. Not until the second half of the 19th century were the cobbles replaced by quarried paving blocks that were hand-dressed with flat squared sides. Many of these came from the Rockport quarries. Pavements of the old rounded cobblestones still exist in a few places on Beacon Hill (fig. 18).

GEOLOGY—TODAY AND TOMORROW

We have looked at some historic events, and we have examined the geology that either played a role in these events or else simply was there, underfoot. We know more about the relationship between man and Earth today, 200 years after Bunker Hill, than we did then. Today, most ambitious undertakings consider geology in some fashion: the Earth is the subject matter of environmental-impact statements; engineers design large structures only after finding out about the geologic properties of the earth materials that will support the structures; an army plans a campaign only after determining the geologic nature of the terrain that it will cross; the farmer calls on the soil scientist to tell him about his soil; developing countries use geologists to find more resources. Few go through school today without taking at least one course in earth science. The number of geologists has multiplied manyfold during the present century.

All this testifies to the growing realization that man is absolutely and inescapably tied to the Earth, no less today than in colonial times. The Earth has always provided support, sustenance, and shelter for man. This is as true where men crowd closely together in cities and towns as in the wilderness. In earlier centuries, people were more aware of their dependence on the Earth than today. The founders of Plymouth and Boston knew that water and soil are prime requisites for a successful town. These still are among the essentials of any society; only our ability to transport has improved, and, in consequence, our reach has become longer.

Yet in spite of the importance of our planet to our very existence, we scarcely know the Earth at all. Our exploration has been con-

FIGURE 18.—Existing cobblestone paving, Louisburg Square, Beacon Hill.

fined to the surface, whereas the vast interior is unknown. Probings by deep mines, oil wells, and borings constitute mere scratches. Our deepest probes are about 1/500 of the Earth's radius. We try to see deeper by means of instruments—primitive "stethoscopes" applied to the Earth's flanks—and we have detected various kinds of evidence that yield clues to internal variations. However, we still can only guess at the composition, structure, and dynamics of the vast interior.

About all we can say now is that there is good evidence of zones of heat concentration where the generation of magmas takes place and from which vertical movements of molten and unmolten rocks are initiated. These heat or energy chimneys appear to be necessary for the equilibrium of the entire Earth system. Many more systems whose nature and function are as yet unknown probably exist. We are, in fact, in much the same position that medicine was in only 500 years ago, when interest in health and the body was intense.

Advances in the geologic sciences are limited by the constraints of technology. When means are developed to delve more deeply and directly into the Earth, we will be taking a giant step forward. The benefit to man's well-being that awaits progress in this direction is geologic science's promise of the future.

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Watercolor of the south end of Boston
by Lt. Byron, 1764,
courtesy of the Bostonian Society