Planning Board

GEOLOGY

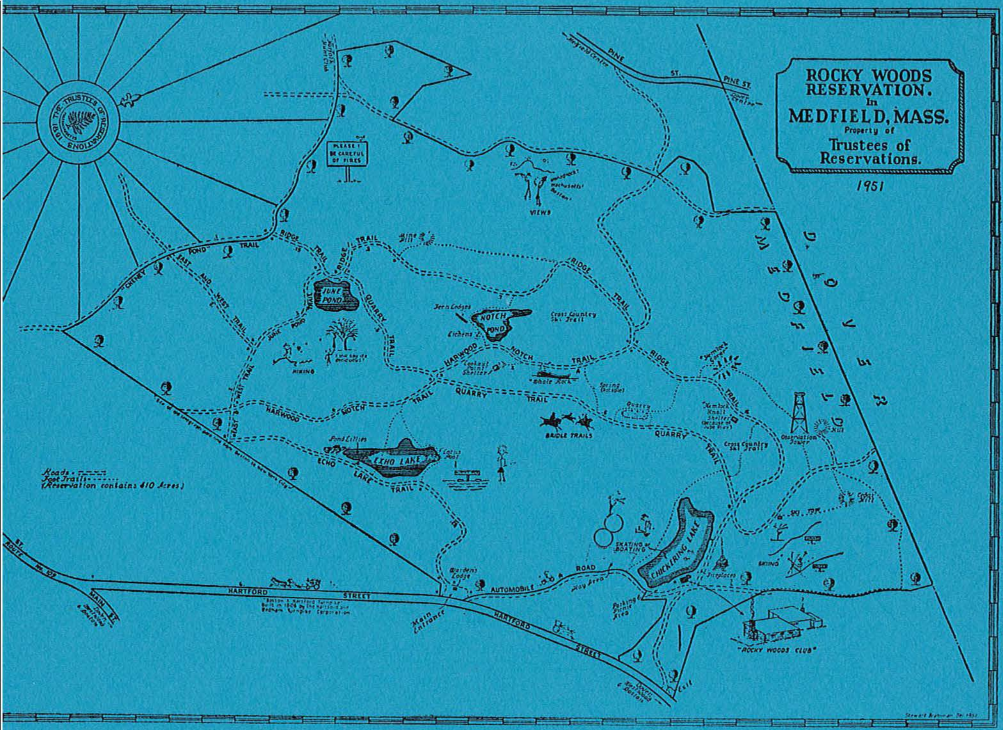
of

ROCKY WOODS RESERVATION

By HERVEY WOODBURN SHIMER

Professor Emeritus of Paleontology

Massachusetts Institute of Technology



Map showing location of Rocky Woods Reservation, Medfield, Massachusetts

The Standing Committee
of
The Trustees of Reservations
dedicates this monograph
to
DR. JOEL E. GOLDTHWAIT
the donor of Rocky Woods

GEOLOGY OF ROCKY WOODS RESERVATION

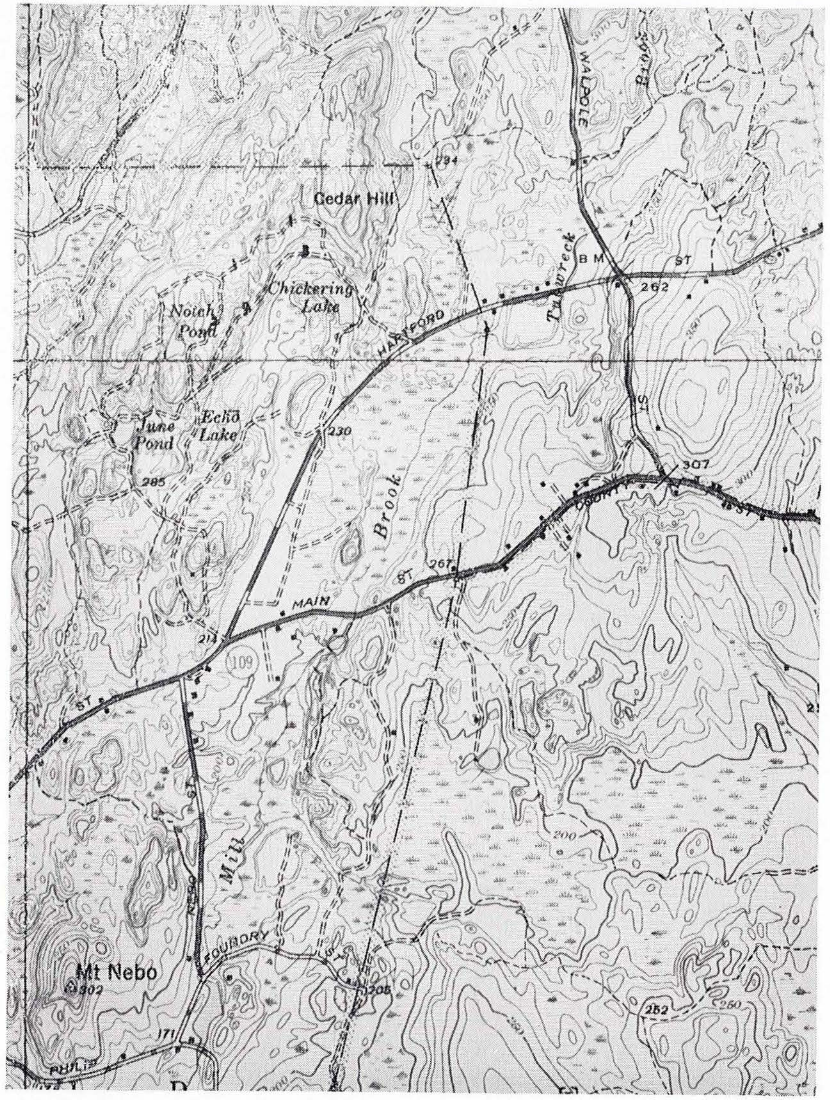
by
HERVEY WOODBURN SHIMER
Professor Emeritus of Paleontology
Massachusetts Institute of Technology

CONTENTS

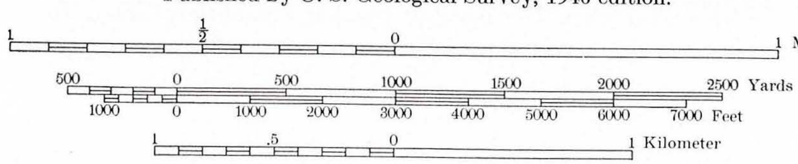
INTRODUCTION

Hills and valleys, streams and meadows, bring delight to the eye, but seldom do they arouse questions about their origin. Landscapes are taken for granted as permanent features of the earth's surface, mysteriously formed and unchanging, somewhat as we think of the earth and sun, moon and stars, as part of an eternal setting. We usually give their origin no thought, just as a child gives no thought to the origin of his home and parents; he takes them for granted. To an adult mayfly, a leaf is likewise a permanent structure, never changing during the observer's few hours of life. To see both landscape and leaf as temporary features in an unending sequence of events requires a long viewpoint. It is man's privilege to acquire such a viewpoint by observation of the forces that are at present modifying the surface of the earth, and whose similar activity through past ages is recorded in hills and valleys and ocean beaches, in sandstones and shale and volcanic rock.

Man may observe the slight changes which are constantly occurring, a new gully on a hillside, a layer of sand upon a meadow. After each rain



The part of the Medfield Quadrangle which contains Rocky Woods Reservation. Published by U. S. Geological Survey, 1946 edition.



Contour interval 10 feet
Datum is mean sea level

the muddy water of streams is evidence of land removal to lake or sea. Taken singly, these events seem trivial, yet the relentless attack of frost and rain, of wind and waves, is remodelling through the years the landscape before our eyes. Geology shows us that all landscapes are evanescent. When, as through a telescope, we look back at the changing earth through the geologic eras, we see that "they melt like snow, these solid lands."

The slow wearing away of the land into the sea, is, however, only a part of the great cycle of the unending making over of the earth's surface. It includes erosion of rocks, the deposition of the resulting sands and muds by rivers and waves, their hardening into a new succession of solid rocks, which in their turn are pushed up into mountains by the restless forces inside the earth. To quote Tennyson again on mountains, "Like clouds they shape themselves and go." Such are the events which through millions of years have made over the surface of the earth.

Climate, too, changes. In the geologically recent past, vast ice sheets covered New England, and the walrus lived off the shore.

And on this always changing surface of the earth, on these contracting or expanding sea beaches, on the hills or low-lying plains, living forms of plant and animal took the places to which they were adapted.

As a "coat of arms" indicates various ancestral activities of the House, so the surface of any part of the earth, with its varying rocks and included fossils, is a "coat of arms", giving evidence of its past history.

We need to be reminded once in a while of the fact that, in addition to our troubled social world, we live just as truly and as inescapably, in a natural world of rocks and herbs and trees, of birds and animals. The maintenance of a normal mental outlook on life is difficult, and we must leave our business at intervals for the stimuli of other lines of thought. Essays, histories, poetry, music, all contribute to enlargement of horizon and the stability of our life philosophy. But in these there are still lacking certain mental stimuli. Because of our heredity we must at times renew our physical and mental contact with nature, with growing things in gardens or on walks in woods, amid which man has lived for a million years. "The groves were God's first temples."

In Rocky Woods there are many facilities for this physical, mental and ethical communion. Here are hills for physical exercise, rocks and trees, shrubs and herbs, birds, and lakes with their life, for mental stimulus, and the quintessance of all these for quiet meditation.

THE EARLIEST PICTURE OF THE REGION

A knowledge of the history of this upland will aid our appreciation of its form, its composition and its life. We then see its present appearance as a temporary structure in its long, ever-changing existence; a single picture in a moving film, which extends many millions of years into the past and will continue for an untold number of years into the future. More than two thousand years ago, the philosopher Heraclitus observed that nothing in this world is stable; everything changes. We see this readily in society and language. In the physical world the changes usually occur much more slowly. We recognize lakes as temporary structures being filled by wash from the land and by plant growth. The hills are lower today than last year through the action of wind and rain.

Our earliest picture of the Rocky Woods region is of high mountains. Such mountains extended over all of eastern Massachusetts. They were the results of a slow process which had probably occupied a million or more years. Far within the earth, the slow-acting forces of heat and pressure had gradually upheaved this region. We may see such a slow action of these unquiet forces within the earth today disturbing the Pacific coastal region of North America. Under increasing heat the matter of the earth's interior had melted and squeezed its way upward, gradually cooling as it came within four or five miles of the surface. Such gradual cooling allowed the elements of the molten mass to crystallize. The result was the coarsely crystalline rocks which now form the heights of Rocky Woods, as well as the basement rocks of all eastern Massachusetts. Whether volcanoes rose in this region from that hot mass to the surface, with a consequent outpouring of lavas, is not known, as all of the rocks above these basement ones have long since been eroded away. Surely, "the hills are shadows, and they flow from form to form, and nothing stands."

ESTIMATING GEOLOGICAL AGE IN YEARS

According to the Uranium clock, our picture was of a scene that existed some 400 million years ago, during what geologists call the Ordovician Period of earth history. While there are various methods for estimating the age of the earth in years, the one usually considered the best is derived from a study of the disintegration of radioactive minerals, especially those containing uranium and thorium. These minerals are formed in some igneous rocks upon their cooling. In radioactivity, transformations take place only from an element of higher to one of lower atomic weight. Both these elements pass through a series of successive stages during their disintegration, which terminate in an isotope of lead. The rate of this movement in nature does not change. It takes six billion years for half

of a mass of uranium to become lead. The order and rate of this disintegration are known with a high degree of accuracy, so that a determination of the amount of the isotope of lead present in the minerals containing uranium makes it possible to determine with some degree of certainty the time when disintegration began. In the present state of knowledge this method can be used only for periods measuring millions of years.

For the most recent period of earth history, the Pleistocene or Glacial Period, especially its last portion, we wish to know the time in years instead of in million of years. For the last 7,000 years man has recorded in writing on clay and stone, on wood and paper, something of his activity and his surroundings. Further knowledge of this time is obtained from the annual growth rings of trees. The variations in the thickness of these annual rings give indication of the weather at the time of their growth. A succession of thin rings indicates an arid cycle, and the opposite, a series of wet years. There are living trees whose life covers over half of this span, humanly long but geologically short. The Tule Cypress near Oaxaca in southern Mexico and several Giant Sequoias in California are estimated to be over 4,000 years old. Studies have been made of the growth rings of trees in various regions, and these records have been linked up, by means of the record of dry and moist cycles, with timbers in long deserted dwellings.

Knowledge of the weather of successive years has been extended back very much farther by studying the varying thickness of glacial varves. Varve is the name given to the layer of mud or sand deposited in a lake during a single year. Varves in glacial lakes vary in thickness according as the season was warm or cold. When warm, the glacial ice would melt more rapidly and the water would carry more sediment to be deposited, making a thicker varve than would be the case during a cold summer. The Swedish geologist deGeer and others have counted the number of varves in the succession of old glacial lakes, from the southern limit of the last glacial advance in northern Germany to the present small ice-cap in north central Sweden. In this way it has been found that about 25,000 years have passed since the glacier began melting back. This number of years is indicated for the melting back of the ice sheet in North America, and is confirmed by the rate of erosion of such gorges as that of the Niagara.

The pollen and other plant material that fell on the lake deposits and thus became trapped in the varves, record the kinds of vegetation of those early times. From these it is seen that the conifer and tundra zones moved southward at intervals, conforming to the minor advances of the retreating ice sheet. These facts have been linked in turn with remains of the presence of man and his varying activities. Thus has been built up a somewhat detailed knowledge of the last 25,000 years of the Glacial Period. This is about the length of time that man has been cultivating food, but only a fraction of the million years that man has been living on earth. The data for the earlier part of the Pleistocene is found in regions south of the glacial advances, such as southern Europe and Asia and northern Africa.

THE ROCKY WOODS RESERVATION

The height of land known as the Rocky Woods is an uneven ridge trending from northeast to southwest. The higher hills, of over 400 feet elevation, are of solid rock and are mostly in the northern part of the Reservation, north of the Quarry Road. From here they descend to 300 feet and less at the southern boundry. The central and southern parts of the Reservation consist usually of loose glacial material, though ledge rocks occur at intervals. Glaciers have carved this southwest trending Rocky Woods ridge into north-south minor ridges, with intervening valleys. The lower parts of these valleys became swamps upon the melting away of the glaciers. Several of these swamps have been artificially dammed, and now form such north-south trending lakes as Echo Lake, Chickering Lake and Notch Pond. Notch Pond at 360 feet elevation is the highest lake in the Reservation; Chickering Lake is 230 feet. The ridge of higher land to the west of Quarry Road forms the drainage divide between the Charles and the Neponset Rivers. Notch Pond empties into the former, Echo and Chickering into the latter.

ROCKS IN THE RESERVATION

Within Rocky Woods there are two types of ledge rock. Both are igneous, that is, they have been consolidated from a molten state. Because their crystals are large enough to be seen by the naked eye both types of rock have been popularly called granites. Neither, however, is a true granite. The lighter colored rock is the Dedham granodiorite. It is pink on fresh surfaces and brown on weathered, and closely resembles granite except that it contains more soda-lime feldspar (plagioclase) and less potash feldspar (orthoclase). Its minerals are gray vitreous quartz, white and pink feldspars, and small amounts of black mica (biotite). Its texture is rather uniform throughout the Reservation.

The dark colored rock is the Salem gabbro-diorite. It varies in composition between a gabbro and a diorite. It is a dark greenish-gray rock composed principally of a gray feldspar and the black iron mineral hornblende. It varies in texture and in the relative abundance of these two minerals, often within a few inches. This rock is often intruded by

dikes or irregularly shaped masses of the granodiorite, which shows that it had solidified before the granodiorite invaded it.

Cedar Hill, north of Ridge Rock, 400 feet north of its junction with Quarry Road, is composed of a fine-grained phase of the gabbro-diorite. The rock at the Shelter, off Ridge Road, is the granodiorite, while north across the road from this we see the granodiorite invading irregularly the coarse-grained gabbro-diorite. At the Shelter off Harwood Notch trail is a finer-grained phase of the gabbro-diorite, while on the west side of the trail south of Notch Pond is another good exposure of the granodiorite.

Both kinds of rocks in the Rocky Woods are made up entirely of crystals visible to the naked eye; there is no uncrystallized ground mass. In the lavas poured out from volcanoes upon the surface of the earth, the cooled rock is all ground mass; there are no crystals as the rock has been cooled too quickly for them to form, and the chemical substances have not had time to arrange themselves in the liquid mass according to their affinities. The deeper within the earth that the cooling takes place, the slower is the cooling, and hence the longer is the time during which the substances in solution may arrange themselves according to chemical affinity. The resultant solid rock is made up of crystals with definite faces and angles. Observation of such crystalline rocks in many places over the earth indicates that the cooling must have taken place at least a mile beneath the earth's surface, and, more usually, four or five miles. The mountains, here, however, need never have been as high as that at one time. More probably, judging by the existing mountains of the earth, they received renewed uplifts at widely separated intervals, during all of which time they were subject to weathering and erosion. However, a corresponding thickness of rock must have been carried away from above the present exposures, which now form the surface rocks in large areas in southeastern Massachusetts.

THE WEATHERING OF ROCKS

The removal of these miles of rock took place under the ordinary processes of weathering which we see around us today, the laws of which are well known. As Bailey Willis says, "In the laboratory of the Master, no reaction occurs except according to law."

We see such weathering taking place now in the Rocky Woods section in both kinds of rocks. Since rocks radiate heat more rapidly than does the air, their temperature at night usually falls so low that the air in contact with them cools below its saturation point. The moisture thus condensed from the air, called dew when it is deposited in the liquid form and hoar frost when deposited as a solid, naturally contains a varying amount of free oxygen and carbon dioxid. These gases are likewise present in rain and other water at or near the surface of the earth. They enter into various chemical combinations with rocks in the processes called oxidation and carbonation, which gradually break up the solid rocks into innumerable small particles. Oxygen is especially noteworthy for its tendency to unite with the iron minerals, causing them to crumble away into red or yellow particles, while carbon dioxid unites with the lime of various minerals, forming lime carbonates. Water sometimes unites directly with minerals in a process called hydration, bringing about the formation of new minerals, with a consequent increase in volume. A familiar example is the mineral limonite, well known by its reddish yellow color. In the Rocky Woods this color, derived from the oxidation and hydration of such minerals as biotite and hornblende, is conspicuous in surface weathering and along seams. It has been estimated that a granite rock converted into soil is increased 88% in volume, largely as a result of hydration.

Rapid changes in temperature also tend to break up a rock, while the entrance of water into cracks thus formed, and the subsequent freezing tend to disrupt it further, giving the water still freer access to the rock, where it brings about additional chemical effects. In this manner the solid rocks at or near the surface of the earth become gradually broken up into finer and finer particles, with the resultant production of much soil and subsoil. This is then removed from heights and sloping surfaces by wind and rain and gravity.

The surface of the United States is being removed at the rate of thirteen ten-thousandths of an inch a year, or one inch in 760 years, according to the United States Geological Survey. Though this amount seems trivial in any one area, it becomes stupendous when considered as a total; for over 270,000,000 tons of dissolved matter and 513,000,000 tons of suspended matter are transported to tidewater every year by the streams of the United States. This total of 783,000,000 tons represents more than 350,000,000 cubic yards of rock substance or 610,000,000 cubic yards of surface soil. If this erosive action had been concentrated upon the Isthmus of Panama it would have excavated the prism for an 85-foot level canal in about 73 days.

EXFOLIATION This is an interesting type of weathering occurring in certain kinds of rock. When the sun shines on a bare rock, its surface is heated and hence expanded more than are the parts beneath the surface. Thus strains are set up between the expanded outer portion and the cooler and hence less expanded inner parts. This expansion and the later contraction brought about by the cooler night air, or even by the passage of a cloud, causes minute cracks to form in the more brittle of the rock crystals, into which

either gases or water may enter, bringing about chemical decay and further expansion. The result is the development of surface layers that look like onion peels. In the rocks of the Rocky Woods these layers are usually from one eighth to one half inch thick. They may be seen on the Whaleback Ledge, especially on its southern end, and on various boulders throughout the Reservation.

FORCES WITHIN THE EARTH

Since the forces at the surface of the earth tend continually to carry all land beneath the surface of the ocean, the very existence of any land is dependent upon its being uplifted from time to time. Otherwise, the ocean would, in a geologically short time, cover the entire earth. The cause of such uplift resides within the earth itself.

Just as the forces at the surface of the earth originate in externally derived heat, gravity, and the revolution of the earth upon its axis, so, similarly, the source of the forces within the earth is internally derived heat, gravity, and possibly the axial revolution of the earth. The internal heat is at least partly due to radioactivity. For example, one gram of radium emits sufficient heat each hour in its disintegration to raise the temperature of 100 grams of water 10 degrees centigrade.

As the forces at the surface initiate the evolution of winds, of rain and of streams, with all their consequences, so the forces within the earth initiate the development of earthquakes and volcanoes, of mountains and plateaus, of continents and ocean basins.

Unlike our knowledge of the work of the forces at the surface of the earth, what we know of the interior and of the forces there active must be largely indirect. It must depend upon facts observed in rocks once deeply buried and now exposed at the surface through long erosion, upon the varying behavior of earthquake shocks as they travel through different portions of the earth, upon the comparative densities of various parts of the earth, upon the characteristics of the deeper rocks when poured forth upon the surface in a molten state. Facts thus obtained must be interpreted in the light of our knowledge of matter derived from field and laboratory experiments. For example, when the geologist is looking for evidence of yielding under stress differences, his examination of the earth is like an engineer's examination of a bridge. Each man is comparing the present condition with an earlier, simpler, unstressed state. When the engineer sees rivet heads pressed off, surfaces scaling, and changes in microscopic structure, he is certain that the bridge has passed through a period of stress. Similarly, when a geologist finds cracks, such as joints and faults, rock beds that must have been originally horizontal but are now closely folded, and parallel arrangements of crystals as in slates and schists he concludes that at least the outer portion of the earth has passed through periods of stress.

HISTORY OF ROCKY WOODS UP TO THE GLACIAL PERIOD

The majority of geologists place the intrusion of the Salem gabbro-diorite and the Dedham granodiorite during the Ordovician, over 400 million years ago. It was a time when much of New England and Quebec was subjected to severe mountain-making disturbances. Since that time New England has been uplifted several times and partially or completely worn down to a plain after each uplift. The Rocky Woods region could not help being affected by such widespread uplifts.

To continue this outline of history,—there was an uplift that formed mountains, probably during the late Devonian, about 300 million years ago, and deep within their base was intruded the molten matter which cooled to form the Quincy Granite. This is now seen in Quincy and the Blue Hills. Rocky Woods is so near this area that it, too, must have been uplifted by the formation of these mountains, as it was, likewise, by the great mountain-making period at the end of the Paleozoic Era, about 200 million years ago, which changed the altitude of all eastern North America. Again, 50 million years later, at the end of the Triassic Period, all central and eastern Massachusetts was uplifted. At this time were poured out such lava masses as now form Mounts Tom and Holyoke.

During the remainder of the Mesozoic Era, that is during 100 million years, all of eastern North America was worn down to a level plain, but at its close, 60 million years ago, it was elevated into a plateau many hundreds of feet high. The elevation brought about the rejuvenation of the rivers upon this broad plain, and they continued to deepen and widen their valleys until today we may get a general idea of the height of this old Mesozoic plain only in the crests of such mountains as the Green Mountains, the White Mountains, the Blue Ridge, and the Appalachians. These are merely the harder rocks in interstream areas of the old plateau, not yet worn away. At the beginning of the Pliocene, some 50 million years later, there was an uplift of several hundred feet. Again the rejuvenated streams began to deepen their valleys, but during the six million years of the Pliocene, the streams had time to sink only comparatively narrow valleys in these hard rocks, up to the time when most of northern North American, including New England, was overrun by glaciers.

Because of these various uplifts of the land and the consequent periods of erosion, the granitoid rocks of the Rocky Woods region, which

had been intruded deep within the earth, now form the surface rocks.

At the beginning of the Glacial or Pleistocene Period, about one million years ago, the landscape had much the appearance that it has today, except that much of the drainage pattern of that time has been obliterated by the later glacial deposits.

DEVELOPMENT OF GLACIERS AND THE GREAT ICE SHEET

Snow quickly passes from its original soft, loose, fleecy-white condition to a granular state, the névé, and thence to porous ice, and finally to solid bluish ice. An early stage of névé is well seen in remnants of snow banks in spring. Snow flakes are white because their crystals, formed of water vapor, are separated by air; soap bubbles are white for the same reason. As snow increases in thickness, the pressure expels some of the air between the snow crystals, the growth of the crystals expels more air and continues the process to solid ice.

As ice and snow increase in thickness the pressure between some ice crystals will finally produce sufficient heat to cause melting at the points of exceptional pressure. The water thus formed will flow, usually down the slope, to regions of less pressure, a fraction of a millimeter distant, and there freeze again. In freezing it expands and hence exerts a pressure upon the surrounding ice. Water in freezing expands one tenth of its original volume and exerts a pressure of 150 tons to the square foot. The result of an innumerable succession of such expansions is to push the ice down the slope. In this way movement of the entire ice mass takes place from regions of greater pressure to those of less, that is, down the slope of the land. Since the melting of only minute particles occurs at any one time, the ice remains solid, rigid, brittle and crystalline at all times.

At the beginning of the Pleistocene the climate of the earth became colder. Although the resulting average temperature was probably not more than nine or ten degrees lower than at present, yet the heat of summer was no longer sufficient to remove the snow which fell in winter in the northern latitudes. The Great Ice Age had begun. In eastern North American the center of snow accumulation was southern Labrador and northeastern Quebec. Thence the ice moved north, east, south and west, but mainly southward, since at that time as at present the greatest supply of moisture came from the south and east. This great southward moving ice sheet was similar to but larger than that which covers Greenland today. On the surface it was level, with a southward slope, but on the under side it conformed to the topography of the land surface which had been carved in pre-glacial time.

Since the snow as it falls partially surrounds many rocks and is frozen fast to projecting points of others and to the soil, it naturally carries this attached material with it when it begins to move forward as a glacier. As it moves, the pieces of rock which project from the base of the glacial ice, in which they are held as in a vise, scrape and grind the rocks over which they pass, thus still further deepening the valleys and adding to the fragments which are being transported. The solid rock floors and sides of the valleys are thus grooved and striated by boulders and pebbles, and polished by sand and rock powder. Such glacial striae and groovings are parallel and show the direction of glacial movement. They are present everywhere in New England where the solid rock has not weathered too deeply since the melting of the ice sheet. The rocks of the Rocky Woods region weather easily, so that the striae on exposed rocks have been largely obliterated. Where the soil has recently been removed from the bed rock such markings show up best.

Where the glacier was even only a thousand feet thick, as it probably was in this locality, the weight on the underlying rock was as much as 30 tons on each square foot.

At times a mass of bed rock would prove more resistant to glacial ice than did the surrounding area. The force of the southward moving ice sheet would shove the ice up over such a solid obstruction, which would be unnoticeable upon the surface of the glacier, a thousand or more feet above. As the ice was pushed over this obstruction it would smooth the rock on the side of approach and pluck off fragments and even huge masses when jointed, from the opposite side, leaving that rugged and at times more or less vertical. Whaleback Ledge, off the Harwood Notch trail is a small example of this action; such minor examples of glacial action are called roches moutonnées. Cedar Hill and the height lodging the shelter off the Ridge Road show the movement of the glacier at their sides and glacial plucking at their southern ends.

GLACIAL DEPOSITS

The work of the great ice sheet was two-fold. (1) It removed all the soil and soft rock, and rounded and polished the ledges of solid rock, and (2) it spread a series of deposits over the region. Whatever the glacial ice held as it moved down from the north it had to drop as it melted. This material was deposited in two ways,—either directly upon the solid rock beneath the melting glacier, or through the medium of streams running as melt water from the ice. These two processes are quite distinct and have resulted in two distinct types of deposits,—unstratified and stratified

When the material was deposited directly from the ice it was not sorted, but the boulders, gravel, sand and clay were heterogeneously mixed. This unstratified material is variously called till, boulder clay or ground moraine. In this grouping belongs all loose material within the Reservation except the superficial mud in the swamps. It is usually the first deposit upon the striated solid rock. When the material has been carried by water and then deposited, it has become, under the influence of gravity and running water, sorted to a greater or less extent, and is hence laid down in layers, that is, in strata. Deposits thus stratified include sand plains such as the flat area at the junction of Hartford and Main Streets. We thus see that the superficial soil and the subsoil, which extend down to solid rock, are transported material, due to the glacier. None of it in New England is to any degree due to the decay of rocks in place.

GLACIAL BOULDERS The loads of rock material (clay, sand, gravel, boulders) that the glacier carried came from varying distances. The larger boulders have usually been carried only a few miles. Many still angular masses have been moved but a few feet, as can be seen on the southern slopes of the hills in Rocky Woods. It is apparent that any angular boulders could in most cases have been transported only a short distance, since the unending action of the ice sheet, with its burden of sediment, is to round the angular fragments that it picks up and to grind them smaller. South of Quarry Road even the large boulders, which have been plucked from the heights north of the Road, have usually rounded corners. When a large boulder has been left stranded by the melting ice upon a narrowly rounded rock summit it is called a "perched boulder".

FOREIGN PEBBLES The rocks transported by the glacier from regions north of the Rocky Woods are of small size in comparison with those torn from the ledges within the Reservation. Yet in spite of their comparatively insignificant size, foreign pebbles and even small boulders of conglomerate and varieties of igneous rocks not occurring in place in the Woods but present north of the Reservation, may be readily found.

LIFE REENTERING GLACIATED LANDS

The earth's surface that a glacier has just abandoned is an absolute desert. To visualize this condition, imagine our hills with their boulder-strewn slopes, the valley floors of sands and muds, with no sign of herb or tree, no moss or fern. But, as may be seen in the wake of retreating mountain glaciers today, lichens and mosses soon begin to creep in over the rocks from spores carried by winds. Next the hardy ferns and flowering herbs take root, and, later, plants with edible fruits and seeds brought by birds and rodents. And still later, full conifer or deciduous forest of upland and lowland is in possession. The return of the resulting decaying organic matter to the ground and its fusion with the mud and sand left by the glacier and that resulting from later disintegration of the rocks, contribute to the making of soil.

Spores and seeds of the various plants would naturally grow best in the kind of locality to which their ancestors had adapted themselves. Thus we now find the Rock-tripe lichen (Umbilicaria pustulata) on the north side of rocks or on those shaded by trees. The same is true of the Polypody fern (Polypodium vulgare). Both of these occur in great abundance on cliffs near the outlet of Notch Pond. At this place also, in soil at the base of the rocks, occurs a profusion of other ferns. Upon the drier uplands some species of blueberries (Vaccinium) find a natural homeland, and on the rocky heights the evergreen Bearberry (Arctostaphylos uva-ursi) finds a congenial habitat. A widespread mat of this trailing, thick-leaved shrub occurs beside the Lookout Rock off the Harwood Notch trail.

In the lower lands, with a deeper and richer soil, the oaks, hickories, sassafras and dogwoods find a suitable environment.

The invasion of land and water mollusks, and of fish and earthworms, is rapid or slow according as the streams flow toward or from glaciated areas. Such slow rehabilitation of the glaciated lands persisted through the thousands of years during which the ice sheet slowly retreated from its maximum southward extension to its present remnants on mountains and in Greenland.

GEOLOGICAL CHANGES SINCE GLACIAL TIMES

Three fundamental forces have apparently been active upon the earth's surface from its beginning, some two billion years ago, to the present:

(1) The force of gravity, causing the earth to pull everything towards itself, that is, downwards. Hence rain falls upon the surface of the earth and the consequent streams flow down hill with their burden of weathered rock material.

(2) The energy of the sun, giving rise to winds and hence to waves. It brings about the evaporation of water, and hence the rain. It is essential to the growth of plants, which are in turn a necessary prerequisite to animal life.

(3) The revolution of the earth upon its axis, giving us night and day, the direction of the primary winds of the earth, its tides and ocean currents.

Many of the agents developed by these forces could not be operative upon the surface of the earth beneath the ice sheet, but as soon as this melted away, the agents of weathering, of rain and the consequent streams, of plant growth, and of waves, would again become active.

Weathering acts so slowly that it has accomplished little during the 25,000 years since the ice sheet melted away from this region. It has, however, roughened the polished surface of rocks, and, in places, has removed the glacial striae. Some iron has been removed from the solid rocks through the oxidation of the iron minerals; more has been removed from the soil, that is, from the surface layer of glacial deposits; for the finer the rock particles the easier it is for water and oxygen to alter them. This iron in solution, carried into ponds and swamps, is deposited as bog iron-ore (limonite). Such deposits are forming today, and comparatively large deposits of it were smelted by the early colonists.

Plant growth in many bogs and swamps has resulted in the formation of peat. This is a brown to black deposit of carbonaceous matter formed by the partial decay of moss, stems, leaves, etc., under a protective covering of water. In such a situation the decay or oxidation of plants is only partial.

Marshes and ponds are temporary features of the landscape. Many that the glacier left behind have become completely filled by sand and mud carried into them by streams. Their drainage has in many cases been aided by the lowering of their water level through natural down cutting by the outlet stream, or man may prolong the life of a pond or change a swamp into a lake by raising the outlet of the stream by means of a dam, as has been done in Rocky Woods.

Thus around us in Rocky Woods we see evidences of the unceasing activities which have modified the earth's surface for 400 million years. Coarsely crystalline rocks, cooled from molten material deep within the bases of mountains, now form the surface rocks. The slow wearing down of these mountains was followed by renewed uplift and further erosion, until not only were the successive uplifted mountains removed, but erosion had cut very deeply into the old, formerly molten mass itself, now cooled into the gabbro-diorite and the granodiorite. Our rounded hills of striated solid rocks, our soil, and all loose material of boulders and sands and clays, are due to the vast ice sheet which covered this region in the geologically recent past.

As Ulysses said after his travels, "I am a part of all that I have met", so, with equal truth, the lands of Rocky Woods could say, "We are part of all that we have met. Both the external forces of sun and rain and ice, and the internal forces of heat and pressure have left their impress upon us."

TABLE OF GEOLOGICAL EVENTS

Cenozoic (Began 60 million years ago).	Recent (Erosion and deposition of sediments). Pleistocene (Erosion of land and deposition of sediments by glaciers). Pliocene. (Uplift of land). Miocene. Oligocene. Eocene Paleocene (Uplift of land).
Mesozoic (Began 190 million years ago).	Cretaceous. Jurassic. (Uplift of land). Triassic.
Paleozoic (Began over 500 million years ago).	Permain (Uplift of land). Carboniferous. Devonian (Uplift of land). Silurian. Ordovician (Uplift of land and intrusion of gabbro-diorite and granodiorite). Cambrian.
Pre — Cambrian (Began about 2,000 million years ago).	

The successive uplifts of this region have raised the granitoid rock-masses (gabbro-diorite and granodiorite) from several miles beneath the surface of the earth to their present height. Throughout 400 million years the land above these granitoid rocks was subject to such weathering as is taking place on rocks now. So that by today, not only have these vertical miles of rock been worn away but erosion has eaten deeply into the granitoid mass itself. The uplifts of land and its erosion took place so slowly as to be unnoted by the life of the times.