St. Olaf College

Local Ecology Research Papers

The natural history of Manitou Heights

Nate Meyer

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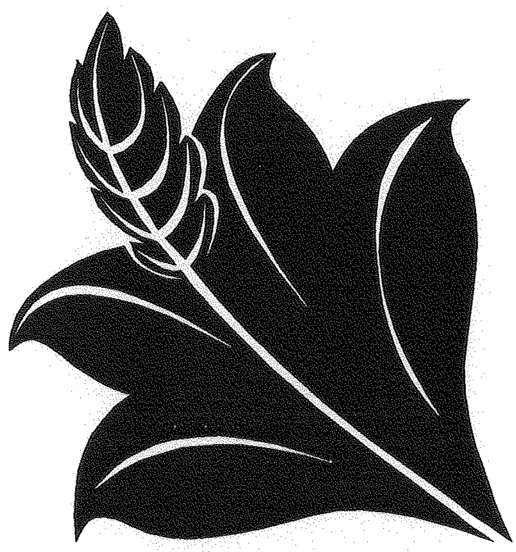
The Natural History Of Manitou Heights



Compiled By: Nate Meyer
Saint Olaf College
April 26, 1996

The Natural History of Manitou Heights: A Short Overview

Compiled By: Nate Meyer

Today, Manitou Heights is the lofty perch of Saint Olaf College. The hilltop is covered in green grasses, coniferous and deciduous trees, web-like concrete walkways, and white limestone buildings. It is home to thousands of book-lugging students, nut-gathering squirrels, masked raccoons, red-breasted robins, screaming blue-jays, glistening salamanders, and many others. Over the rim of the hill, asphalt streets stretch to the buildings of Northfield, I-35, and Apple Valley. During spring and summer, black patches of dirt, golden prairies, deep-blue wetlands, and green forests spread over the landscape. In winter, there is a vast expanse of pearly-white snow. Yet, this place has not always held its present form.

Ask yourself, how and when did Manitou Heights actually develop? This answer lies in a tale that stretches across billions of years. However, three parts of this tale are particularly interesting and important. For the next few pages, I would like to focus on the stories contained in the underlying bedrock, the topographical relief, and the native trees of Manitou Heights.

The Bedrock:

The bedrock, buried a few meters underneath the sidewalks and soil of the hill, tells a watery tale. It begins about 550 million years ago, when the interior of the North American continent began to subside. This allowed the oceans to transgress inland about one kilometer every 100,000 years. Eventually, water slowly poured across this area from a lowland, called the Ancestral Forest City Basin, in eastern Iowa. Manitou Heights was submerged in a northern extension of this basin, called the Hollandale Embayment, that covered much of southeastern Minnesota and southwestern Wisconsin.

For over 100 million years, warm, tropical seawater sloshed over this landscape. In fact, Manitou Heights actually resided a short distance *south* of the equator at that point! The water probably never rose above 100 meters deep, and fluctuated over time. Moreover, numerous plants and animals inhabited these shallow, equatorial seas. When the bedrock under Manitou Heights formed, lime-secreting algal seaweed was sprouting from this landscape. Straight-shelled cephalopods, related to the nautilus and octopus, dominated the diverse fauna. Some of these animals constructed cone-shaped shells as large as 3-4 meters long and .3 meters in diameter. Other notable animals included thick-shelled trilobites, bi-valved brachiopods, gastropods, bryozoans, crinoids, horn corals, and tiny conodonts (Fig 1). Animals from every phylum except vertebrates lived in these ancient seas (Matsch and Ojakangas 1982, Schwartz and Thiel 1976, Austin 1972, Webers 1972).

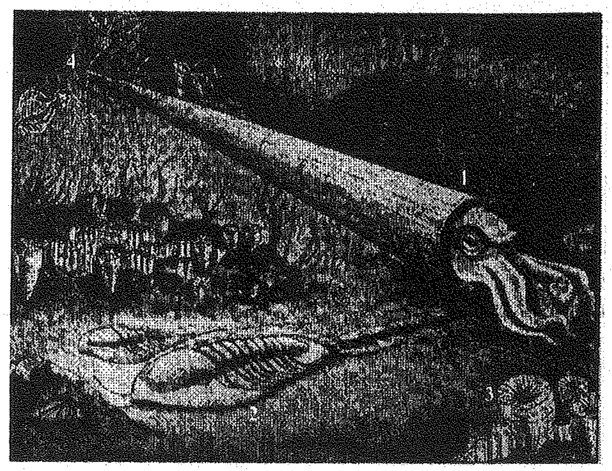


Fig 1: Panoramic view of Ordovician sea floor. Pictured animals include 1) cephalopod, 2) trilobite, 3)horn coral, 4)crinoid. (From Matsch and Ojakangas 1982.)

Detritus, eroded from exposed lands along the edges of the embayment, continually washed into the shallow water, and settled over this landscape. These sediments piled up, buried the remains of dead organisms, and lithified to form layer after layer of fossiliferous sedimentary rock. The bedrock underlying Manitou Heights contains a number of strata deposited at a relatively late point in this timeperiod. Specifically, these strata comprise the St. Peter Sandstone, the Glenwood Formation, and the Platteville Formation. They reflect a fluctuation in the water that covered this area (Mossler 1995, Austin 1972, Thiel 1944).

The well-rounded, white quartz grains of the St. Peter Sandstone settled on a beach when the shoreline of the embayment was close to Manitou Heights. The Glenwood Formation, which lies on top of the St. Peter, includes a basal layer of sandstone followed by a layer of shale. These strata were deposited as transgressing seas pushed the shoreline farther from this area.

The Platteville Formation, which caps these strata, marks the peak of this transgression. It was contains three layers of limestone that formed as calcium carbonate precipitated out of deep water far from the shoreline. Consequently, the Platteville Formation reflects environmental conditions much like the widespread carbonate bank that presently lays offshore of the Bahamas. The lower layers of this limestone comprise some of the most fossiliferous rocks that ever lithified in the inland seas. There is also a layer of bentonite clay within the Platteville Formation that formed when ash from a volcanic eruption rained down upon the water covering Manitou Heights, and settled over this landscape. This eruption caused widespread death of the flora and fauna inhabiting the area. Presently, pieces of St. Peter Sandstone can be found strewn across the slope behind Kildahl and Rand halls. I have also found pieces of Platteville limestone in the restored prairies north-northwest of campus (Matsch and Ojakangas 1982, Austin 1972) .

The Topographical Relief:

The story contained in the topography of the Manitou Heights begins long after the inland seas retreated from this area. At the beginning of this tale, the landscape had been exposed to the forces of weathering and erosion for over 400 million years. Plants and animals spread onto the land. Mammals and flowering plants evolved. Manitou Heights had moved north of the equator, and climactic conditions had become more temperate. But, the hill had not attained its present relief. Indeed, this lofty perch was refined during the most recent ice age.

Within the past 1.6 million years, climate reversals periodically "chilled" North America. During these intervals, average temperatures dropped, and the Laurentide Ice Sheet spread outward from the highlands of Labrador west of Hudson Bay. The immense glaciers (possibly over 1000 meters tall) plucked up rock and soil as they slowly flowed over the continent. They flattened hills, and gouged deep **U**-shaped valleys. Powerful streams, fueled by meltwater, shot from the edges of the glacier, cutting the landscape with swift currents and clastic sediments. When the climate warmed, the ice sheets retreated, dumping quantities of drift (crushed rock), creating moraines, lakes, and other topographic features that disclose their path. Plants and animals, including mammoths, mastodons, saber-toothed cats, giant beavers, ground sloths, and others, followed the melting glaciers, re-colonizing the barren ground (Fig 2) Slow weathering and erosion shaped the exposed landscape (Matsch and Ojakangas 1982, Bray 1977, Schwartz and Thiel 1976).

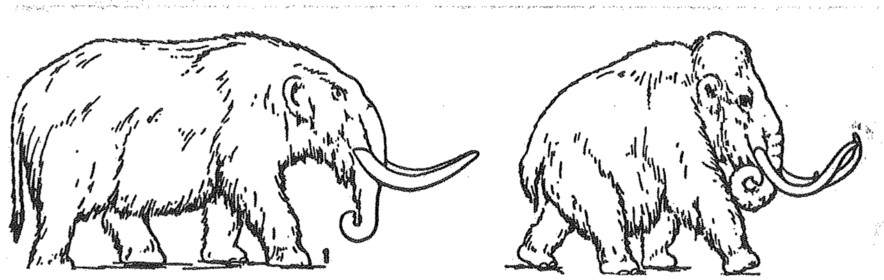


Fig 2: Representation of Mastodon (left) and Mammoth (right) that inhabited this landscape during interglacial periods. (From Schwartz and Thiel 1976.)

The glacial record of North America is largely incomplete. Each successive ice sheet tends to destroy the topographic features created during preceding glacial advances. Only landmarks from the largest ice sheets, those which progressed farther than any subsequent advance from this timeperiod, still mark the North American landscape. Furthermore, the process of constant weathering and erosion has obscured the oldest features. Although geologists have noted more than seven glacial advances during the last 700,000 years, the landscape only provides evidence that three, or possibly four, ice sheets scraped over Manitou Heights (Patterson and Hobbs 1995, Gibbons, Megeath, and Pierce 1984). Undoubtedly, each of these glaciers helped to carve the topographical relief of the hill, and erosion during subsequent inter-glacial periods refined its shape and contour. Yet, it was the final ice sheet that defined the present relief of this lofty perch.

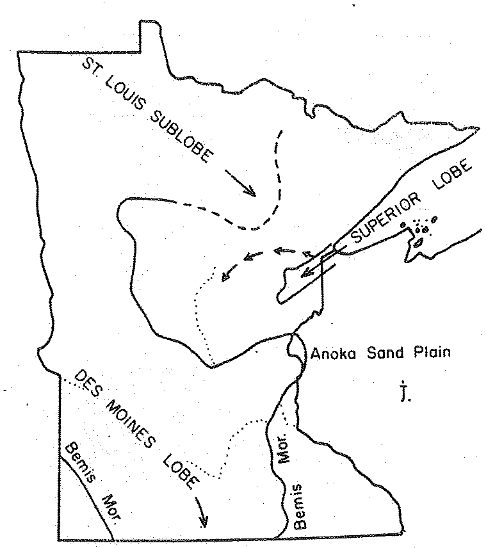


Fig 3: General sketch of the Des Moines Lobe about 14,000 years ago (From Wright Jr. 1972.)

About 30,000 years ago, an extension of the most recent ice sheet, called the Des Moines Lobe (Fig 3), began to spread eastward from the south-central part of Minnesota (Patterson and Hobbs 1995, Matsch and Ojakangas 1982, Bray 1977, Wright Jr. 1972). Eventually, the glacial ice struck the western edge of the hill. As the ice slowly ascended this slope (probably moving 1-2 meters per year), it ripped up the soft St. Peter Sandstone, and carved a relatively gentile relief. When the glacier reached the top of the hill, it gained momentum, and chiseled a shallow east-facing slope. The ice also poured over the northern and southern rims of the hill, gouging the numerous valleys and amphitheaters that contour these parts of the hill. Finally, it slid down the eastern slope of

Manitou Heights, creating more valleys, amphitheaters, and a steep relief (Schmidt 1945).

Evidence suggests that this process may have been repeated at least twice. The ice sheet pushed over campus and reached a point east of Northfield called the Morland margin. It retreated, and then advanced again around 14,000 years ago to a point extending through eastern Northfield dubbed the Bemis moraine. The hill was coated with layers of gray-drift and huge boulders (like the one presently situated north of the Science Center) during each retreat. In addition, obscure channel scarps surround the northern and southern slopes of Manitou Heights. These were cut by streams that emerged from the edge of the ice sheet when it had melted west of the hill (Fig 4). No doubt, the swift current of these streams helped to define the slope of Manitou Heights (Patterson and Hobbs 1995).

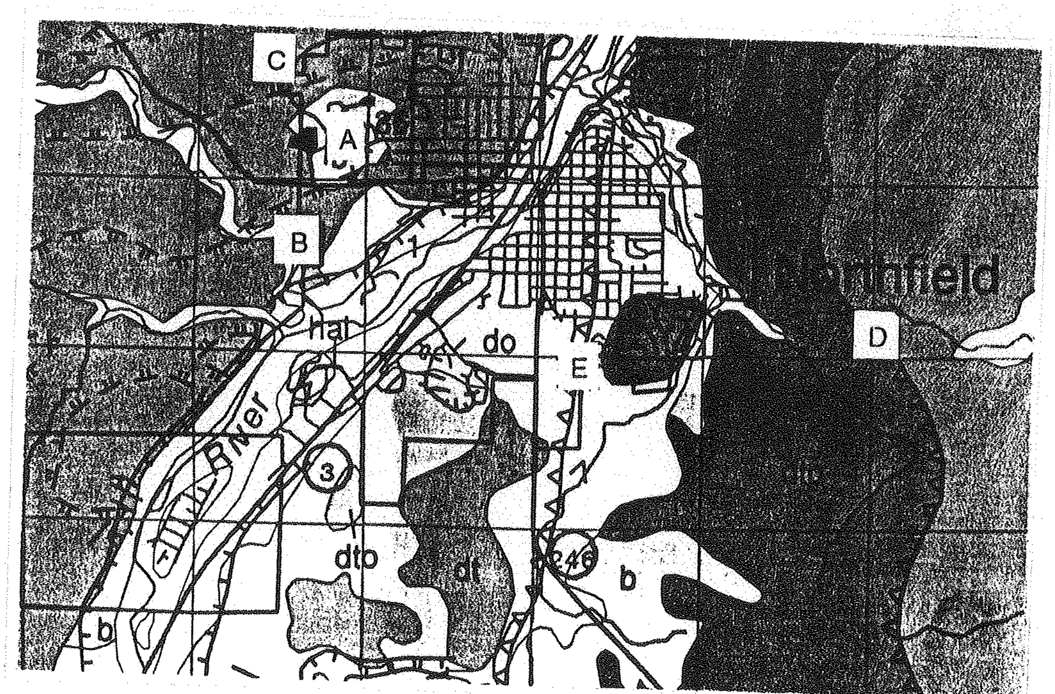


Fig 4: Map picturing the surficial geology of Manitou Heights. A) the hill, B) and C) channel scarps, D) Morland margin, E) Bemis moraine (From Patterson and Hobbs 1995.)

The Native Vegetation:

The leafy story contained in the native trees on the hill begins where the icy glacial tale ends. Shortly after the most recent glacier melted away from this area for the last time, vegetation began to sprout from the bare land. By 11,000 years ago, spruce forests dominated this landscape. Then, pines replaced the spruces about 10,000 years ago. As the glacier retreated farther, and climate warmed, the vegetation succeeded to a more temperate deciduous forest predominated by oaks and elms (Matsch and Ojakangas 1982).

However, the forests eventually declined altogether, and prairies spread across this landscape. Evidently, the climate had grown drier over time. Wildfires periodically burned over this area, maintaining the prairie vegetation. Patches of deciduous trees were constrained to low-lying wet areas that offered fire protection. But, the trees would not be restrained forever. For thousands of years, they slowly expanded over the protected lowlands. Fire-resistant oaks began to sprout among the prairie grasses. Oaks comprised approximately 40-70 percent of the vegetation in this area by 3,800-3,000 years ago. Other trees, such as ironwood, sugar maple, American elm, and basswood were also present in small numbers.

Oak woodlands probably covered the landscape for over 3,000 years. But, evidence suggests that precipitation increased markedly around 400 years ago (possibly due to a short climate reversal, called the Little Ice Age, between the mid-thirteenth and mid-nineteenth centuries). Consequently, the threat of wildfires diminished. This allowed less fire-resistant, shade-tolerant trees to rapidly replace the dominant oaks. Within one hundred years, the oak woodlands had largely diminished (Grimm 1983).

From about three-hundred years ago through the present, at least some of this area was covered with maple-basswood forest. The forest was dominated by mature sugar maple, basswood, American elm, slippery elm, and ironwood trees. Other notable trees include four species of oak, aspen, cottonwood, two species of ash, and boxelder (Daubenmire 1936, Grimm 1983). These woods contained many of the herbaceous plants and animals inhabiting the forest stands on campus today. Yet, the woods encompassing Manitou Heights were also inhabited by bears, and wolves as late as the 1850s. In the 1880-90s, the forest covering the hill was extremely dense. It contained many large trees, ginseng roots, and yellow lady-slippers. The understory was thick, tangled, and hard to navigate. In fact, the eastern rim of the hill was supposedly the only location that offered an unobstructed vantage from Manitou Heights when the Saint Olaf was founded. A sea of trees covered the remainder of the hill (Shaw 1992, Schmidt 1945).

Sadly, most of the maple-basswood forests that once covered this landscape have been destroyed over the past 100-150 years. Part of the woods that crowned Manitou Heights were cut before the college was founded. The original trees growing in Norway Valley were cut shortly before 1899 (Fig 5). The valley was replanted with a thousand conifers, and native trees have sprouted through natural reforestation processes (Shaw 1992). In fact, the forest remnants on campus today are comprised mainly of second-growth trees.

Fig 5: Picture of Norway Valley in 1900. The cut-over area was replanted with a thousand conifers donated by Rev. L.M. Dahl. (Felland Photo from Saint Olaf College Archives.)

The End:

Hopefully, these three tales convey the breadth of natural history behind the development of this lofty perch. Tropical seas covered Manitou Heights for over 100 million years. Immense ice sheets, and swift streams carved the topographic relief of the hill. Spruces, pines, prairie grasses, oaks, and Big Woods have covered the campus in the last 11,000 years. Cephalopods, trilobites, crinoids, algal seaweed, ginseng, yellow lady-slippers, wolves, bears, deer, and many others lived in this area. Indeed, the development of Manitou Heights encompasses a long, exciting history.

Of course, this area has changed dramatically over the past hundred and fifty years. Cultivated fields, restored prairies, wetlands, and roads have largely replaced the forests that once surrounded Manitou Heights. Most of the trees that covered this hill in the 1880-90s were cut during the development of Saint Olaf College. The topographic relief of the hill has also been changed to provide good foundations for the buildings that comprise the present campus. Wolves, bears, ginseng, and yellow lady-slippers have disappeared from the forested slopes. Yet, the natural history is still present. It whispers through the native trees that dot the hill, the shape and contour of the slopes, and the bedrock under passing feet. The next time that you gaze over Manitou Heights and the surrounding landscape, look for these stories. Think about the long development of this hill, and imagine how the landscape may change over the next few thousand, or million years.

The Natural History of Manitou Heights: Timeline

Compiled By: Nate Meyer

Precambrian (3.8 BY- 570MY BP):

-Pre-3.6 through 2.7 BY BP

Granitic gneisses, exposed in the Minnesota River Valley, evidence the early origins of Minnesota and Manitou Heights. Geologists, Ojakangas and Matsch (1982), suggested the stones are remnants of lava that intruded, and metamorphosed lithified sedimentary and volcanic rock about 3.6 billion years ago. Consequently, the basement rock (original crust) of Minnesota was likely intact by that point. Of course, the hill would not have existed at that early time. This area was probably part of a flat, lifeless ocean floor.

-2.4 BY BP

It is probable that the landscape was exposed by 2.4 billion years ago, and that wind and water had already begun the process of cutting away at the bare rock. In fact, potential glacial deposits (dated 2.4-2.1 BY old) have been discovered at five sites --Ontario north of Lake Huron, both east and west of Hudson Bay, the Upper Peninsula of Michigan, and southwestern Wyoming. Many geologists believe these glacial deposits to be the result of a widespread continental glaciation (Fig 1). If true, the glacial ice might have played a part in the erosion of this area's early-Precambrian rocks. But, this evidence is clearly hypothetical because no deposits have been found in Minnesota (Matsch and Ojakangas 1982).

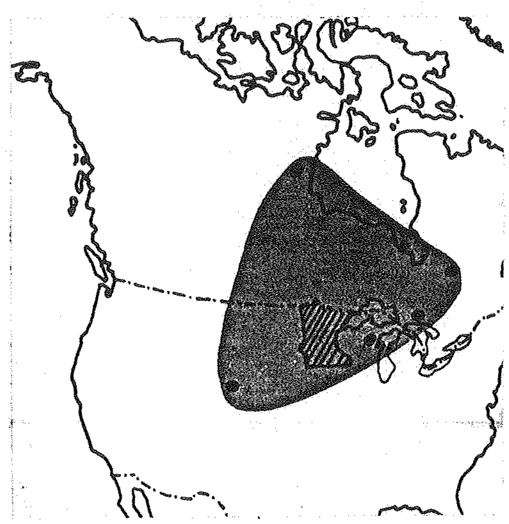


Fig 1: Possible extent of Precambrian glaciation in North America. Five dots illustrate locations where the rocks identified as lithified glacial deposits have been found. (From Matsch and Ojakangas 1982.)

-1.1-1.2 BY BP

About 1.2-1.1 billion years ago, renewed geologic activity literally “ripped” across this landscape. Essentially, North America began to tear apart along a rift which extended from Lake Superior through this area and south to Kansas (Matsch and Ojakangas 1982, Morey 1972). Basaltic lava flowed out into this zone much like it is doing along the Mid-Atlantic Ridge today, except it was happening on dry-land. However, the action stopped after a few tens of millions of years. The continent did not split in two, and a new ocean never formed. If the process had continued, Manitou Heights would probably be a coastal area today.

Instead, vertical faults caused by rifting began to slip, and lands along the rift sank to form an intermittent basin. Runoff from surrounding highlands collected in the basin, and dumped eroded detritus into meandering rivers and lakes. Some of these lithified sediments were pulled from a well in nearby Faribault (Thiel 1944). They suggest that Manitou Heights was submerged under a large, shallow lake with strong wave and current action (Fig 2). Also, a weathered zone at the top of the formation denotes that the landscape was exposed and eroded for a long period after the lakes dried. This was a lifeless, rocky landscape within a shallow basin at the end of the Precambrian Era.

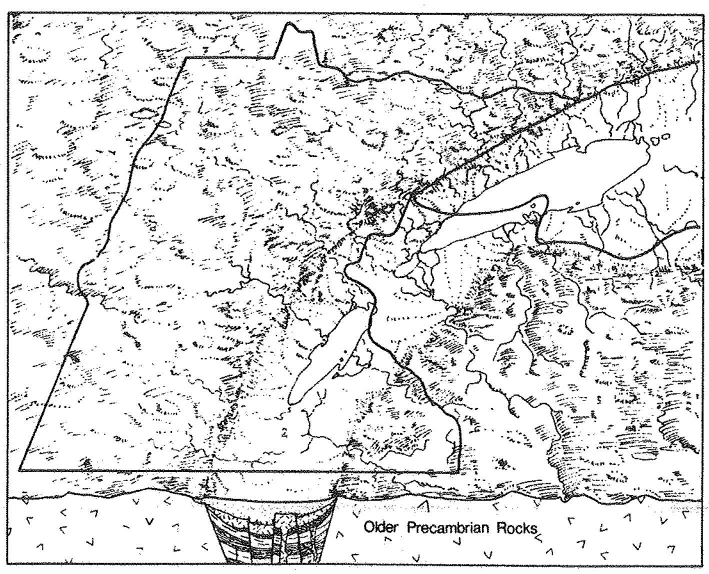


Fig 2: The basin as it may have appeared in Minnesota after rifting stopped. The lake in the lower part of the basin may have extended over Manitou Heights. (From Matsch and Ojakangas 1982.)

Paleozoic Era

-Late-Cambrian Period (550-505 MY BP)

About 550 million years ago, the interior of the North American continent began to subside. This allowed the oceans to transgress inland about one kilometer every 100,000 years. Eventually, water slowly poured across this area from a lowland, called the Ancestral Forest City Basin, in eastern Iowa. Manitou Heights was submerged in a northern extension of this basin, called the Hollandale Embayment, that covered much of southeastern Minnesota and southwestern Wisconsin (Matsch and Ojakangas 1982, Schwartz and Thiel 1976, Austin 1972, Webers 1972).

At this point, Manitou Heights rested a short distance *south* of the equator. Warm, shallow (about 100 meters deep) water sloshed over the landscape. Single-celled algae and several types of algal seaweed lived in these sun-filled seas. In addition, animals from every phylum except vertebrates inhabited the submerged landscape. Two animals, bi-valved brachiopods and hard-shelled trilobites, were extremely abundant. Brachiopods first appeared in these inland seas, and they swelled to compose almost one-third of the fauna by the end of the period (Fig 3). Trilobites were the largest, most highly developed animals in these seas (Fig 4). Some species of these organisms even grew up to .6 meters long! Ancient gastropods (snails), sponges, worms, and many others also lived in this area.

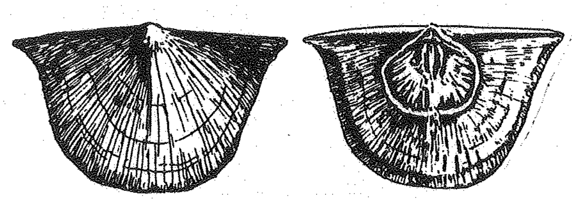


Fig 3: Representation of a brachiopod fossil--both upper (left) and lower (right) shells are pictured. (From Matsch and Ojakangas 1982.)

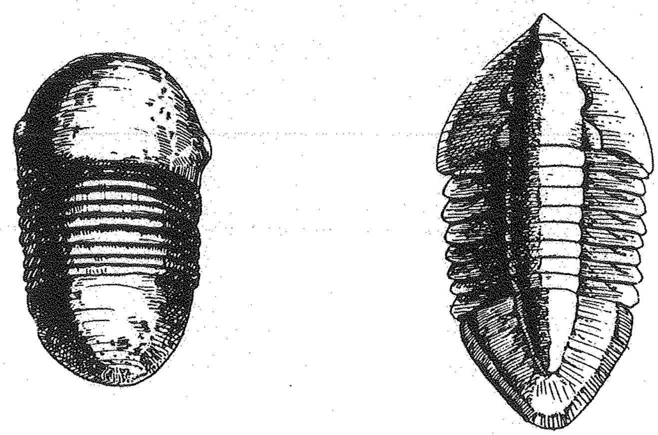


Fig 4: Representation of trilobite fossils. (From Matsch and Ojakangas 1982.)

-Ordovician Period (505-438 MY BP)

The environment of the Ordovician was very similar to the Cambrian, but sea levels were generally higher in this area. Schwartz and Thiel (1976) explained that ancient seas advanced intermittently farther and farther throughout the millions of years of the Ordovician. The Arctic ocean spread over the continent to meet an extension of the present Gulf of Mexico and another arm from the Pacific Ocean. At the maximum submergence during this timeperiod at least 60 percent of the continent was under water. Furthermore, the equator actually cut through Minnesota at this point.

Numerous plants and animals inhabited these equatorial seas. Lime-secreting algal seaweed sprouted from this landscape (Matsch and Ojakangas 1982, Austin 1972, Webers 1972). Straight-shelled cephalopods, of which the nautilus and octopus are modern examples, were the most highly developed animals in Ordovician seas. Some of these animals constructed cone-shaped shells as large as 3-4 meters long and .3 meters in diameter. Other notable animals included trilobites, brachiopods, gastropods, bryozoans, crinoids, horn corals, and tiny conodonts (Fig 5).

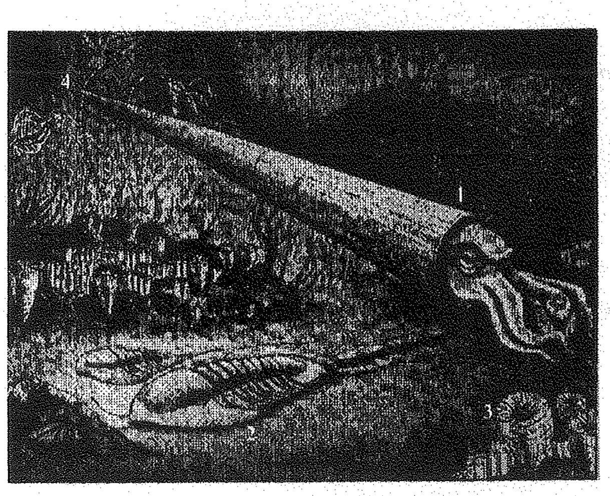


Fig 5: Panoramic view of Ordovician sea floor. Pictured animals include 1) cephalopod, 2) trilobite, 3)horn coral, 4)crinoid. (From Matsch and Ojakangas 1982.)

-Silurian through Mississippian Periods (438-320 MY BP)

Inland seas had regressed from this area by the mid-Silurian Period (about 430-400 million years BP), exposing Manitou Heights to the forces of erosion. For nearly 100 million years, this area was situated on a flat peneplain with sluggish streams slowly cutting away at the surrounding landscape. Land plants most likely began to inhabit the area sometime in this interval. Amphibians may also have moved over this landscape during the Mississippian Period (about 360-320 million years BP).

-Pennsylvanian Period (320-286 MY BP)

Sedimentary rocks in the eastern United States provide evidence that streams were flowing faster over the surrounding landscape during the Pennsylvanian Period. Lush vegetation, including tree-sized ferns and giant horse-tails, grew in numerous swamps. Amphibians, reptiles, and abundant insects crawled and buzzed over the land. Did they inhabit Manitou Heights? Probably, but there is no record of their remains.

Mesozoic Era

-Triassic Period (245-208 MY BP)

The equator still sliced through Minnesota at the beginning of the Triassic Period. But, the continent moved north during this timeperiod, and the equator ran across Florida by about 200 million years ago. At this point, the area was definitely covered in vegetation. Streams and wind continued to erode the landscape. Ancient topographical features, hills and valleys, became more pronounced.

-Cretaceous Period (144-66.4 MY BP)

This area had moved above 30 degrees latitude by the mid-Cretaceous Period, but the environment was still tropical. It is possible that dinosaurs were living in this area. Schwartz and Thiel (1976) explained that some highly rounded and polished pebbles associated with Cretaceous sediments from the southeastern part of Minnesota have been identified as the gastroliths (gizzard-stones) of dinosaurs. Flowering plants also began to inhabit this area during the Cretaceous. Over thirty species, including sequoias, magnolias, and sassafras, have been identified in Minnesota. Perhaps, they covered Manitou Heights.

Cenozoic Era (66.4 MY BP-Present)

-Tertiary Period (66.4-1.6 MY BP)

During the Tertiary Period, the rise of the modern Rocky Mountains affected the climate of this area. Manitou Heights began suffering more temperate weather conditions. Oreodonts (sheep-like animals), titanotheres (rhinoceroses), and many other mammals probably inhabited the landscape (Matsch and Ojakangas 1982, Schwartz and Thiel 1976). Moreover, the continent continued to move north, as streams and wind constantly eroded the area. In fact, the topography around Manitou Heights was beginning to take shape at this point. Schmidt (1945) suggested that the hill was part of a large plateau, stretching east toward the Cannon River. It was capped with Platteville limestone and edged with a much steeper, cliff-like relief.

-Quaternary Period (1.6 MY BP-Present)

Within the past 1.6 million years, climate reversals periodically "chilled" North America. During these intervals, average temperatures dropped, and the Laurentide Ice Sheet spread outward from the highlands of Labrador west of Hudson Bay. The immense glaciers (possibly over 1000 meters tall) plucked up rock and soil as they slowly flowed over the continent. They flattened hills, and gouged deep U-shaped valleys. Powerful streams, fueled by meltwater, shot from the edges of the glacier, cutting the landscape with swift currents and clastic sediments. When the climate warmed, the ice sheets retreated, dumping quantities of drift (crushed rock), creating moraines, lakes, and other topographic features that disclose their path. Plants and animals, including mammoths, mastodons, saber-toothed cats, giant beavers, ground sloths, and others, followed the melting glaciers, re-colonizing the barren ground (Fig 6). Slow weathering and erosion shaped the exposed landscape (Matsch and Ojakangas 1982, Schwartz and Thiel 1976).

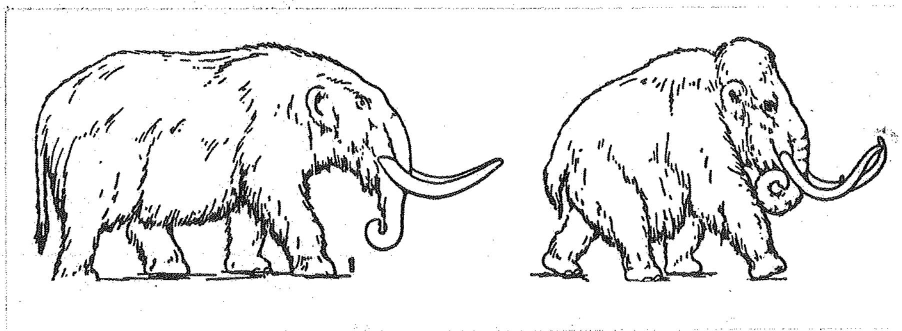


Fig 6: Representation of Mastodon (left) and Mammoth (right) that inhabited this landscape during interglacial periods. (From Schwartz and Thiel 1976.)

The glacial record of North America is largely incomplete. Each successive ice sheet tends to destroy the topographic features created during preceding glacial advances. Only landmarks from the largest ice sheets, those which progressed farther than any subsequent advance from this timeperiod, still mark the North American landscape. Furthermore, the process of constant weathering and erosion has obscured the oldest features. Although geologists have noted more than seven glacial advances during the last 700,000 years, the landscape only provides evidence that three, or possibly four, ice sheets scraped over Manitou Heights (Patterson and Hobbs 1995). Undoubtedly, each of these glaciers (and possibly others) helped to carve the topographical relief of the hill, and erosion during subsequent inter-glacial periods refined its shape and contour.

--600,000 years BP

The first ice sheet (peaked about 600,000 years BP) advanced at least two times, and at its maximum extent, may have stretched clear to Kansas City, Missouri and Peoria, Illinois. This ice sheet probably covered Manitou Heights for quite some time, maybe even tens of thousands of years. Moreover, glaciers that presently cover parts of the planet suggest that the ice was probably more than 1,000 meters thick. Till deposited during the retreat of this glacier may be exposed in roadcuts near Faribault (Bray 1977).

A mild, moist interglacial period followed this glaciation. The ice retreated long enough for erosion and weathering to greatly change the post-glacial landscape. Deep river valleys were cut into the land. The fossil record from this interglacial stage also suggests that Manitou Heights was probably covered with a succession of tundra, grasslands and forests inhabited by mammoths, mastodons, saber-toothed tigers, musk oxen, llamas, bears, pronghorn antelope, and many other animals we know today.

--400,000 years BP

During the second glacial cycle (peaked about 400,000 years BP), the ice sheet intermittently spread in at least three advances nearly as far as the first. Bray (1977) pointed out that erratics (glacially deposited rocks) from Minnesota have been found along the terminal edge of this advance. Again, the ice sheet covered this area for a long time. Likewise, it was followed by another long interglacial period. Once the ice retreated, the climate was very similar to the preceding interglacial period. However, there is little evidence of the flora and fauna which inhabited this area. The remains of giant beavers the size of bears have been uncovered in till near Minneapolis. Also, fossils from Iowa suggest that the landscape was covered with forests populated by giant ground sloths, tapirs, and many of the plants and animals present in the last interglacial period.

--125,000 years BP

The third ice sheet (peaked about 125,000 years BP) advanced at least three times into Minnesota, but its extent was more limited. This ice sheet may never have passed over Manitou Heights. Perhaps, it simply gave this landscape a strong "chill," and shifted the environment toward tundra. In any event, the interglacial period following the retreat of this ice sheet was much shorter than the others. It may only have lasted about 25,000 years. The fossils of mastodons have been found in till from this interglacial period.

--30,000-14,000 years BP

About 30,000 years ago, an extension of the most recent ice sheet, called the Des Moines Lobe (Fig 7), began to spread eastward from the south-central part of Minnesota (Patterson and Hobbs 1995, Matsch and Ojakangas 1982, Bray 1977, Wright Jr. 1972). Eventually, the glacial ice struck the western edge of the Manitou Heights. As the ice slowly ascended this slope (probably moving 1-2 meters per year), it ripped up the soft St. Peter Sandstone, and carved a relatively gentile relief. When the glacier reached the top of the hill, it gained momentum, and chiseled a shallow east-facing slope. The ice also poured over the northern and southern rims of the Manitou Heights, gouging the numerous valleys and amphitheaters that contour these parts of the hill. Finally, it slid down the eastern slope of Manitou Heights, creating more valleys, amphitheaters, and a steep relief (Schmidt 1945).

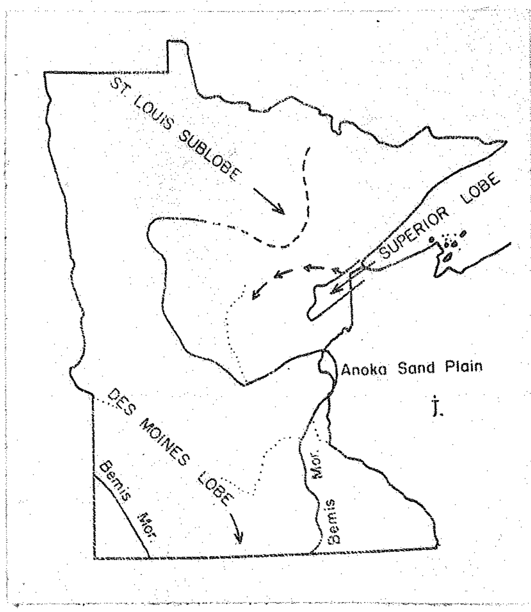


Fig 7: General sketch of the Des Moines Lobe about 14,000 years ago (From Wright Jr. 1972.)

Evidence suggests that this process may have been repeated at least twice. The ice sheet pushed over campus and reached a point east of Northfield called the Morland margin. It retreated, and then advanced again around 14,000 years ago to a point extending through eastern Northfield dubbed the Bemis moraine. The hill was coated with layers of gray-drift and huge boulders (like the one presently situated north of the Science Center) during the final retreat. In addition, obscure channel scarps surround the northern and southern slopes of Manitou Heights. These were cut by streams that emerged from the edge of the ice sheet when it had melted west of the hill (Fig 8). No doubt, the swift current of these streams helped to define the slope of Manitou Heights (Patterson and Hobbs 1995).

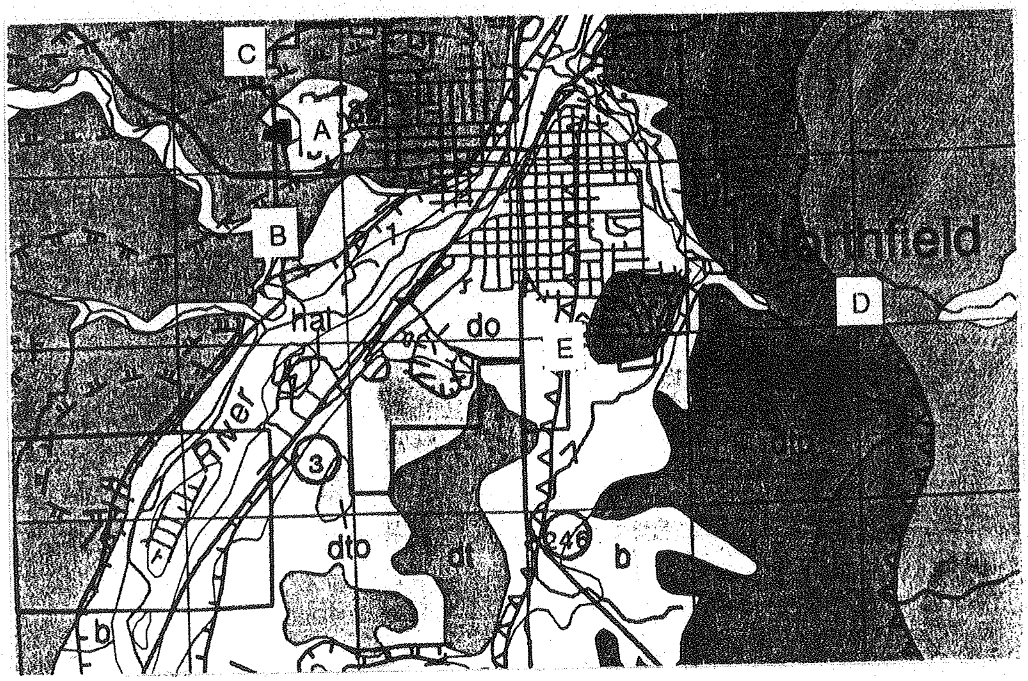


Fig 8: Map picturing the surficial geology of Manitou Heights. A) the hill, B) and C) channel scarps, D) Morland margin, E) Bemis moraine (From Patterson and Hobbs 1995.)

--Post-glacial through 6,000 years BP

Shortly after the most recent glacier melted away from this area for the last time, vegetation began to sprout from the bare land. Spruce forests dominated this landscape for quite some time. Then, pines replaced the spruces about 10,000 years ago. As the glacier retreated farther, and climate warmed, the vegetation succeeded to a more temperate deciduous forest predominated by oaks and elms (Matsch and Ojakangas 1982). However, the forests eventually declined altogether, and prairies spread across this landscape.

6,000-3,800/3,000 years BP

Prairie grasses were likely the dominant vegetation covering this landscape 6,000 years ago (Grimm 1983). Evidently, the southern Minnesota climate became drier as the ice-sheet retreated. Fires periodically swept over the landscape, maintaining the prairie. Patches of forest were constrained to low-lying, wet areas which offered the trees some protection from burning. At this point, Manitou Heights may have looked much like the restored prairies north-northwest of campus. Bison and other grassland animals possibly inhabited the area.

Yet, the forests would not be restrained forever. Trees slowly spread across more of the fire-protected landscape. Aspens and fire-tolerant oaks began to sprout among the prairie grasses. Over the course of a few thousand years, oak savanna conditions succeeded the prairie in certain areas. In fact, an oak forest eventually replaced most of the prairie. Oaks comprised approximately 40-70 percent of the vegetation in this area by 3,800-3,000 years ago. Other trees, such as ironwood, sugar maple, American elm, and basswood were also present in small numbers.

3,800/3,000-300 years BP

Oak woodlands probably covered the landscape for over 3,000 years. But, evidence suggests that precipitation increased markedly around 400 years ago (possibly due to a short climate reversal, called the Little Ice Age, between the mid-thirteenth and mid-nineteenth centuries). Consequently, the threat of wildfires diminished. This allowed less fire-resistant, shade-tolerant trees to rapidly replace the dominant oaks. Within one hundred years, the oak woodlands had largely diminished (Grimm 1983).

300 years BP-Present

From about three-hundred years ago through the present, at least some of this area was covered with maple-basswood forest. The forest was dominated by mature sugar maple, basswood, American elm, slippery elm, and ironwood trees. Other notable trees include four species of oak, aspen, cottonwood, two species of ash, and boxelder (Daubenmire 1936, Grimm 1983). These woods contained many of the herbaceous plants and animals inhabiting the forest stands on campus today. Yet, the maple-basswood forest encompassing Manitou Heights were also inhabited by bears, and wolves as late as the 1850s (Shaw 1992).

In the 1880-90s, the forest covering the hill was extremely dense. It contained many large trees, ginseng roots, and yellow lady-slippers. The understory was thick, tangled, and hard to navigate. In fact, the eastern rim of the hill was supposedly the only location that offered an unobstructed vantage from Manitou Heights when the Saint Olaf was founded. A sea of trees covered the remainder of the hill (Shaw 1992, Schmidt 1945).

Sadly, most of the maple-basswood forests that once covered this landscape have been destroyed over the past 100-150 years. Part of the woods that crowned Manitou Heights were cut before the college was founded. The original trees growing in Norway Valley were cut shortly before 1899 (Fig 9). The valley was replanted with a thousand conifers, and native trees have sprouted through natural reforestation processes (Shaw 1992). In fact, the forest remnants on campus today are comprised mainly of second-growth trees.

Fig 9: Picture of Norway Valley in 1900. The cut-over area was replanted with a thousand conifers donated by Rev. L.M. Dahl. (Felland Photo from Saint Olaf College Archives.)

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I set out on a walk around Manitou Heights one sunny spring day, wading deeply into the season's brilliant colors and vibrant energy. My footsteps carried me along a winding path through grasses, trees, and finally to an overlook on the slope beside Rand hall. From the lofty vantage, I gazed over green athletic fields, golden prairie, dark forest stands, the edges of a partially wooded wetland, rectangular patches of black dirt, and the softly undulating hills that flow toward the northern horizon. Then, I began to wonder what the landscape had looked like before the college was built. In my mind's eye, I traveled back in time I imagined standing under the wind tossed waves of ancient seas. I watched swift streams slowly carve the hill. Huge ice sheets scraped past, refining the physical features of Manitou Heights. They melted away, leaving layers of drift and great boulders. I pictured forests sprouting from the landscape and different animals making their homes on the hill. I thought about Native Americans hunting among the trees and settlers running plows over cleared land. Suddenly, I wanted to find out how the hill formed, where it had been, and how it had changed over the years.

The changing landscape is a never-ending story. Today, Manitou Heights is home to Saint Olaf College. It is heaped with limestone buildings, concrete sidewalks, asphalt roads, thousands of students, faculty, and staff. But, it has been so many other things. The present is simply one sentence of a longer tale. It sinks into the body of surrounding paragraphs, relying on their structure. The hill, as we see it now, resulted from natural processes working constantly over hundreds of millions of years. Subsequently, looking into the past, into the procession of these processes, develops a better understanding of the present. If we ask any question about Manitou Heights, the answer probably lies at least partially within the hill's developmental history, and the context of this tale.

Natural history might be defined as the study of these landscape tales. Nature writes in an obscure language--the structure of rock, the contour of strata (separate layers of rock), fossilized flora and fauna, the shape of the landscape, and much more. A naturalist attempts to read and interpret these messages, and construct pages of the tale. He or she is a story-teller of sorts, a bard who sings the song of a piece of land.

So, I shall be a bard for a few pages. After looking at the beautiful landscape of Manitou Heights, and scanning the grand picture that lies around the hill, I set out to read its natural history. I poured over pages of research, and archival photos for clues to the story of the hill. Slowly, I formulated a tale. Now, I shall sing the song of this bit of land.

The Story:

There is no known geologic record in this area for most of the Precambrian Era, a time period which stretches from the formation of the oldest known rocks around 3.8 billion years ago to a point 570 million years BP.

However, geological clues from elsewhere in Minnesota and surrounding states draw a partial picture of the landscape's earliest development. Granitic gneisses, exposed in the Minnesota River Valley, evidence the early origins of Minnesota and Manitou Heights.[1] Geologists, Ojakangas and Matsch (1982), suggested the stones are remnants of lava that was intruding, and metamorphosing lithified sedimentary and volcanic rock about 3.6 billion years ago. Consequently, the basement rock (original crust) of Minnesota was likely intact by that point.

Of course, the hill would not have existed at that early time. This area was probably a featureless seafloor. The geologists explained that some pillowed basalt formations (lithified 2.7 billion years BP) from the northern part of the state erupted from ocean rifts (cracks) at depths as great as 1000m below the surface of the water because they lack the cavities caused by gases escaping from lava under less pressure. At this point, biological organisms were non-existent. The landscape was lifeless. Imagine the featureless surroundings, shaded by the quantities of water sloshing overhead which softened the intensity of approaching sunlight, and shuddered periodically by the forces of volcanic eruptions!

Again, it is difficult to discern exactly when this area initially rose above the ocean's surface during the long Precambrian Era. However, it is probable that the landscape was exposed by 2.4 billion years ago, and wind and water

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[1] I refer to Manitou Heights as a geographic locale, not a topographic structure.

had already begun the process of cutting away at the bare rock. In fact, Ojakangas and Matsch cited evidence from several locations--Ontario north of Lake Huron, both east and west of Hudson Bay, the Upper Peninsula of Michigan, and southwestern Wyoming--where possible glacial deposits have been found. The lithified glacial till, called *tillites*, in Ontario have been bracketed by dating related igneous rocks. They appear to be about 2.4-2.1 billion years old. Many geologists believe these glacial deposits to be the result of a widespread continental glaciation (Fig 1). If true, the glacial ice might have played a part in the erosion of this area's early-Precambrian rocks. But, this evidence is clearly hypothetical because no deposits have been found in Minnesota.

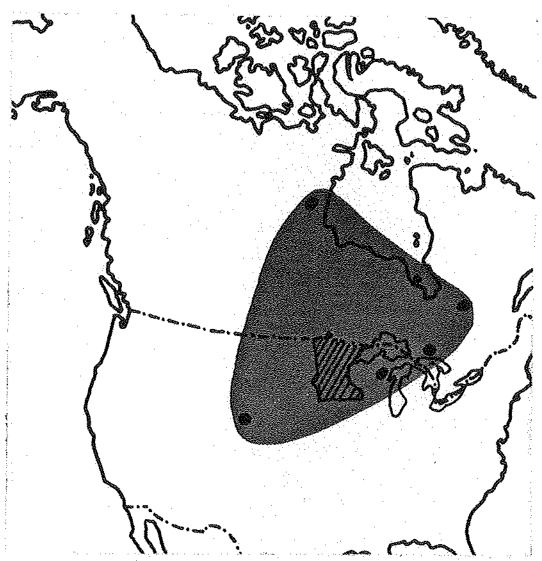

Fig 1: Possible extent of Precambrian glaciation in North America. Five dots illustrate locations where the rocks identified as lithified glacial deposits have been found. (From Matsch and Ojakangas 1982.)

About 1.2-1.1 billion years ago, renewed geologic activity literally "ripped" across this landscape. Essentially, North America began to tear apart along a rift which extended from Lake Superior through this area and south to Kansas (Matsch and Ojakangas 1982, Austin 1972, Morey 1972). Basaltic lava flowed out into this zone much like it is doing along the Mid-Atlantic Ridge today, except it was happening on dry-land. However, the action stopped after a few tens of millions of years. The continent did not split in two, and a new ocean never formed. If the process had continued, Manitou Heights would probably be a coastal area today.

Instead, vertical faults caused by rifting began to slip, and lands along the rift subsided to form an intermittent basin. The resulting geographic-low was subjected to sedimentation. Basically, runoff from surrounding highlands collected in the basin, and dumped eroded detritus into meandering rivers and lakes. Some of these lithified sediments were pulled from a well in nearby Faribault (Thiel 1944). They suggest that Manitou Heights was submerged under a large, shallow lake with strong wave and current action (Fig 2). Also, a weathered zone at the top of the formation denotes that the land was exposed and eroded for a long period after the lakes dried. Thus, this was a lifeless, rocky landscape within a shallow anticlinal basin at the end of the Precambrian Era. It was once again being grinded by the forces erosion.

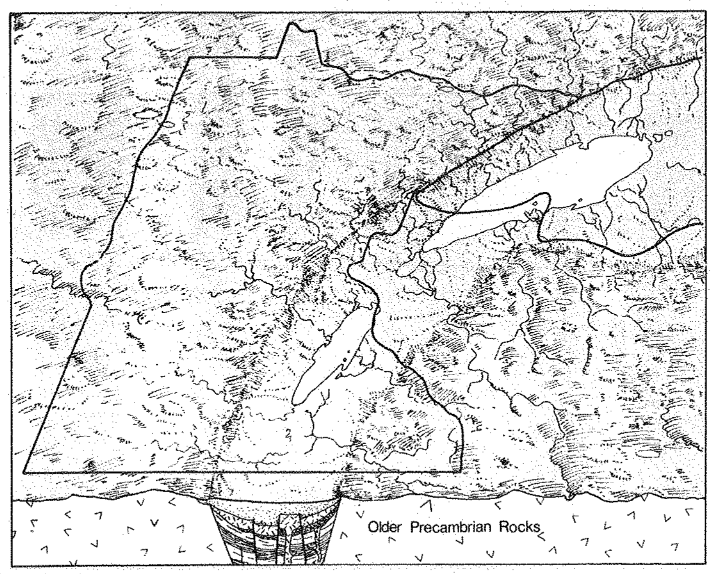

Fig 2: The basin as it may have appeared in Minnesota after rifting stopped. The lake in the lower part of the basin may have extended over Manitou Heights. (From Matsch and Ojakangas 1982.)

Inland Seas:

The end of the Precambrian signifies the start of the Paleozoic Era (570 million years BP). It also signals the beginning of the "concrete" geologic record of Manitou Heights. All of the rocks known to underlie the hill formed within the first two periods (Cambrian and Ordovician), or 130 million years of the Paleozoic. The rocky debris pulled from a well that was drilled into Manitou Heights in 1935 included over 210 meters of these lithified deposits (Thiel 1944).

One might call this timeperiod an "age of inland seas." Once again, oceanic waters spread over this area. Sandy, silty sediments settled over the landscape, creating layer after layer of sedimentary rock. Animals that died in the area were buried in the deposits, and eventually fossilized in the lithified stone. The composition, and fossil content of the strata, as well as other geophysical information draws a clear picture of the natural history of these 130 million years. In this case, the tale is full and vivid.

It may be hard to imagine inland seas pouring over the Midwest. Yet, sea-levels have fluctuated up and down a number of times throughout the history of the planet. In fact, geologic records prove that the sea-level rose steadily during the Cambrian Period (Fig 3). Geologists, George Schwartz and George Thiel (1976), said that 35 percent of the North America was flooded by late-Cambrian time.

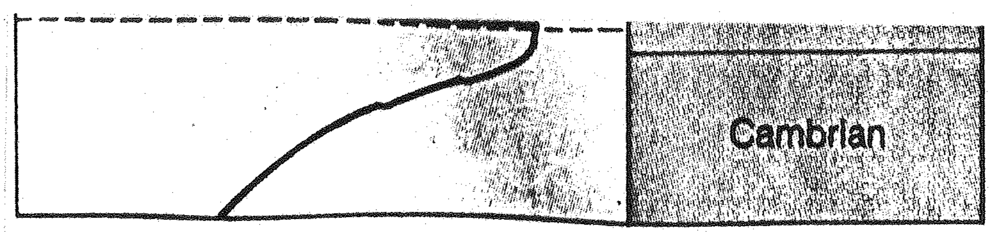

Fig 3: Reconstructed record of rising sea-levels during the Cambrian Period. (From Skinner and Porter 1987).

The mechanisms which drive the changes in sea-level have been highly debated. It seems unlikely that ocean water actually increases and decreases enough to account for the fluctuation. If all of the glaciers presently capping the planet's surface melted away, the oceans would only rise about 70 meters. That could never cover 35 percent of the continent. A much more plausible explanation blames periodic changes in lithospheric buoyancy for causing shifts in sea-levels. In other words, the outer crust of our planet "floats" on the denser mantle. Subsequently, tectonic activity like volcanism, rifting, or changes in the rate of seafloor spreading affects portions of the crust, making landmasses more or less buoyant over time. Continents rise and sink. The Midwest, sinking at a rate of 2.5 centimeters per year, would fall about 183 meters over 700,000 years. This would cause the oceans at their present level to flood the Mississippi River Valley clear into southeastern Minnesota. Slow changes in the continent's buoyancy could definitely account for the rising level of inland seas during the Cambrian, which only transgressed into the area at a rate of about one kilometer every 100,000 years (Matsch and Ojakangas 1982, Schwartz and Thiel 1976).

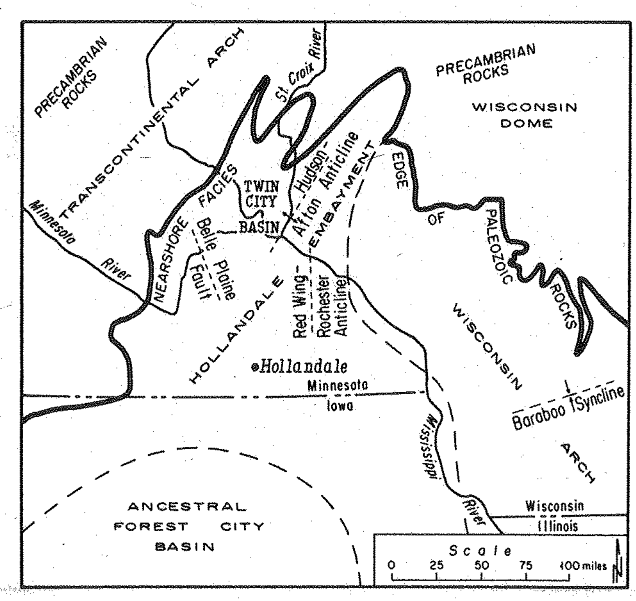

Fig 4: Map showing the Hollandale Embayment and surrounding structural features. (From Austin 1972.)

The transgression of inland seas during early Paleozoic Era is specifically attributed to the development of geosynclines (major downwarped zones) along the central, stable continent that measured thousands of kilometers long and a few hundred kilometers wide. During the late-Precambrian and beginning of the Cambrian, the Cordilleran Geosyncline was forming in the West; the Appalachian Geosyncline was forming in the East; and the Franklin Geosyncline was forming in the North. As the downwarped areas sank, the ocean spread over them. Then, much of the rest of the continent started to subside about 550 million years ago (Matsch and Ojakangas 1982). This allowed the oceans to spill over the geosynclines and transgress across much of the rest of the continental interior. The water flooded into the lowlands of southeastern Minnesota from the Ancestral Forest City Basin in eastern Iowa (Austin 1972). Manitou Heights laid within a northern bay of the inland sea called the Hollandale Embayment. The bay stretched into southeast-central Minnesota and southwestern Wisconsin, bounded by a highland called the Transcontinental Arch in the west-northwest and a highland called the Wisconsin Dome in the east-northeast (Fig 4).

Sediments, carried by streams from the Transcontinental Arch and Wisconsin Dome, immediately began to settle over this landscape, and eventually compressed to form stone. George Austin (1972) completed a detailed study of these strata. His results provide evidence that the depositional environment in this area shifted a number of times. While the planet-wide sea level generally rose during the Cambrian Period, it was actually fluctuating mildly over Manitou Heights. The water transgressed and regressed over the Hollandale Embayment in non-uniform cycles.

Austin separated the fluctuations into four basic depositional categories: sandstone (well sorted), mixed sandstone (poorly sorted), argillite shelf, and carbonate shelf-reef. These categories correlate with shifts from a nearshore beach through progressively deeper shelves, which culminate in a carbonate reef environment. Simply, as the sea transgressed, the water covering Manitou Heights had less and less energy to carry suspended sediments. Well-sorted sandstones denote the force of strong currents caused by heavy stream and tidal action near the shoreline of the inland sea. The movement of the water created enough energy to suspend all but the largest, heaviest, most spherical particles of sand. Bigger, rounder bits of sand would settle to the seafloor before smaller, coarser bits. As the shoreline moved away from this area, the water was less affected by tides or streams; it had less energy. Thus, the water was increasingly unable to carry the weight of sediments. First, sand particles fell without being sorted. Then, progressively finer pieces of silt settled. Finally, calcium carbonate actually precipitated out of the deepest, quietest waters.

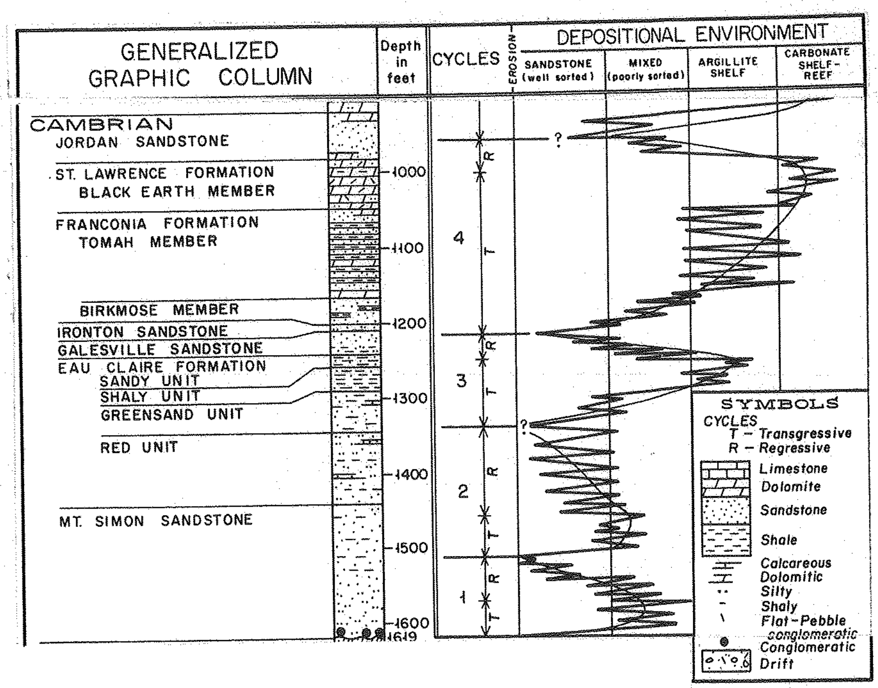

Fig 5: Generalized graphic log of shifting depositional environments of Cambrian strata. Main fluctuations are represented by thin line superimposed over the irregular thick line that denotes minor fluctuations in the depositional environment. (From Austin 1972.)

There were four main fluctuations in the Cambrian seas which covered this area (Fig 5). The water initially poured over Manitou Heights, transgressing to a point where sandstones become poorly sorted, and then regressed back to a near shore beach environment. The second thrust was similar, but less severe. There is an unconformity between the second and third cycles. The sea left this area altogether for a number of years. When the water transgressed again, Manitou Heights was eventually far enough from shore that silt settled over the landscape. During the last Cambrian fluctuation, the water moved even farther inland, laying the first Paleozoic carbonate deposits on this landscape at the peak of the transgression. Then, the sea regressed past this area once more, leaving the landscape exposed to erosion.

The fossil content of these strata proves that plants and animals were periodically living in the aquatic habitat that surrounded Manitou Heights during the Cambrian Period. Actually, the lithified remains of animals are much more abundant in Paleozoic rocks than earlier timeperiods. While animals existed during the late-Precambrian Era, their bodies were usually soft, small, and degraded nearly completely before getting fossilized. On the other hand, many animals had developed hard shells by the beginning of the Paleozoic which dissolved more slowly, became buried in sediments, and eventually preserved in rock strata. Ojakangas and Matsch (1982) suggest that these shells evolved in response to higher intensities of ultraviolet radiation, greater physical stresses from wave and current energy, and higher predatory stresses from less-spacious, crowded near shore habitats. In any event, the well-preserved remains of Cambrian fauna provide some good information about the ancient inhabitants of this landscape.

Schwartz and Thiel (1976) pointed out that when Cambrian seas inundated this area, they brought with them animals belonging to every phylum except the vertebrates. Two animals, brachiopods and trilobites, are relatively abundant throughout the Cambrian strata. Brachiopods first appeared in these inland seas, and they swelled to compose almost one-third of the fauna by the end of the period (Fig 6). Actually, a few of these ancient animals even still exist in today's oceans. The brachiopod lives its life enclosed in a bivalved shell. The upper shell is somewhat smaller than the lower, and the two are hinged together at one end. The organism uses a fleshy stalk, extending from the posterior of the lower shell, to attach itself to rocks and other objects on the seafloor.

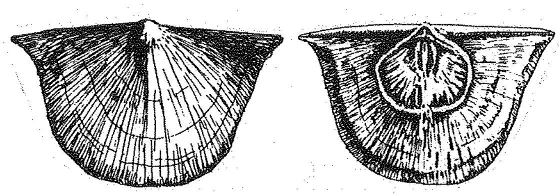

Fig 6: Representation of a brachiopod fossil--both upper (left) and lower (right) shells are pictured. (From Matsch and Ojakangas 1982.)

The trilobite, unlike the brachiopod, has disappeared completely from the planet's oceans (Fig 7). Yet, trilobites were the largest, most highly developed animals of their time. Some species of these organisms even grew up to two feet long! The odd-looking animals had bodies that were divided into three flattened, longitudinal lobes. Their heads were covered with thick chitinous shields, and a shell covered the rest of their body, extending in a number of segments across the thorax and abdomen. The last few segments of the shell were fused to form another hard shield over the tail. Trilobites also had a pair of compound eyes with thousands of lenses. They belonged to the phylum *Arthropoda* which includes other animals like the lobster and the crawfish.

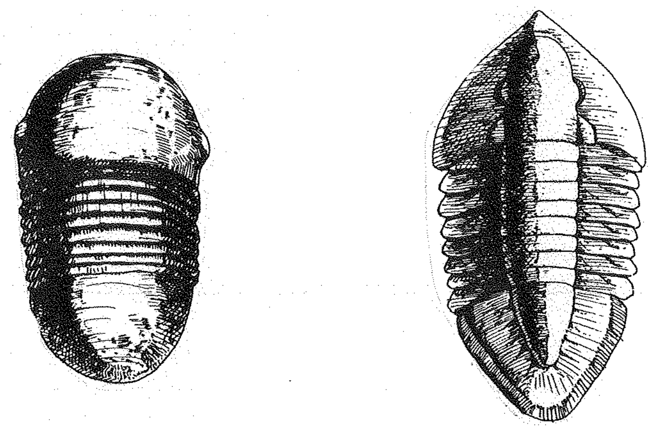

Fig 7: Representation of trilobite fossils. (From Matsch and Ojakangas 1982.)

Along with brachiopods and trilobites, the Cambrian fossils contain the remains of ancient gastropods (snails), sponges, and worms. The strata also include signs of single-celled algae and several types of algal seaweed. Moreover, the presence of these fossils in the Cambrian rocks prove that the seas covering Manitou Heights seldom rose above 100 meters in depth. The lithified remains denote waters of normal salinity. They also suggest that the environment was quite warm (Matsch and Ojakangas 1982, Austin 1972, Webers 1972)!

Today, Manitou Heights is a land of ice, snow, and long winters. Yet, it was not always such a cool place. This area is presently situated at a relatively high latitude in the Northern Hemisphere of the planet. But, the North American continent is moving. It slowly slides over the mantle as a part of the larger lithospheric plates that compose the planet's outer crust. Geologists have tracked the historic progression of these movements by looking closely at the orientation of magnetized mineral crystals in certain igneous and metamorphic rocks from this continent. Some minerals, the most important of which is magnetite, can become permanently magnetized. As molten lava or super-heated metamorphic rocks slowly cool, individual crystals of these minerals polarize in line with the magnetic field which surrounds the planet. The crystals harden like fixed compass needles, pointing toward the magnetic pole. While the continents move, these crystals retain their original orientation. Thus, the inclination and declination of these tiny compass needles disclose the position of the magnetic pole relative to the position of the rock when it hardened. Consequently, plotting the changes in the orientation of the magnetized crystals contained in rocks of different ages from this landmass provides a record of tectonic movement. Using this technique, geologists place this area much closer to the equator during the Cambrian than it is today. In fact, the entire North American continent was tilted eastward. The arrowhead in northern Minnesota pointed toward the South, and the equator cut through the continent just North of the present western edge of the state (Fig 8). Manitou Heights was situated a short distance *south* of the planet's mid-section. The seas that covered the landscape were indeed warm, and tropical.

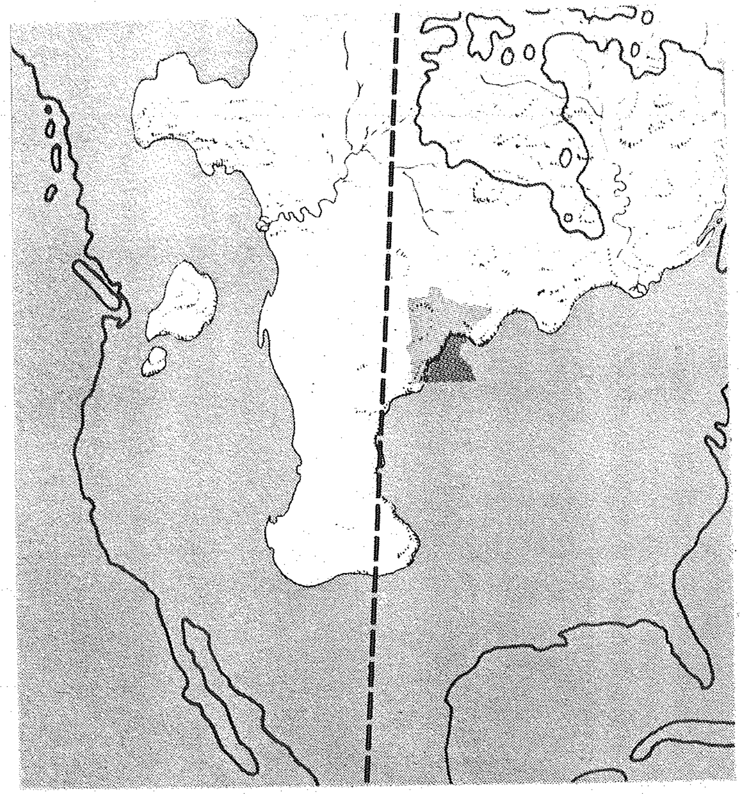

Fig 8: Map showing position and orientation of Minnesota relative to equator during the late-Cambrian. (From Matsch and Ojakangas 1982.)

Picture Manitou Heights as it must have appeared during the late-Cambrian Period. Strong, equatorial sunlight flowed down over ancient seas, sparkling across wind-tossed waves. The light filtered down into the warm, shallow water, glancing off the nearly flat landscape at the bottom. There was no hill, just an expansive beach, shelf, or carbonate bank. Sometimes, algal seaweed was sprouting from the floor, and trilobites or snails moved quietly among the leaves. Sponges and brachiopods dotted partially buried rocks. The scene grew brighter and darker as the sealevel rose and fell over millions of years. Two times, the water retreated past this area, leaving the dry, cracking landscape of bare rock exposed to the erosive forces of winds and tropical rains. When the Cambrian drew to a close, the seas began transgressing for the fifth time, once again submerging this area under warm waters.

The peak of the fifth transgression of inland seas marks the beginning of the second, Ordovician Period (505 million years BP). The environment of the Ordovician was very similar to the Cambrian, but sea levels were generally higher in this area. Schwartz and Thiel (1976) explained that ancient seas advanced intermittently farther and farther throughout the millions of years of the Ordovician. The Arctic ocean spread over the continent to meet an extension of the present Gulf of Mexico and another arm from the Pacific Ocean. At the maximum submergence during this timeperiod at least 60 percent of the continent was under water. In addition, aged streams moved sediments more sluggishly from exposed areas. The seas had less energy to carry the suspended debris. As a result, the Ordovician strata under Manitou Heights are dominated by carbonates.

Austin (1972) discerned four major fluctuations in the depositional environments of the Ordovician (Fig 9). Three of these four cycles culminated in carbonate shelves. In addition, both the first and second fluctuations ended with possible unconformities. This area may have been exposed during these intervals, so some lithified nearshore sediments were possibly eroded. The third fluctuation was less severe. The depositional environment shifted from a nearshore beach to a deep argillite shelf and then regressed slightly. Finally, the seas transgressed again, depositing carbonate sediments on this landscape.

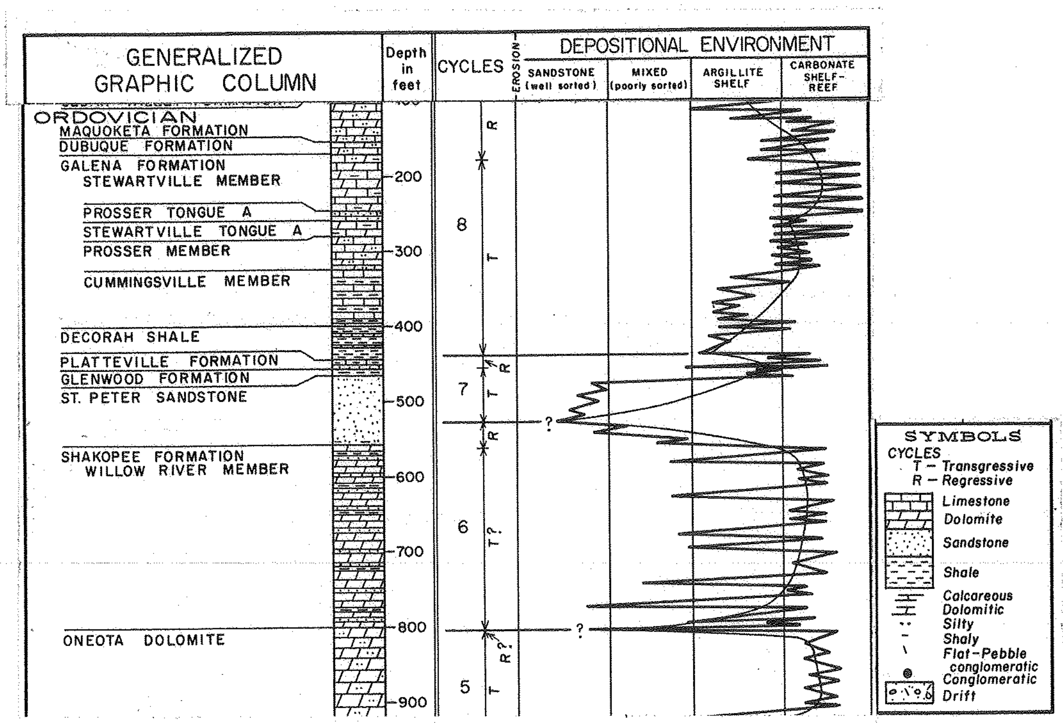

Fig 9: Generalized graphic log of shifting depositional environments of Ordovician strata. Main fluctuations are represented by thin line superimposed over irregular thick line that denotes minor fluctuations in the depositional environment. (From Austin 1972.)

The fauna of the Ordovician seas were much more diverse than their Cambrian predecessors. Paleontological studies have identified more than 1600 species in mid-Ordovician strata alone. While trilobites and brachiopods became considerably more abundant during this period, they no longer dominated the ancient seas. Cephalopods, of which the nautilus and octopus are modern examples, were the most highly developed animals in Ordovician seas (Fig 10). Many of these straight-shelled cephalopods inhabited cone-like shells. As the individual grew, it added to the length and breadth of its shell, leaving the older part unoccupied. Over time, the shell grew long and straight. By middle to late Ordovician, some of these cephalopods were creating shells .3 meters in diameter and three to four meters long (Schwartz and Thiel 1976).

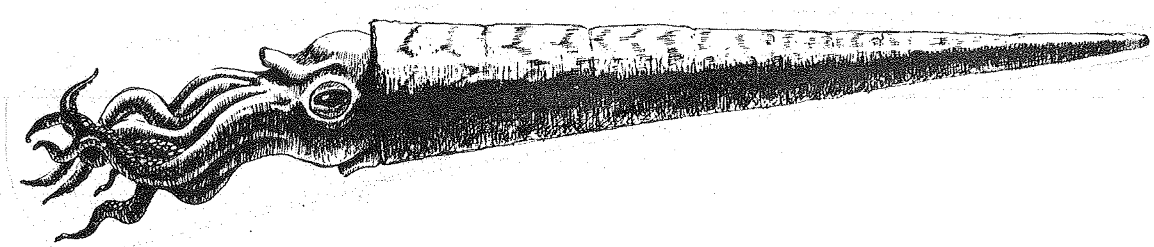

Fig 10: Representation of straight-shelled cephalopod. (From Matsch and Ojakangas 1982.)

Sponges became more abundant during the Ordovician. One of the most important was an odd type commonly called the "sunflower" sponge because its markings resemble the pattern of seeds in a sunflower. Crinoids, called "stone-lilies" due to their resemblance to plants, inhabited the seas in this area as well. The crinoids had long, slender stems capped with an oval-shaped organism that sported a crown of feathery tentacles. It used these tentacles to create minute currents that wafted particulate food into its mouth. Other animals included bryozoans, gastropods, and horn corals. Lime-secreting algae were also widespread in the Ordovician seas. Of course, the fossilized remains of these flora and fauna evidence the fact that the seas were still tropical, shallow, and contained waters of relatively normal salinity (Matsch and Ojakangas 1982, Schwartz and Thiel 1976, Webers 1972). Moreover, the equator actually sliced through the central part of Minnesota during this timeperiod (Fig 11).

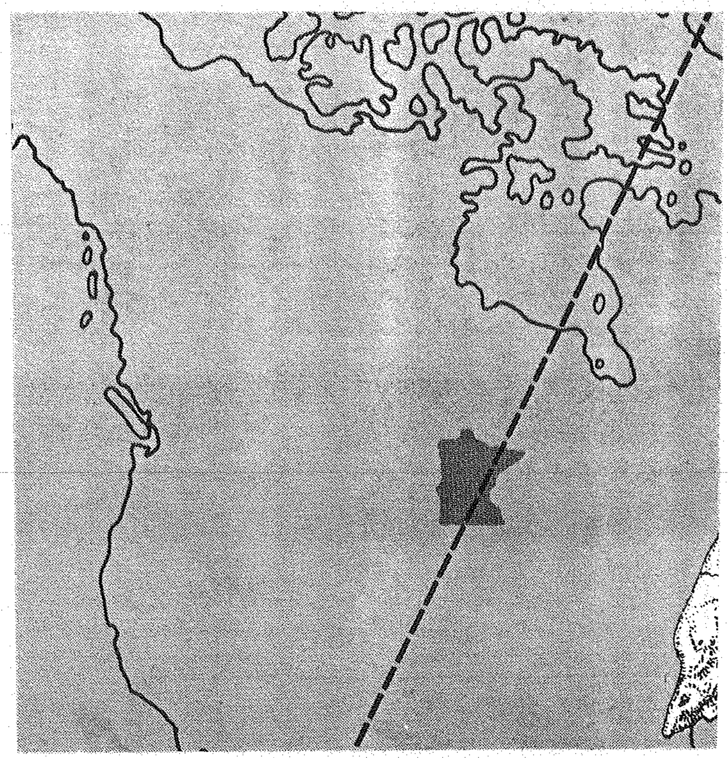

Fig 11: Map showing position and orientation of Minnesota relative to equator during the Ordovician. (From Matsch and Ojakangas 1982).

Three sections of middle Ordovician strata are specifically important to the natural history of Manitou Heights. The St. Peter Sandstone, Glenwood Formation, and Platteville Formation comprise the bedrock of this hill (Mossler 1995, Thiel 1944, Schmidt 1945). The St. Peter Sandstone is the oldest of the three. It is composed of yellow-white, rounded, well-sorted, pure-quartz sand grains. This sandstone was formed during the last large quartz deposition of the Ordovician. Actually, the rock in this area rests within the northern edge of an expansive sand formation that covers 585,000 square kilometers in the middle part of the United States, and totals about 20,000 cubic kilometers!

The St. Peter was deposited on a nearshore beach during the regressive phase of the second fluctuation of the Ordovician seas and the transgressive phase of the third. Fossils are sparse in the St. Peter, including only a few mollusks, such as cephalopods and gastropods (Matsch and Ojakangas 1982, Austin 1972, Webers 1972). Pieces of this sandstone are scattered along the sloping edges of Manitou Heights. They are especially evident on the wooded hill behind Rand and Kildhal halls. In some places along this hill, the soil "glitters" because of the presence of quartz sand grains eroded from this rock. There is also a large outcropping of St. Peter Sandstone along the Cannon River in the Rice County Wilderness Park a few miles east of campus on Highway 3.

The Glenwood Formation lies on top of the St. Peter Sandstone. It is composed of a grayish-green or yellow shale with a basal layer of sandstone. The Glenwood was formed as the seas transgressed farther into the Hollandale Embayment during the third fluctuation of Ordovician seas. During this period, Manitou Heights gradually changed from a nearshore beach to a deeper offshore argillite shelf. The water deposited sand and then clay carried from some exposed location on the Transcontinental Arch west or southwest of this area. Like the St. Peter, the lower, sandy layer of the Glenwood Formation contains few fossils. But, the younger shales are full of fossils (Austin 1972, Webers 1972). The flora and fauna inhabiting this landscape were increasing during this period. I have found no noticeable exposures of the Glenwood Formation on Manitou Heights. This paragraph of the landscape's natural history is buried under soil and vegetation.

The Platteville Formation is the youngest member of the Ordovician bedrock of Manitou Heights. The rock is composed of three different members:

1) The Pecatonica Member is a yellowish brown, medium to fine grained dolomite or dolomitic limestone.

2) The McGregor Member is a gray to olive-gray, fine or very-fine grained limestone with rippled bedding that suggests gentle wave action

3) The Carimona Member is a medium to fine grained, light olive-gray or buff limestone with interbedded shale.

The Platteville was deposited during the peak of the third fluctuation of Ordovician seas in this area. At that point, Manitou Heights was situated on a widespread, tropical carbonate bank much like the modern Bahamas. The seafloor would have been relatively quiet, and covered with a carpet of calcareous muck in which cephalopods sank up to two-thirds of their shell depth. When these animals died, the exposed portion of their shells usually dissolved before the remains were completely buried. Consequently, the fossil record of the Platteville reflects long periods of time in relatively short intervals of stone.

Nevertheless, the Platteville Formation contains some of the most fossiliferous strata formed during the Paleozoic Era. The oldest rocks contain widespread bottom-dwelling communities dominated by brachiopods. In slightly younger beds, cephalopods, trilobites, crinoids, and gastropods grow more abundant. In fact, cephalopod fossils attain their highest diversity in the lower-Platteville. These strata also contain the record of a huge volcanic eruption that poured ash over Manitou Heights during this period. The ash, which caused widespread death of the flora and fauna inhabiting the Hollandale Embayment, is now preserved as a layer of bentonite clay (Matsch and Ojakangas 1982, Austin 1972, Webers 1972).

Professor Edward Schmidt published a geological history of Manitou Heights in 1945. In this study, he noted that the Platteville caps the bedrock of the hill from its northwestern edge to a line stretching roughly between Yitterboe Hall and the Science Center (The slope between Holland hall and the Science center may mark this point). He said the formation was about four feet thick in the Boutelle quarry that once laid a short distance west of Agnes Melby hall, and decreased eastward, finally disappearing at the line mentioned above. Schmidt also reported finding a three meter long cephalopod fossil in the quarry. Today, this ancient tropical shelf, its record of abundant life, and the ash from a volcanic eruption are buried under the hill's soil. Like the Glenwood Formation, there are no obvious outcrops of this rock on Manitou Heights. However, I have found pieces of the limestone scattered among the rocky debris in the soils of the restored prairie that skirts the northwestern edge of campus.

The Intervening Years:

The strata that form the bedrock of Manitou Heights mark the last record of sedimentary deposition from Ordovician seas. After this point, the natural history of the area is once again obscured for a period spanning nearly 430 million years. However, some inferences can be made. Ordovician strata in other parts of the Hollandale Embayment prove that the final transgression of inland seas covered this landscape. However, the water had regressed for the final time by the mid-Silurian Period of the Paleozoic (about 430-400 million years BP), exposing Manitou Heights to the forces of erosion. For nearly 100 million years, this area was situated on a flat peneplain with sluggish streams slowly cutting away at the lithified Ordovician sediments. Land plants most likely began to inhabit the area sometime during this period. Amphibians may also have moved over this landscape during the Mississippian Period of the Paleozoic (about 360-320 million years BP).

Lithified sediments in the eastern United States provide evidence that streams were flowing faster over the surrounding landscape during the Pennsylvanian Period (approximately 320-286 million years BP). Lush vegetation, including huge, tree-like ferns and giant horse-tails, grew in numerous swamps. Amphibians, reptiles, and abundant insects crawled and buzzed over the land. Did they inhabit Manitou Heights? Probably, but there is no record of their remains. The record of tectonic movement also proves that North America was tilting from a dominant East-West to North-South orientation.

The equator still sliced through Minnesota at the beginning of the Triassic Period of the Mesozoic Era (about 245 million years BP). But, the continent moved north during this timeperiod, and the equator ran across Florida by about 200 million years ago. At this point, the area was definitely covered in vegetation. Streams and wind continued cutting down into the landscape. Ancient topographical features, hills and valleys, became more pronounced.

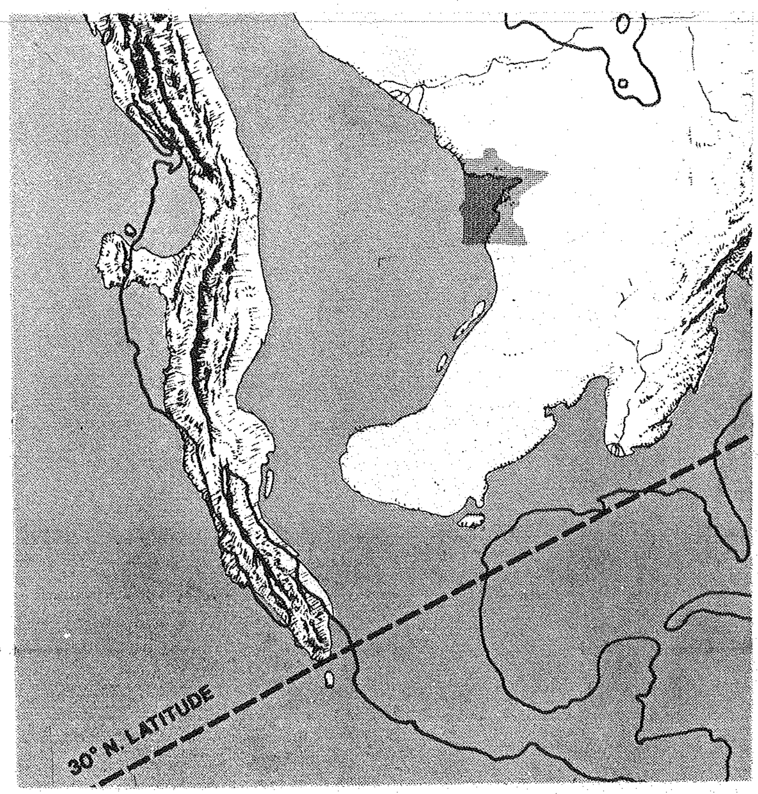

Fig 12: Map showing position and orientation of Minnesota during the mid-Cretaceous. (From Matsch and Ojakangas 1982.)

This area had moved above 30 degrees latitude by the Cretaceous Period (144-66 million years BP), but the environment was still tropical (Fig 12). It is possible that dinosaurs were living in this area. Schwartz and Thiel (1976) explained that some highly rounded and polished pebbles associated with Cretaceous sediments from the southeastern part of Minnesota have been identified as the gastroliths (gizzard-stones) of dinosaurs. Flowering plants also began to inhabit this area during the Cretaceous. Over thirty species, including sequoias, magnolias, and sassafras, have been identified in Minnesota. Maybe, they covered Manitou Heights.

During the Tertiary Period of the Cenozoic Era (65-2 million years BP), the rise of the modern Rocky Mountains began to affect the climate of this area. Manitou Heights became more temperate. Oreodonts (sheep-like animals), titanotheres (rhinoceroses), and many other mammals probobly inhabited the landscape (Matsch and Ojakangas 1982, Schwartz and Thiel 1976). Moreover, the continent continued to move north, while streams and wind constantly eroded the area. In fact, the topography around Manitou Heights was beginning to take shape at this point. Schmidt (1945) suggested that the hill was part of a large plateau, stretching east toward the Cannon River. It was capped with Platteville limestone, and had a much steeper, cliff-like relief.

Ice Age:

The natural history of Manitou Heights becomes clearer again during the Quaternary Period of Cenozoic Era (1.6 million years BP through the present). The first part of the Quaternary has been called the "Great Ice Age." Periodically during the past 1.6 million years, the climate cooled in the Northern Hemisphere, and the huge Laurentide ice sheet began to grow outward from the highlands of Labrador west of Hudson Bay in Canada. Glaciers scraped over much of Canada, through Minnesota, and farther south, following low-lying parts of the landscape. Initially, they "bulldozed" the land, redefining topographical contours, picking up rock, soil, and vegetation as they spread. Animals in their path were forced to migrate southward. Then, average temperatures would rise, and the glaciers retreated, leaving a layer of drift (unsorted glacial debris), boulders, hills, moraines, and lakes to mark their path. Powerful streams, fueled by meltwater, flowed from these melting ice sheets and cut into the landscape. Flora and Fauna also colonized the newly uncovered areas after each glaciation.

Geologists have noted at least seven glacial advances during the past 700,000 years (Patterson and Hobbs 1995). However, the continental record of these ice sheets is incomplete. This has been attributed to a process called "obliterative overlap." Essentially, the progression of one glacier tends to destroy the record of previous advances. Thus, only the topographical markings left by glaciers which spread farther than any subsequent advance continue to mark the landscape. Geologists, Anthony Gibbons, Joe Megeath, and Kenneth Pierce (1984), completed a study that suggested only three random glacial advances out of ten are likely to be noticeable because of obliterative overlap. Actually, the landscape record of North America provides proof that at least three, and possibly four ice sheets passed over this area. Each of these glaciers (and any others that have been erased) tore away parts of Manitou Heights. They rapidly softened cliff-like contours, and diminished the eastern extension of the hill. By and large, they cut the present shape of this landscape

The first ice sheet (peaked about 600,000 years BP) advanced at least two times, and at its maximum extent, may have stretched clear to Kansas City, Missouri and Peoria, Illinois. This ice sheet probably covered Manitou Heights for quite some time, maybe even tens of thousands of years. Moreover, glaciers that presently cover parts of the planet suggest that the ice was probably more than 1,000 meters thick. Till deposited during the retreat of this glacier may be exposed in roadcuts near Faribault (Bray 1977).

A mild, moist interglacial period followed this glaciation. The ice retreated long enough for erosion and weathering to greatly change the post-glacial landscape. Deep river valleys were cut into the land. The fossil record from this interglacial stage also suggests that Manitou Heights was probably covered with a succession of tundra, grasslands and forests inhabited by mammoths, mastodons, saber-toothed cats, musk oxen, llamas, bears, pronghorn antelope, and many other animals we know today (Fig 13).

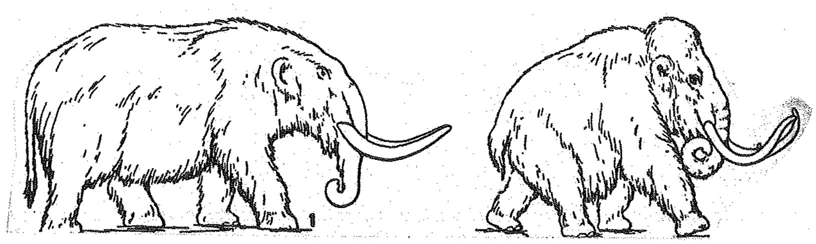

Fig 13: Representation of Mastodon (left) and Mammoth (right) that inhabited this landscape during interglacial periods. (From Schwartz and Thiel 1976.)

During the second glacial cycle (peaked about 400,000 years BP), the ice sheet intermittently spread in at least three advances nearly as far as the first. Bray (1977) pointed out that erratics (glacially deposited rocks) from Minnesota have been found along the terminal edge of this advance. Again, the ice sheet covered this area for a long time. Likewise, it was followed by another long interglacial period. Once the ice retreated, the climate was very similar to the preceding interglacial period. However, there is little evidence of the flora and fauna which inhabited this area. The remains of giant beavers the size of bears have been uncovered in till near Minneapolis. Fossils from Iowa also suggest that the landscape was covered with forests populated by giant ground sloths, tapirs, and many of the plants and animals present in the last interglacial period.

The third ice sheet (peaked about 125,000 years BP) advanced at least three times into Minnesota, but its extent was more limited. This ice sheet may never have passed over Manitou Heights. Perhaps, it simply gave this landscape a strong "chill," and shifted the environment toward tundra. In any event, the interglacial period following the retreat of this ice sheet was much shorter than the others. It may only have lasted about 25,000 years. The fossils of mastodons have been found in till from this interglacial period.

The final ice sheet also spread across Minnesota in a number of advances (Matsch and Ojakangas 1982, Bray 1977, Wright Jr. 1972). However, much more is known about this sheet's movement through this area because of its comparative recency. In fact, it is possible to trace actions of the glacier as it passed over the hill.

Around 30,000 years ago, an arm of this glacier, called the Des Moines Lobe, started to grow outward from the southcentral part of the state (Fig 14). The ice pushed east toward Manitou Heights. Schmidt (1945) reportedly saw striae (scratches caused by glacial movement) on bedrock in the Boutelle quarry that pointed southeast--the direction of the ice advance. Essentially, the ice approached the hill along its northwestern edge, and began to ascend the slope. But, the hill obstructed the forward momentum of the ice and induced some shearing. Higher parts of the ice sheet flowed down over lower ice that had slowed. Simultaneously, some ice was being deflected toward both the southeastern and northern edges of the hill. This process of shearing and deflection forced more ice to pass over those parts of Manitou Heights than along its central axis. As the ice pushed upward, it continually tore away pieces of the Platteville limestone, and quickly eroded the soft St. Peter Sandstone. Thus, the western slopes of Manitou Heights became much more shallow.

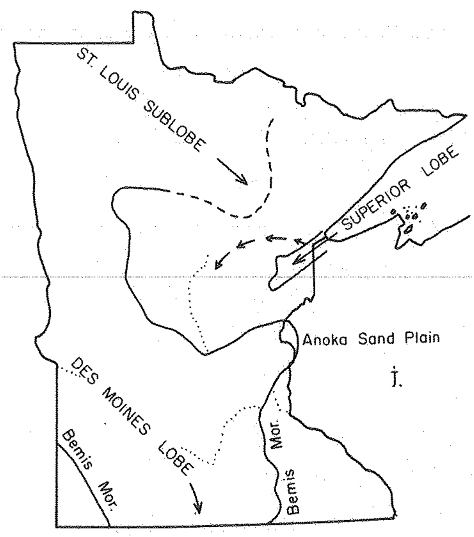

Fig 14: General sketch of the Des Moines Lobe about 14,000 years ago (From Wright Jr. 1972.)

When the ice arrived at the hill's summit, it moved forward with greater momentum, plaining down the limestone until it disappears at the previously mentioned line and grinding the sandstone into a gentile eastward slope. Meanwhile, parts of the sheet poured over the northern and southern rims of the hill, carving and defining the numerous amphitheaters and valleys that mark its edges. Schmidt noted that the ice, had it eroded these valleys for a longer period of time, might have cut the hill in two pieces, adjoining Norway Valley and another amphitheater between Steensland and the Library. The section of the hill upon which Old Main is situated would have become a separate, tiny stump. Then, the glacier tumbled over the eastern rim of the hill, creating steep slopes and valleys as it cracked, crumbled, and slid downward. Finally, the sheet pushed to a point that extends east of Northfield called the Morland margin.[2]

This process was repeated at least twice. After the initial advance, the glacier retreated, possibly even reaching the central part of the state. About 14,000 years ago, it proceeded again to a point extending through eastern Northfield called the Bemis moraine. However, the climate in this area was not cold enough to sustain the second ice-sheet. Geologists, Carrie Patterson and Howard Hobbs (1995), explained that the flat-topped, circular hills that lay a short distance west of Manitou Heights formed when holes melted in the stagnant ice-sheet filled with sediment. Subsequently, the ice retreated from this area once again, leaving a thick coating of gray-drift and some large boulders to mark its passing. The boulder that stands north of the Science Center was probably deposited during this retreat.

[2] Look to Schmidt (1944) for a more detailed description of glacial movements over Manitou Heights.

The geologists also noted two obscure channel scarps that skirt the northern and southern edges of Manitou Heights. Carrie Patterson (personal communication) explained to me that powerful streams emerged from the margins of this retreating ice-sheet, and followed the channels around the hill toward the Cannon River. The erosion caused by these streams helped to refine the topographical relief of the hill (Fig 15). They "sharpened the edges" so to speak. Subsequently, a part of Manitou Heights flowed into the Cannon River and far away from here.

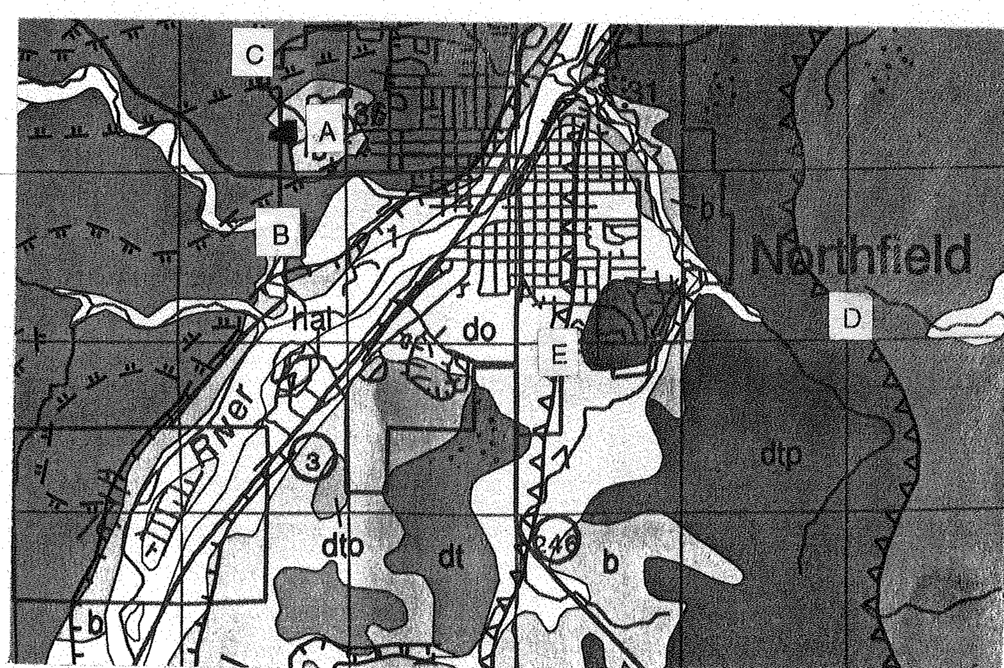

Fig 15: Map picturing the surficial geology of Manitou Heights. A) the hill, B) and C) channel scarps, D) Morland margin, E) Bemis moraine (From Patterson and Hobbs 1995.)

Post-glacial Vegatational Succession:

When the Des Moines Lobe retreated completely from this area, Manitou Heights looked much like it does today. Most of the topographical changes that have taken place since then are attributable to the construction of Saint Olaf College. For instance, some valleys and amphitheaters have been partially filled to provide proper building foundations. Yet, the natural history of Manitou Heights did not end when the last ice sheet melted. A number of vegitation changes shifted the leafy cover of the hill.

Although there is no record in this area, tundra conditions presumably dominated the landscape shortly after the last ice-sheet retreated. But, coniferous forests, which followed the melting ice, quickly succeeded the tundra. Studies of pollen grains that were buried in the sediments of lakes and bogs after the ice retreated suggest that spruce dominated this forested landscape for at least three-thousand years. About 11,000 years ago, birch and alder started to replace the spruce. Then, red pine and jack pine trees began to dominate the forest composition 10,000 years ago (Matsch and Ojakangas 1982). At that point, the vegetation cover of Manitou Heights may have looked something like mature forests in the north-central part of Minnesota. The animals living on the hill would also have been similar to the present inhabitants of that part of the state. Mammoths, mastodons, horses, ground-sloths, and many other animals that lived in Minnesota during the previous interglacial periods disappeared around 9,000 years ago.

As the post-glacial climate gradually warmed, deciduous trees, such as oaks and elms, replaced the conifers. However, the deciduous trees eventually declined, and prairie succeeded the forests. Pollen studies, conducted by Eric Grimm (1983), suggest that prairie grasses were likely the dominant vegetation covering this landscape 6,000 years ago. Evidently, the southern Minnesota climate became drier as the ice-sheet retreated. Fires periodically swept over the landscape, maintaining the prairie. Patches of forest were constrained to low-lying, wet areas which offered the trees some protection from burning. At this point, Manitou Heights may have looked much like the restored prairies north-northwest of campus. Bison and other grassland animals possibly inhabited the area.

Yet, the forests would not be restrained forever. Trees slowly spread across more of the fire-protected landscape. Aspens and fire-tolerant oaks began to sprout among the prairie grasses. Over the course of a few thousand years, oak savanna conditions succeeded the prairie in certain areas. In fact, an oak forest eventually replaced most of the prairie. Oaks comprised approximately 40-70 percent of the vegetation in this area by 3,800-3,000 years ago (Grimm 1983). Other trees, such as ironwood, sugar maple, American elm, and basswood were also present in small numbers.

Oak woodlands dominated this area until the 1500-1600s. At that point, a change in climate conditions (possibly related to a climate reversal between the mid-thirteenth and mid-nineteenth centuries dubbed the Little Ice Age) initiated another shift in forest composition. Grimm (1983) noted that sediment influx in the southern Minnesota lakes he studied increased about four-hundred years ago, suggesting a marked increase in precipitation. Consequently, the frequency and intensity of wildfires probably diminished. This allowed less fire-tolerant tree species to rapidly overtake most of the oak woodlands. Over the course of about a hundred years, more shade-tolerant trees replaced the oaks in this area.

From around three-hundred years ago through the present, maple-basswood forest has covered at least part of Manitou Heights and the surrounding landscape. It is composed mainly of mature sugar maple, basswood, American elm, slippery elm, and ironwood trees. Other notable trees include four species of oak, aspen, cottonwood, two species of ash, and boxelder (Daubenmire 1936, Grimm 1983). The maple-basswood forest is fairly dense. In the summer, the leafy branches of the closely packed trees block almost all available sunlight from reaching the forest floor. But, flowering-plants are abundant in the spring. They sprout from the leaf covered soil and flower before the trees leaf-out. Shortly after winter snows melt and April showers start to fall, the forest floor explodes with the colors of jack-in-the-pulpits, trout lilies, dutchman's breeches, and many more. While most of these "early-risers" die by the beginning of summer, other plants continue to grow in shaded areas and sun-filled gaps. Of course, animals are also abundant in the maple-basswood forest. They range from salamanders to chickadees, cardinals to raccoons, and red squirrels to lady-bugs. No doubt, many of the animals that live in these forests today also inhabited the hill before Saint Olaf College was founded. Yet, one Northfield resident, D.F. Kelly, commented in a county history that these woods were also home to wolves, and bears as late as the 1850s (Shaw 1992).

Schmidt (1945) described the forest covering Manitou Heights during the 1880-90s as “wild, dense, and jungled.” He explained that in many places the thick, tangled underbrush made it hard to walk. The canopy was so dense that “the usual moss growth signs by which to tell where north is were lacking.” Both ginseng plants (a popular source of holistic medicinal teas), and yellow lady-slippers were numerous in the woods, but indiscriminate harvest had eradicated them by the early 1900s. One of the basswood trees on Manitou Heights measured fully 4.5 meters in circumference at chest level. Schmidt also said that the only place to get an unobstructed view off Manitou Heights was from the eastern rim of the hill. He continued: “In all other directions tall trees shut off the outlook. A climb to the roof of the Old Main improved things somewhat, but even from that lofty place about all that you could see in the obstructed directions was an ocean of leaves.” Imagine the sea of green leaves touched by silver moonlight, and the quiet winds of Manitou Heights punctuated by the howl of wolves! This must have been a truly beautiful place when the college was founded.

It is important to note, however, that most of the original maple-basswood forest has been cut down over the past 100 years. Obviously, Manitou Heights has not been immune to these saws and axes. In fact, some portion of the hill's forests were cut before Saint Olaf purchased the property. During a picnic excursion to Manitou Heights in the spring of 1876, Mrs. Mohn (the wife of Saint Olaf's first president) and a group of students discovered a grassy field on the hilltop that had once been cultivated. Mrs. Mohn also described ascending the hill along a "woodman's road (Shaw 1992)." This description suggests that the trees atop Manitou Heights were cut regularly. Yet, Schmidt's comments concerning the forest cover of the 1880-90s prove that the trees were still largely intact when the college was founded. It seems that Manitou Heights was crowned with a combination of mature and second-growth trees at that point.

Norway Valley was also cleared during the late-1800s. The college actually purchased the parcel of land containing the valley in 1889. But, the former owner had cut most of the trees in that area for cordwood shortly before the sale. Although the valley had once contained a dense stand of huge maple trees, they were nearly destroyed. As a type of "penance" for this destruction, the college attempted to re-forest the area (Shaw 1992).

Norway Spruce and possibly pine trees were planted on some portion of the Norway Valley. Schmidt (1945) explained that the valley was originally named "The Vale of Tawasentha" because of its similarity to one described in Longfellow's poem, "Hiawatha:"

"In the Vale of Tawasentha,
In the green and silent valley,
Stood the groves of singing pine trees,
Green in summer, white in winter,
Ever sighing, ever singing."

Yet, the valley was incomplete; it lacked "singing pine trees." In order to remedy this apparent problem, Rev. L.M. Dahl donated the funds necessary to purchase and plant a thousand conifers in the valley (Fig 16). Once these trees had grown, the valley reminded students and faculty of their native Norway. Thus, the valley became known as the Norwegian Valley, which shortened over time to Norway Valley. Consequently, a few of these conifers still stand in that area. The deciduous hardwoods that presently cover most of Norway Valley likely resulted through natural regrowth processes.

Fig 16: Picture of Norway Valley in 1900. The cut-over area was replanted with a thousand conifers donated by Rev. L.M. Dahl. (Felland Photo from Saint Olaf College Archives.)

There is still one last piece of Manitou Heights' natural tale that I would like to pursue quickly. Did Native Americans ever inhabit hill? I have heard rumors that this was a Dakota burial ground before European immigrants settled the area. But, I found no evidence to support this claim. In fact, I was unable to obtain any "concrete" evidence that native peoples inhabited Manitou Heights before the college was founded. Yet, the Dakota people definitely lived close to this area for quite sometime after 1740.

There is a sparse record of Dakota people inhabiting the immediate area. John Wesley North, the founder of Northfield, traveled with a group of companions to Faribault in 1855. The party reported seeing wigwams and a squaw with two papooses in the forest enroute to the settlement. D.F. Kelly claimed that the woods encompassing Manitou Heights were the favored hunting grounds of the Dakota in this area. He also purportedly witnessed a scalp dance in 1856 that was probably held near the railroad tracks between Saint Olaf and Greenvale Avenues. In addition, Mrs. Mohn wrote that a colored man from Northfield had said he was born in a cabin on the southeast side of Manitou Heights. She also suggested that there may have been an Indian trail cutting through a stand of trees south of the campus and up the hill between the Art Barn and Manitou Cottage (Shaw 1992). Perhaps, the Dakota actually walked and hunted among the trees that covered Manitou Heights.

The End:

The final sentences of this tale are filled with the construction of Saint Olaf College, limestone buildings, over a hundred years of students, staff, and faculty walking over the hill, agriculture, habitat restoration, and much more. Their song is sung in detailed historical studies and campus archives. Indeed, these last few words seem to cover the hill. But, let us not forget the rest of the tale, the words that lie between the buildings, and underneath passing feet. These are the sentences written in the bedrock, trees, and contours of Manitou Heights. These are the songs whispered by fossils, rock compasses, pollen grains at the bottom of lakes, and many other things. I have only touched the surface of this long story. Look deeply into any part of this tale, and it shall grow in breadth. There are many more paragraphs that need to be interpreted.

Yet, my song is done. I end with a single suggestion. Look once again over Manitou Heights and the surrounding landscape. Think about all of the places that the hill has been, and how it has changed. Swim back through history. Imagine the bare rock rising from the oceans. Picture warm, tropical seas pouring overhead, and retreating. Stand under the water amidst algal seaweed, trilobites, cephalopods, crinoids, gastropods, and other flora and fauna. Watch as streams and wind cut into the exposed landscape, or huge ice sheets slowly carve and define the hill. Imagine mastodons, giant beavers, and saber-tooth cats. Walk over the post-glacial tundra, and through pine trees, prairie, and maple-basswood forests. Listen as wolves howl. Remember the natural history of Manitou Heights, the amazing story written across the development of the hill, and think about the many ways that it affects the present and future.