THE LAST BILLION YEARS OF THE GEOLOGICAL HISTORY OF THE TOWN OF LEXINGTON

by

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1984

edited by R. Green, A. Levine, and F. Ludwig (1987)

FOREWORD

This pamphlet has been prepared to give interested persons a little information about what happened geologically in the Town of Lexington during the last billion years, before humans appeared on the scene.

Many of us have wondered about how the rock hills, flat sandy areas, and peat-floored marshes formed. Others, interested in rocks and minerals, have no doubt noticed the rocks in natural outcrops and man-made road-cuts, and the boulders piled up to mark boundaries, and wondered how the rocks got where they are now. Whence came the sand and pebbles in the streams, and why do some valley bottoms have that rich, black soil? Why do the streams run where they do, and why are ponds located where they are? In short, when and how did all of this happen?

Every hill, every rock, every valley, every deposit of gravel, sand, or loam has a long and interesting history. As curious humans, we cannot help but wonder how these features came to be.

I hope that the following comments will answer some of those wonderings.

In order to prepare even a brief history of the minute segment of Earth within the bounds of the Town of Lexington, one must seek the help of many different scientists. The following statements are based in part on publications by some of these scientists, on discussions with others, and on observations that I myself have made during the past forty-five years. A short list of publications and maps that I have found useful is appended. Reference to them is indicated by a superscript number ([1]). A glossary of technical terms is included on page 8.

THE GEOLOGICAL RECORD IN LEXINGTON

In writing a geological history of our Town, one has two separate but closely related records to examine and interpret: the record preserved in the solid rocks, and that preserved in the loose materials--the sediments--that cover the bedrock.

The older record is preserved in the solid-rock foundation that may be seen at the surface, in limited natural outcrops, or man-made excavations. More commonly, however, it is concealed beneath a blanket of sediments, a body of water, or a sheet of ice. The rock in this foundation, which constitutes the crust of the Earth, contains the 4.5 billion year old record of that crust before

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it was covered by the present day sediments.[6]

The second and more recent record is preserved in the surficial blanket of unconsolidated sedimentary material--boulders, gravel, sand and silt, and here and there the organic residue offormer vegetation--which, in the Town of Lexington, dates back little more than 10,000 years.[5,7,8]

The oldest foundation rocks in Lexington have an age of approximately 630 million years. This age has been determined by geologists who have measured the ratio of isotopes in minerals of these rocks. Inasmuch as the rocks dated are igneous, hence formed from the melting of still older parent rocks, it is evident that there must have been such parents, though we have no direct evidence of the nature or age of them except that they were no older than 4.5 billion years, the estimated age of the first crust to form on Earth.[6] Lexington's foundation rocks will be discussed briefly a little further on.

The sediments that mantle the foundation rocks in Lexington were deposited by lobes of the great continental glacier that formed in northern Canada a million or so years ago. The ice in certain of these lobes flowed southward into the United States, as far as the Midwest and New England, before stopping and leaving winding ridges of unsorted rock debris called moraines. The glacier's lobes then stagnated, finally melting back to their source in Canada.

Glacial geologists can only guess that the lobes of the glacier first reached the Boston area several hundred thousand years ago. They know rather accurately, however, that the glacier stagnated over the Boston area and began to break up and melt away about 15,000 to 12,000 years ago.[11]

Inasmuch as there is no bedrock in the Lexington area younger than the foundation rocks mentioned above (i.e., younger than 630 million years) and there is no recent record that goes back farther than the beginning of glaciation around a million years ago, it follows that there is a long time gap between the glacial period and the time when our foundation rocks were formed, for which we have no rock record of what happened in our Town.

Fortunately, we do have knowledge of what was going on elsewhere in North America, and even quite nearby in New England, during this long time gap. Ancient basement rocks were being invaded by magmatic fluids, metamorphosed, and uplifted into mountain ranges, only to be worn down again. Large plates of the crust collided, then pulled apart, and volcanoes developed along the sutures. An example of one such zone is the Bloody Bluff block and fault zone at the intersection of old Massachusetts Avenue and Route 2A (Marrett Road) that has been attracting considerable attention lately. Experts on plate-tectonics ("continental drift" of past years) tell us that the fault zone exposed in the bluff marks a location where two large plates of the North American continent collided, one plate moving eastward over the other plate. They report that the fault plane dips steeply to the west and strikes in a NE-SW direction.[14-16]

It is probable that a mountain range several miles high once stood in Massachusetts and the States to the north, but was worn down long before the birdlike dinosaurs walked in the mud flats of the Connecticut River region 200 million years ago.[9] In fact, it would seem that eastern Massachusetts has been a land area since the time of those dinosaurs, with a widespread system of rivers slowly eroding the land down to the gently undulating mature topography that now lies beneath the glacial deposits laid down only a few tens of thousands of years ago.

In short, we can only try to imagine what happened in the Lexington area during that 630 million year gap by learning more about what went on in neighboring areas near and far.[10,13]

THE PLEISTOCENE CONTINENTAL GLACIER[11]

Let us now return to the part of Lexington's geological history that we know most about, the formation of the widespread mantle of glacial deposits that make up so much of our landscape.

The glacial geologists and the meteorogists tell us that a million or so years ago ("recently" to the geologist), the climate in both of the polar regions began to change noticeably. Snow began to accumulate faster than the sun's heat could melt it. As the snow packed and changed to ice, the ice became thicker and began to move radially outward under its own internal weight. As the ice sheet expanded outward, great lobes and tongues developed along its margin. These pushed outward, at first following lowlands and then overriding higher and higher surface features, until the entire surface was covered. Eventually the Pleistocene glacier (this is the name geologists use for this recent continental glacier) was one great expanse of nothing but ice, as in present Greenland and Antarctica.

As the lobes and tongues of ice along the distant margins of the sheet advanced into the adjacent lowlands, they became irresistible bulldozers. They scraped loose the weathered surface materials and fractured rock, which were then incorporated in the basal part of the glacier. As they were slowly pushed over hard rock surfaces, the incorporated rock flour and coarse particles acted as an abrasive that polished and grooved the solid bedrock.

Such a smooth bedrock surface, with grooves and striations aligned in a general N-S direction (actually S 15^{o} E at present), and ending abruptly upslope to the south in shattered rock, is beautifully preserved on the large natural outcrop near the parking lot of the Josiah Willard Hayden Recreation Centre on Lincoln Street. The grooves clearly show that the glacier moved across the Town in a slightly southeasterly direction from its Canadian source. It follows, therefore, that the numerous foreign boulders, cobbles, and all of the finer sediments present in Lexington were transported by the glacier from bedrock sources in northern New England and adjacent southern Canada.[11]

During its original advance southward across the Lexington area, the glacier had scraped the soil and weathered rock off the hills and scoured out the north-south trending valleys and their tributaries. Most of the scrapings were probably dropped in Long Island Sound or pushed up onto the Island to make the terminal moraine that marks the glacier's farthest southward advance. This moraine has subsequently been worked by water to yield the sand for the long stretch of beach along Long Island's south shore.

After a period of meltback caused the ice front to move back into Massachusetts, another surge in glacial activity pushed the ice front as far south as the axis of Cape Cod, and its recessional moraine now forms the backbone of the peninsula. This moraine helped to provide the sediment for the sand plain on which the Edwards Air Base now stands.

Then as the southern edge of the glacier began to break up, as long ago as 15,000 years, over eastern Massachusetts, the debris held in the ice settled to the bedrock floor. The melt waters, white with suspended rock flour, rushed southward and southeastward, over and around large blocks of stagnant ice, carrying sand and gravel down the sluiceways they followed on their way to the sea. The rock flour spread over the Boston Basin to become the well-known Boston Blue Clay. The sand and gravel filled isolated depressions and drainage channels with thicknesses in tens of feet. The largest boulders were left stranded at all levels as erratics. Blocks of ice were left intact, surrounded by, and even buried beneath the sand and gravel dropped by the decelerating melt waters. When these particular blocks finally melted, they left shallow depressions that became ponds which, in turn, became marshes, and finally enclosed basins floored with peaty soil. Luscious blueberries have been grown and harvested on the loam in such an enclosed basin on Adams Street for many years.

For brief periods during and after the recession of the glacier's southern edge, some areas were covered by shallow lakes, like glacial Lake Concord, which extended into the Lexington area and left thin deposits of sand at levels around 120-150 feet above sea level.

THE LANDSCAPE

The Lexington landscape consists of low, rounded rock hills separated by interconnected flat-bottomed valleys whose floors are covered with unconsolidated sediments of glacial origin. Here and there throughout the Town, a few features of the landscape have been altered locally by road cuts, excavations for sand and gravel, and artificial fills. On the whole, however, the overall surface has changed little in the last 10,000 years since the glacier melted away.

If all the unconsolidated materials that mantle the hills and fill the valleys were removed, we would see a bedrock surface of probably less than 500 or 600 feet relief. Mt. Whipple, the highest hill in the Town of Lexington, is 374 feet above mean sea level.[19] The lowest valley, now filled with glacial deposits, is probably not more than 100 to 125 feet below mean sea level.[4]

A constant reminder of the recent Pleistocene Glacier, and impressive evidence of the great transporting power of the ice, are the boulders, large and small, that are scattered over the Lexington landscape. Many of these have been put to good use: witness the blocky granite boulder that marks the LINE OF THE MINUTE MEN on the Lexington Green; the ones arranged along the boundary of the parking lot along Worthen Road that calls attention to Hastings Park; and the gigantic block of coarse, gray granite, with its narrow quartz dike and polished and grooved surface, indicating glacial abrasion, that was placed at the intersection of Lincoln Street and Worthen Road to memorialize Josiah Willard Hayden's great gift to Lexington's youth. Whether the boulders were brought to the Town by human hands or dropped here by glacial ice, they were surely involved in some way with the Pleistocene Glacier.

THE VALLEY SEGMENTS

The topography of Lexington is dominated by the complex of flat-bottomed valley segments. Quite a few of these areas, once covered by lingering melt waters from the stagnant ice farther north, are now only swamps or marshlands. An example is Tophet Swamp along Hartwell Avenue, where the Town dump was once located. Another is the strip along Concord Avenue alongside the golf links, which becomes flooded during periods of unusually heavy rainfall.[19]

Some of these former marshy areas, such as the strip of black soil along Waltham Street opposite the roadway to the Jonas Clark Junior High School, are sites of productive truck farms. The Redick family has been harvesting luscious blueberries on a loam-filled basin on Adams St. for many years, and the well-known Wilson Farm in East Lexington flourishes on a broad, loam-covered valley bottom area.

The Great Meadow, also in East Lexington, and now a dry marsh most of the year, was once covered by a body of water deep enough for operation of a small excursion boat. This body of water was a temporary feature, however, which was produced by a dam constructed at the south end. When the dam was removed, the water level dropped back below the surface, and the Meadow again became a marsh. We know that the Meadow area is a former valley segment now filled with some 22 feet of glacial sand overlain by 5 to 7 feet of tough, brown peat. This peat, and surface foot or two of muck, represent the residue of many years of plant growth when the area was a post-glacial marsh.[1]

Broad, flat-bottomed valley segments, which now stand far enough above the water table that they are not flooded except under conditions of excessive and prolonged rainfall, constitute most of the flat areas between the rock hills. These are remnants of dismembered sluiceways down which the glacial melt waters rushed on their way southward and eastward toward the Atlantic around 10,000 years ago.[18]

One such segment trends in a southeasterly direction and constitutes most of the northeast half of the Town. Its general elevation is approximately 200 feet above mean sea level, and it is underlain by tens of feet of typical river-deposited sand and gravel. A portion of this segment drained southward, then north-eastward, cutting the spectacular Shaker Glen on the way.[4] Another portion drained southward across Concord Avenue along Beaver Brook, through Waltham, Belmont and Watertown to the Charles River.

Flat-topped deposits of sand that characterize the aforementioned valley segment are specially noticeable because most of the Town's school buildings are built on these areas: e.g. Diamond and the former Muzzey Junior High Schools, Fiske, Munroe, Estabrook, and Hancock Schools, and the Senior High School. No doubt most of the school sites just mentioned were chosen because they provided the desired flat areas for playgrounds and parking.

In some local areas that lie around 200 feet above mean sea level, ground water may come to within a few feet of the surface. Such was the condition in the site along Waltham Street that was selected for the Senior High School buildings and campus. Because of the quicksand condition under the building site, sheet-metal piling had to be used in pouring the concrete for the foundations of the buildings. Similar conditions were encountered during excavation for sewer lines along Vine Brook east of Waltham Street.

Lexington old-timers will remember that, before Hartwell Avenue was laid out westward from Bedford Street, there was a prominent, flat-topped ridge of sand that extended from Bedford Street beyond the tracks of the Boston and Maine Railroad to the west. Most of the ridge is now gone, the cleanly washed sand having been removed for construction purposes, but a small portion of it still remains just west of the Bedford Street-Hartwell Avenue intersection. This interesting feature, with a flat top at approximately 150 feet above mean sea level, is regarded as a delta deposited into the waters of Lake Concord at its high stage.[18]

Quite in contrast to the aforementioned delta is the glacial material that has recently been extensively excavated during construction in the Drummer Boy Housing Development, half a mile northeast of the intersection on Bedford Street. Here can be seen an excellent display of morainal debris, full of quite large blocks of foreign rocks embedded in a chaotic groundmass of gravel, sand and fine rock flour.

So today, some 10,000 years after the last surge of the continental glacier stagnated, broke up, then melted back to its source in Canada, the Town of Lexington has a varied combination of surface features that give an unusual character to the landscape. Clearly a great glacier, perhaps several thousands of feet thick, once passed our way.

Some people have wondered if mankind's pollution of the atmosphere, and his abuse of the great rain forests of the tropics, might produce the conditions that would bring on another worldwide Ice Age in the near future. Could we, in actuality, be living in an interglacial period? Good questions, those are! It should be remembered, however, that we are not yet completely out of the great Pleistocene Ice Age. The large landmass of Antarctica is still covered with ice, Greenland has an icecap nearly three miles thick, and the higher mountain ranges in both hemispheres have extensive mountain glaciers. Perhaps we should be glad that those ice masses have not melted away, because if they were to melt completely, sea level would rise hundreds of feet and almost every major city in the world would disappear beneath the waves![2]

Enough, then, of the Pleistocene Glacier and what it did for the Town of Lexington. Let us now take further note of the rock foundation over which the ice moved.

THE ROCKS OF THE HILLS AND RIDGES

In the Town of Lexington today, the highest of the rock hills and ridges that rise above the widespread, flat valley segments reach a common elevation of around 350 feet above mean sea level, with the exception of Mt. Whipple, the highest point in the Town, which reaches 374 feet. These hills and ridges consist of igneous and metamorphic rocks which are approximately 630,000,000 years old. There had, of course, to be still older parent rocks that were melted and then crystallized into the different igneous rock types, just as there had to be older rocks that were squeezed and recrystallized into the metamorphic types. So far, such older parent rocks have not been discovered in the Lexington area. Furthermore, as stated earlier, no rocks younger than the igneous and metamorphic types are known to be present in Lexington. Hence the following discussion will have to be limited to the rocks we know to be present.

THE IGNEOUS ROCKS[17]

The most common rocks that can be seen in the Town of Lexington are igneous in origin and characteristically black or pinkish in color, hence we can talk about the "black" rocks and the "pink" rocks.

There are numerous natural outcrops and man-produced exposures of a group of dense black rocks that are massive in structure (i.e., have a homogeneous appearance) and crystalline in texture. Those that have large crystals easily visible to the naked eye are rocks that slowly crystallized from molten material (magma) deep within the Earth's crust. Those of finer grain solidified more quickly nearer the surface. The ones that are densest and so fine-grained that a special microscope is needed to see that they are even crystalline, were formed from molten material that cooled quickly near or at the surface as products of volcanic action. Geologists call the coarse-grained crystalline rocks plutonic and the fine-grained ones volcanic.[12,17]

Regardless of texture, however, all the aforementioned rock types have essentially the same bulk chemical composition, which consists of slightly different combinations of iron, magnesium, calcium, aluminum, silicon and oxygen. They differ only in the minerals which the foregoing elements combined to form.

Gabbros are composed of minerals including plagioclase feldspars, amphiboles and pyroxenes, and olivine. Having large amounts of iron and calcium, they are the heaviest and blackest of the plutonic rocks. Diorites, which closely resemble gabbros, contain smaller percentages of plagioclase feldspar and ferro-magnesian minerals, and small percentages of alkali feldspar and quartz. These two rock types grade into one another in the Town of Lexington and are named the Salem Gabbro-Diorite.[3] An exceptionally fine road cut in this type of black rock can be easily examined, and collected from along the right side of the exit from Route 2, heading west, onto Waltham Street.

Volcanic rocks of the same age and composition as the gabbro-diorite, namely basalts, layered tuffs, and ash beds, are also present in road cuts along Routes 2 and 128. These are places to take extra care if stopped because of the danger from the fast-moving traffic. Fortunately there are other places in town where similar rocks can be examined. For one example, there is a cliff of amphibolite which is well exposed and easily accessible in Kinneen Park on Burlington Street.

A pink granite intrudes both the plutonic and volcanic types of black rocks, and can be easily examined in the beautifully cleaned off natural outcrop near the parking lot on Lincoln Street of the Josiah Willard Hayden Recreation Centre. This outcrop is a textbook example of the contact zone between intruded and intruding rocks. Pink porphyritic granite, with large feldspar crystals surrounded by a finer groundmass of feldspar and quartz, invades a dense basaltic black rock in thin dikes more or less parallel with the contact. There has also been some faulting in the dikes along the contact, and some of the thicker dikes contain fragments of the basalt. The outcrop is even more interesting because of the polishing and grooving done to the surface by the glacier as the ice slipped along the gently sloping surface of the outcrop.

THE METAMORPHIC ROCKS[17]

Some of the outcrops and exposures in Lexington and adjacent towns are composed of metamorphic rocks - gneisses, schists, and greenstones. Gneisses are coarsely crystalline rocks that have parallel layers or bands of quartz and certain silicate minerals alternating with generally wider layers of black platy minerals like black mica or hornblende. They have resulted from the recrystallization of many kinds of parent rocks, and hence vary greatly in composition, but are always strongly banded and coarse-grained. Gneiss may be found in outcrops in the hill north of the sand pits in the Lower Vine Brook conservation area.

Schists, in contrast to gneisses, are typically fine-grained, strongly foliated, and composed of quite thin layers of such platy minerals as the micas, amphiboles, and chlorites.

Greenstones result from the alteration of fine-grained volcanic rocks like ancient basaltic lava and associated ash. In natural outcrops they are likely to show strong spheroidal weathering and a tendency to crumble readily. Serpentine is a familiar greenstone widely used for corridors and hallways in large public buildings.

Examples of the rock types mentioned in the preceding paragraphs can be seen in cuts along Routes 2, 2A, and 95 (128). Observe the rocks as a companion drives through the road cuts as slowly as possible. Route 2, as it ascends Belmont Hill from the Boston Basin and farther out as it approaches the Waltham Street exit, is a particularly good location. So is Route 95 (128) between Routes 2 and 3 in the Lexington - Burlington area.

Better still is to get maps of the town of Lexington and the surrounding towns, a copy of an elementary book on rocks, some companions who are also enthusiastic "rock hounds" and go hunting in the recreation and conservation areas of our town. (Rocks and Rock Minerals by Pirsson and Knopf is an excellent book. Never mind that it was published a long time ago; the contents are still valid.) Join the happy ones that Sir Walter Scott described long ago in his St. Ronan's Well (1824) as follows:

> "... and some rin up hill and down dale,
> knapping the chucky stanes to pieces wi' hammers,
> like sae mony road-makers run daft --
> they say it is to see how the warld was made!"

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GLOSSARY

Amphibole - One of a group of closely related minerals which are complex hydrous silicates containing calcium, magnesium, and iron. The crystals are often long or needle-like and sometimes are fibrous. Hornblende, actinolite, and tremolite are amphiboles. The amphiboles are similar to the pyroxenes.

Amphibolite - A metamorphic rock containing mostly amphibole and plagioclase feldspar.

Ash bed - A layer of material that originated from small particles (less than 4 millimeters in size) that were ejected from a volcano.

Basalt - A fine-grained, dark, dense igneous rock. It is formed from lava and is very common. Basalt is mainly pyroxenes and plagioclase feldspar but the individual crystals are usually too small to be noticed.

Chlorite - A mineral (or group of very similar minerals) that is composed of hydrous magnesium and iron-aluminum silicates. It is usually green.

Delta - Deposits formed in a lake or sea from material carried by a stream or river.

Dike - Sheetlike intrusions which typically cross layers of the rock which has been intruded. The intrusions were formed from magma seeping into cracks.

Fault - A sheetlike fracture in the earth's crust along which there has been or may be relative motion of the two sides.

Feldspar - A group of minerals which are very common. They are all aluminum silicates combined with various metals. The potassium-containing feldspars (orthoclase, microcline) are classified separately from the feldspars that contain sodium or calcium (plagioclase feldspars).

Ferro-magnesian mineral - A mineral which contains iron, magnesium, or both.

Foliate - Having a planar or wavy sheetlike structure. This type of structure is found in metamorphic rocks more often than in igneous rocks.

Hornblende - A dark green to black mineral which is one of the amphiboles.

Hydrous - A term used to indicate that water molecules are chemically incorporated into the structure of a mineral.

Granite - A coarse-grained igneous rock containing quartz, feldspar, and dark minerals (frequently mica).

Igneous rock - A rock formed by crystallizing or solidifying from a molten state.

Loam - A type of soil containing a mixture of sand, silt, clay, and organic matter. This is the type of soil that is good for agriculture.

Magma - Molten rock which is below the ground. (Molten rock which is above ground is termed lava.)

Metamorphic rock - Rock which has been altered without being melted. Heat, pressure, and deposition of dissolved minerals are agents of metamorphism.

Mica - One of a group of minerals which can be cleaved into thin flexible sheets. They are composed of aluminum silicates with other metals.

Moraine - A deposit of debris that was collected and left by a glacier.

Plagioclase feldspar - A feldspar which contains sodium or calcium chemically combined with aluminum silicate.

Plate-tectonics - The study of the motions of rigid pieces of the earth's crust (i.e., plates) and the results of those motions.

Pleistocene Epoch - The time period defined geologically from layers or fossils in rocks and which extends from 2 million to about 10,000 years ago. This time interval is commonly referred to as the "ice ages".

Plutonic rock - A rock which solidified from a magma far below the surface and cooled slowly so that large crystals were able to form.

Porphyry - A rock which contains large crystals of one type of mineral imbedded in a finely-grained mass of other minerals.

Pyroxene - A group of closely related minerals which are complex silicates combined with calcium, magnesium, iron or other metallic elements. They are similar to the amphiboles but the silicates are not hydrous in the pyroxenes. The pyroxenes frequently have a needle-like or fibrous structure.

Quartz - A very common mineral consisting of crystalline silica (a chemical combination of silicon and oxygen: SiO_2). Sand usually consists mostly of quartz grains. Many kinds of rocks contain quartz and there are a number of forms of quartz which are semiprecious gems (e.g., amethyst).

Sediment - Loose material, such as gravel, sand, silt, or clay, which has been deposited or accumulated at some location. When sediments are bound into a solid mass, sedimentary rock has been formed.

Silt - Loose sedimentary material with a particle size intermediate between sand and clay.

Spheroidal - Having a shape almost like that of a sphere.

Strike - The compass direction of the line which is the intersection of a horizontal plane with a fault plane (or other kind of plane).

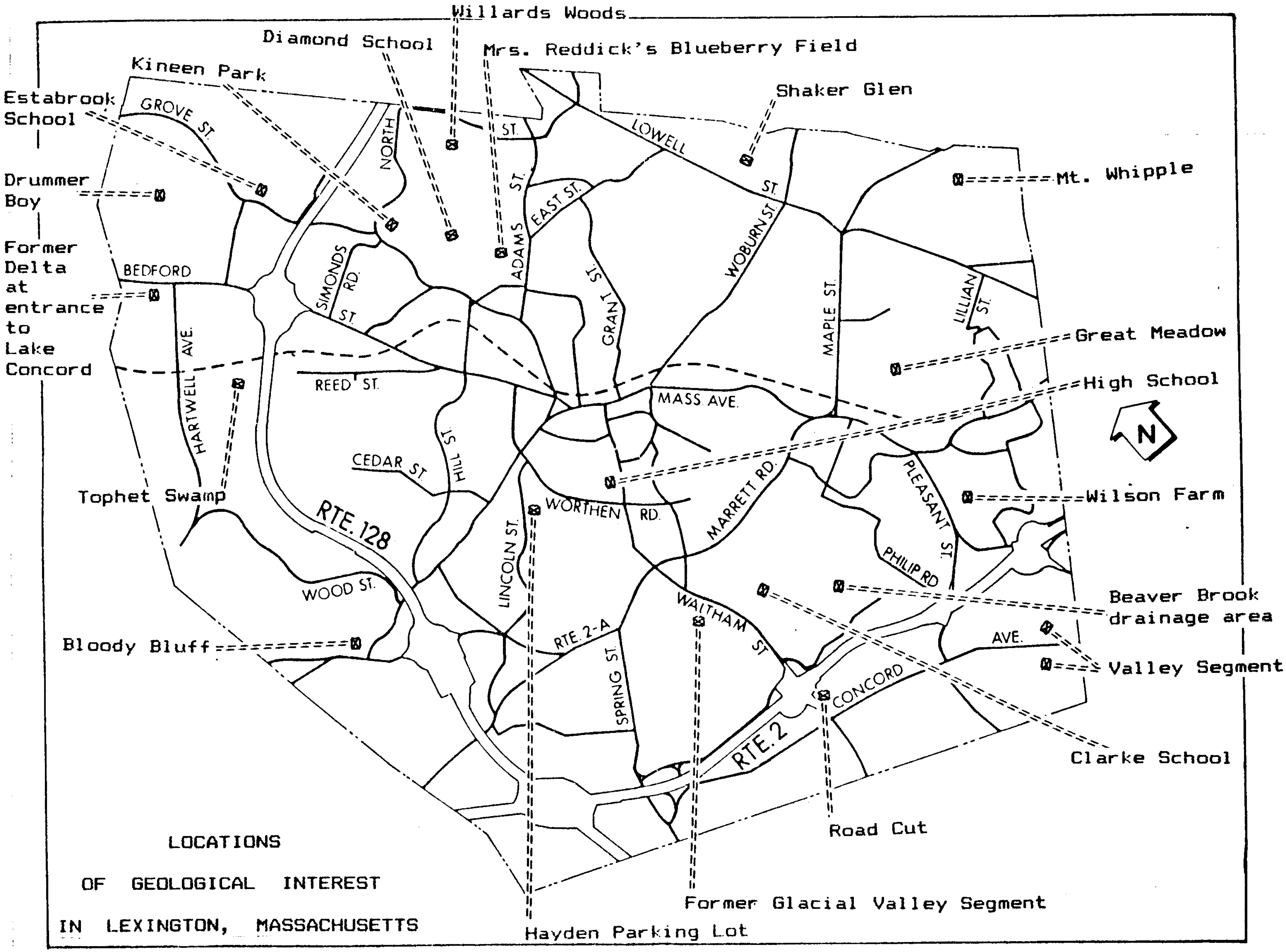
Terminal moraine - A moraine left by a glacier along the line of its furthest advance.

Topography - The shape of the earth's surface (i.e., the heights of features as shown on a map) and distribution of important surface features (such as rivers, lakes, etc.).

Tuff - A fine-grained rock formed from consolidated volcanic ash and dust.

Unconsolidated material - Material consisting of loose particles that are not bound into a solid mass.

Volcanic rock - Rocks which formed from molten material on or above the surface of the earth.



LOCATIONS

OF GEOLOGICAL INTEREST

IN LEXINGTON, MASSACHUSETTS