Geology of Nahant

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… but you don't have to be in the 6th grade to have some fun with the topics covered here

I. **Introduction.** What aspects of Nahant are included in "geology"? Most people would say that geologists could help explain how Nahant's rocks and soil formed; why Nahant is almost (but not quite) an island; or why 40 Steps Beach is made up of rounded rocks and pebbles whereas Short Beach is sandy. Most people would also say that you need to learn from a biologist if you want to understand a tree. That is true, but a biologist needs to know something about soils (geology) in order to understand the plants in a particular area, just as a geologist needs insight from physics to understand the forces that develop when waves are funneled into narrow cracks in rocks. If your goal is to understand Nahant as it is today, you can look for input from a number of different "ologies":

Geology: Where did the land/rock/soil come from? Is Nahant's landscape frozen in time, or is "geology" an active process that continues to modify where we live? How do people's activities contribute to changes in the landscape? Are all changes bad?

Biology: What plants & animals live on Nahant and offshore? How has this changed over time?

Meteorology: What is the effect of large storms on the coastline? What happens if a storm hits at high tide? Low tide?

Oceanography: Ocean currents, waves, tides, sea temperature, chemistry, marine life: Why is the water temperature at Nahant beaches colder than water just to the south, at Newport RI for example? What implications for sea life does this imply?

Astronomy: How does the rotation of the Earth, that carries Nahant under and away from the Moon and Sun once each day, cause high and low tides? Why are there a few times during the year that tides are unusually high and unusually low? How would you use this information if you obtained your living from the sea?

Archeology: Where did Native Americans live? How did they use Nahant? What evidence of early settlers on Nahant exists? What can we learn about how people lived in the past? Are they mainly different from us because we have video games and they didn't, or did people in the past live by fundamentally different sets of rules?

Geography: How does nature affect the human development of a place like Nahant?
Why did shoe and textile mills develop in Lynn and Lowell, but not in Nahant? Nahant has lots of rock, right on the coast where it would have been easy to ship – why did the big quarries for building stone and cobblestones develop in Quincy, Gloucester and Rockport instead of in places like Nahant or the Boston Harbor Islands?
History: We'll make this an honorary "ology" – what happened in the past, and why?

For the rest of this discussion we will focus on "geology", but I wanted to warn you that I take a pretty wide view of what "geology" includes, and you need to step outside the confines of just "geology" if you want to understand some important processes that affect Nahant.

II. **"Boundaries" and the Main Ingredients of the Geology of Nahant today.** People who live in a coastal community like Nahant know that "nature" can change very quickly: if you don't like high tide, wait 6 hours plus a few minutes and it will be low tide. Although a lawn or some trees will look pretty much the same from one day to the next, the ocean almost never does. Winds can change quickly, causing rapid changes in the direction and height of waves. A beach can experience large waves of pounding surf one day, but the water can be flat calm a day or two later. A hurricane can arrive, last a few hours, and continue on its way. In Nahant, we live in a place where three different boundaries meet (air/land, air/sea, land/sea), and the events that we experience are more complicated than people who live far from the sea typically experience.

In science fiction stories, sometimes there are stories about "Mole People" who live underground. Such people wouldn't have to worry as much or at all about summer/winter seasonal changes or the effects of storms along the air/land boundary, although earthquakes would still be a problem. All of the rest of us live <u>at</u> the Earth's surface though, and we are affected by events that happen on this air/land boundary. In addition, events at the water/land boundary (tides, waves, etc.) influence community life and natural processes (like beach erosion) in places like Nahant. Finally, the fact that the air/water boundary is nearby explains why it is commonly 10 to 15^{o} cooler in Nahant during the summer than it is inland, and also why Nahant is warmer in the fall than nearby towns: plants continue to grow in Nahant into the fall long after frost has killed the same flowers just across the causeway in Lynn. (These effects happen because air warms up and cools down much more quickly than water can. So, in the summer the 50-60^{o} seawater keeps us cooler than the 80-90^{o} land temperatures away from the coast, and in the winter the same seawater helps keep us a little warmer than towns farther inland.)

The sketch below is my cartoon view of what, to me, are the three types of boundaries (air/sea, sea/land, air/land) that influence Nahant's "geology":

Air

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                     _________________
                    /       Land       \
  Air              /                    \
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  Sea            /      Nahant     Land   \  Sea
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III. **Rocks and Geologic History of Nahant.** A summary of the geologic history of Nahant, from oldest to youngest follows. I will indicate gaps in our knowledge by ******.

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Precambrian period. Geologists think the earth formed about 4.5 billion years ago. There is no record preserved in rocks at Nahant until early in the Cambrian period. Precambrian/Cambrian boundary about 600 million years ago.
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Weymouth Formation. Sedimentary rocks form when grains (clay, silt, sand, gravel, boulders, etc.) being transported by moving water or air are deposited when the water or air slows down. Sedimentary rocks can also form by chemical processes – salt layers are left behind if a sea dries up, and limestone can form by accumulation of shells or other chemical processes. The Weymouth Formation is package of sedimentary layers (limestone and siltstone) along the cliffs at East Point (stay well back away from the cliffs). It was deposited in Lower Cambrian time, around 580 million years ago. Louis Agassiz, a famous Swiss geologist who worked at Harvard and lived in Nahant from the 1850's, was the first person to describe the sedimentary rocks at Nahant. (You can find references to Agassiz in the book Nahant by Stanley Patterson and Carl Seaburg, published by the Nahant Historical Society.) The limestone beds are white to gray; the siltstones are gray, green and black. Some have oval "concretions" of chert: a silica (quartz) rich rock. The siltstones are thought to be deposited in deeper water than the limestones above them, so geologists think that the water was getting shallower and shallower as the rock unit was deposited. (This might mean that sealevel was dropping, or that the land was rising, or perhaps that the shoreline was moving out to sea for some other reason). The rocks at Nahant are similar to sedimentary rocks exposed in Quincy, Weymouth, and Attleboro – so, where possible we use an already-defined name (Weymouth Formation), rather than inventing new names like "Nahant Formation".

Other Cambrian-age rock packages with similar fossils to the Weymouth Formation can be found sprinkled along the eastern U.S. from Florida to Newfoundland, and in Ireland and elsewhere in western Africa and Europe. However, fossils in the Weymouth Formation are distinctly unlike those in rocks of the same age in New York State or further west. Geologists believe this means that the scattered fragments, including the Weymouth Formation, were not deposited on the North American continent when they formed. Instead, they formed somewhere else on the earth (some geologists believe they were once a part of Peru!) and, by slow plate-tectonic motions over hundreds of millions of years, were broken up and rafted to their present locations during large-distance faulting or continental collision. These contrasting fossil assemblages provide some of the most convincing evidence that the Appalachian Mountain chain contains bits and pieces of completely unrelated rock types, so the Nahant rocks are critically important to geologists.

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Unknown time separates Weymouth Formation from sills and dikes, following. The sills and some dikes seem to be older than the Nahant Gabbro, dated at 460-490 million years.

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Sills and dikes. Sometimes the earth's interior rock melts, to form a hot glowing "magma". Liquid rock is less dense than the rock that it melted from, so it tends to rise towards the surface if it can, for the same reason that a soccer ball will rise toward the surface if you push it beneath the water and let go. (In the soccer ball's case, the air in the ball is a LOT less dense than the water surrounding the ball, so the force "pushing" the ball upwards is very strong. Magmas don't usually rise that fast unless they are really gassy like the ones that bring diamonds to the surface, but the idea is the same.)

Sometime after the Weymouth Formation sediments were deposited, the earth's mantle melted beneath the sediments, and a kind of <u>magma</u> called "basalt" formed. Basalt is a common magma type – the Hawaiian volcanoes are almost entirely basalt, as are the eruptions along all of the center of the Atlantic Ocean that push North and South America a bit farther away from Africa and Europe each year. Sometimes the magma reaches the surface to make a <u>volcanic eruption</u> (a lava flow, for example), but sometimes it freezes inside the earth before it reaches the surface. In this case, it forms an <u>intrusion</u> into pre-existing rock. Both types (volcanic, intrusive) are examples of <u>igneous</u> rock: rock that forms by cooling of magma. Most of the rocks of Nahant are intrusive igneous rocks; I have not seen any volcanic rocks in Nahant.

If magma is rising upwards through a horizontal stack of sediments (a plate of pancakes), and the route upwards is blocked, the magma may force its way sideways, perhaps following a horizontal plane of weakness separating two pancakes (sedimentary layers). The magma would squeeze into the new fracture, and force the overlying pancakes (sedimentary layers) up to make room. The cooler pancakes (sedimentary layers) would quickly freeze the magma if the layer wasn't very thick. This would leave a solidified <u>intrusive igneous rock</u> in a horizontal position, parallel to the sedimentary beds, that we call a <u>sill</u>. The sill is younger (more recent) than the rocks it intrudes, and the contacts the sill makes with the sedimentary rock are more or less parallel with the sedimentary layering. Because the layering is parallel to the sedimentary layers, you have to be enough of a geologist to recognize an igneous rock when you see one – otherwise you might just think it is a big package of sediments. Two sills have been mapped in the Weymouth Formation on the Boston-side of East Point.

Because the Weymouth Formation sedimentary rocks are now tilted on edge, like a deck of cards on end, **some geologic force must have folded or faulted the Weymouth Formation** to move them from their original horizontal to their present near-vertical position. It is possible that this tilting occurred after the sills intruded, but before (some of) the dikes (described below) formed.

If magma is rising through more-or-less vertical fractures through rock, and some of it freezes, another kind of igneous intrusion, called a dike, forms instead of a sill. A dike and a sill are the same sort of feature, except a dike is a (more or less) vertical fracture filling and a sill is a (more or less) horizontal intrusion. There are over 100 dikes exposed around East Point – one of the densest accumulations of dikes known from anywhere in the northeast. This much intrusion always has significant impacts on surrounding rocks. For one thing – the magma brings in a lot of heat, so the surrounding rock can be metamorphosed (new minerals grow in the rock). Another impact is that the shape and size of surrounding rock will change. Say a friend holds a thick phone book with the pages pointing down, and you put a flat hand in between a pair of pages. Your hand represents the frozen magma that now fills the dike: intruding your hand into the pages (intrusion of magma into the rock) pushes the rock on both sides out to either side, and the phone book (the intruded rock unit) is now a little wider than it was before. If you put your other hand between another pair of pages, the same thing happens again: the phone book is now wider by two hands (dikes). If 70 of your friends also can figure out how to get their two hands into the same phone book at the same time – the phone book is in for a lot of stretching, and so is the earth's crust whenever as many dikes intrude the rock as you can see in Nahant.

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We don't know exactly when the sills and dikes intruded the Weymouth Formation. The sills have been crosscut by dikes, and you can find places where an older dike has been cut across and offset by a younger dike. So, the sills and dikes represent several generations of intrusive igneous activity. The relationship of the dikes and sills to the Nahant Gabbro (see below) is not certain – some dikes may be older than the gabbro, although some are younger because they crosscut the gabbro.

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Nahant Gabbro (intruded 460-490 million years ago). If magma cools in a large mass beneath the earth's surface, the slow cooling permits crystals to grow larger than in the smaller dikes and sills. A "gabbro" is a coarse-grained (large crystals) igneous rock formed when basalt magma cools slowly. The Nahant Gabbro is about 100 million years younger than the Weymouth Formation sedimentary rocks. It has been dated by radioactive decay methods to be between 460-490 million years old, which makes intrusion of the Nahant Gabbro an "Ordovician" age event. (The words geologists use as shorthand references to large blocks of time will not be familiar to most people. You can find the geologic time chart on the internet in many places – the U.S. Geological Survey's example is at http://geology.er.usgs.gov/paleo/geotime.shtml, for example (web address active as of 9/2004.)

Some **basalt dikes** crosscut the Nahant Gabbro, so there was some magma intrusion following the crystallization of the main mass of the intrusion. It is not known whether this activity represents a closing phase of the Nahant Gabbro intrusion, or is "significantly" (millions of years, 10s of millions, 100s of millions…) younger in time.

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Uncertain time gap between Nahant Gabbro and dikes from faulting and folding described below.
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Faulting and folding. From 40 Steps Beach, a path goes up to the top of the cliff where you have a good view of Egg Rock. You can see dikes that crosscut the Nahant Gabbro, as well as younger fractures filled with white quartz and/or calcite, and with grass-green (or, pistachio-green) epidote crystals. These fractures are younger than the rocks described above, since they offset both gabbro and dikes. Water flowing through the fractures (while the rock you are standing on was still "some distance" down in the earth) deposited the quartz, calcite, and epidote. If you walk across the rocks (Cedar Point) separating 40 Steps Beach from the beach at the Marine Science Center, you will see other examples of fractured and offset dikes, and cross-cutting dikes. At the top of the rock knob at the southeast side of 40 Steps Beach, if you look along the rocks towards the sea you will see folded "sheeting joints". Sheeting joints are parallel cracks in rocks near the earth's surface, that look like the "cracks" between the layers of an onion. They form in rock that is near the earth's surface, when the overlying rock erodes away, allowing the deeper rock to expand upwards a bit while its "feet" are still firmly hooked into deeper rock. Lots of places have rock with sheeting joints (you can see them in any Vermont granite quarry, for example) but the highly cool thing about Nahant's sheeting joints is the fact that ours have been *folded* (I haven't tried squeezing an onion sliced in half to try to demonstrate how this might have come about, but you can if you have the courage.)

We don't know when the faulting and the folding occurred, except that it has to be younger than the Nahant Gabbro and the dike intrusion, since they are all affected. It is possible that faulting and/or folding could be related to the *Alleghanian Orogeny*, a Late Carboniferous/Early Permian mountain building event around 280 million years ago that is generally thought to represent the time of final assembly of "North America" into the units we see today, including the rocks of Nahant. Following the Alleghanian Orogeny, there was no Atlantic Ocean: you could have walked east from "Nahant" into rocks that are now exposed on the west coast of Africa (in southern Morocco and northern Mauritania).

If the faults and/or folds were not caused by Alleghanian forces (you would fold, too, if a big raft of Weymouth Formation sedimentary rocks was shoved into your car in the parking lot, driven by Africa homing in on North and South America), it might have been related to the *opening* of the Atlantic Ocean beginning about 200 million years ago in the

Triassic. The mantle beneath eastern North American began making basalt in huge amounts for some reason, and this rising basalt pushed the crust up and outwards. Repeated dike injection began to push the two plates apart, and Africa/Europe began to slowly move east away from the Americas.

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There is a gap of 200-300 million years of "lost time" in Nahant's geologic record following the faulting/folding event(s). The next youngest event is the glacial erosion (scouring of smooth bedrock surfaces) and deposition (deposits of glacial "till" on the bedrock by advancing or retreating glaciers). The last glaciers started melting back 10,000 years ago.

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Although the earth has undergone periodic glacial epochs from Precambrian time forward, evidence for glaciation in Nahant is limited to the most recent periods beginning about 200,000 years ago, when a number of ice ages came and went. New England has undergone several pulses of ice advance and retreat, and the glacial record is very complicated because a new ice advance tends to plow up much of the sediment record left from the previous pulse, and rivers from melting glaciers can wash away much evidence from the glacial period just ending. We think the ice in Boston at the height of the last ice advance was about 900 feet thick. This is based on studies that suggest that Mt. Katahdin in Maine was almost-but-not-quite ice-covered, so if you know how thick the ice was that part of Maine, and how ice behaves (in a plastic manner, so "really thick ice" in Maine/Southern Canada would spread out sideways in a predictable way "downhill"), you can estimate how thick the ice layer would be a couple of hundred miles downstream in the Boston area. Beneath a glacier, soft, fractured rock erodes quickly whereas harder rock resists erosion. Big Nahant and Little Nahant were probably left standing because they were formed of more resistant Nahant Gabbro. The rock in between was eroded away more easily, perhaps because the rock there was more fractured, which would make it easier for the ice to break up and carry away.

Streamlined hills called **drumlins** commonly form at the base of thick ice sheets. Many of the islands in Boston Harbor, and a number of hills across New England, are drumlins. Nahant may be an example of this form of deposit, but it does not seem a "classic" drumlin form if so.

The sediment that lies on the bedrock (Nahant Gabbro, etc.) in Nahant is full of clay, sand, and stones. There are angular stones, as well as fairly rounded ones. This hodge-podge of grain sizes and grain shapes is common in **till**, a sediment that is deposited at the base of advancing glaciers or left behind when the ice gradually melts. An advancing glacier carries a large amount of sediment in its base, and this material can be plastered onto the top of the rock over which the glacier is moving. The angular fragments and the wide mix of grain sizes, from tiny (clay) to large (rocks), are evidence that the sediment was not transported by moving water (river or waves at a beach), since being bounced around in a streambed would quickly round the grains and separate the fine particles from the coarser ones. It is not uncommon to see fragments of rock that do not occur on Nahant in the glacial till. Pink-to-purple, fine-grained Lynn Volcanics are especially easy to spot. A good place to study till is along the path to the top of the rock ledge at the north side of 40 Steps Beach – you can see sediment exposed along the way up, but it is also exposed along the top of the rock cliff.

900 feet of ice (and even thicker towards the north, where the glaciers advanced from) represents a huge amount of water that must have come from "somewhere". Where did the water come from? The world's oceans supplied the water, and worldwide sealevel was significantly lower 15,000 years ago than it is now. (Some people think the "beach" off Nahant would have been located farther out than Provincetown – a long way to haul your cooler and beach chairs! It wouldn't have mattered, though, because with 900 feet of ice in Nahant, nobody was going lobstering around here anyhow.) So, sealevel drops when glaciers expand. Nahant would not have been an "island" then – just bumps on the land surface, buried in ice.

When a glacier melts, two things happen: the water runs back downhill quickly to the sea (so, sealevel starts to rise quickly at the end of a glacial period), and the rock can relax because it doesn't have 900 feet of ice on it any more.

When you sit or lie on a mattress, your body weight squashes the mattress down. When you get up, the springs in the mattress push it back up pretty quickly. If you put 900 feet of ice on Boston, it weighs a lot and the rocks beneath the ice are forced down, just like the mattress when you are on the bed. Unlike the springy mattress though, rock is verrrrrrrrrrryyyyyyyyyyyy slow to relax (this is partly why people don't use rocks for mattresses...the other reason, of course, is that they weigh a lot). So, once the glaciers left by melting away, the sea came flooding back in but for a while Nahant (and the rest of the Boston area) would still have been at a lower elevation than our current elevation. It is possible (even likely), that for a while, all of Nahant was below sealevel, until the upward-springing of the rock brought us back above the surface. When you jump off a diving board, it doesn't just come back up once and stop – it goes too far up, flaps back down, etc. a few times before coming to rest. A diving board is really springy (like a mattress), so the motion stops in a few seconds. Rock is verrrrrrrrrrrrrryyyyyyyyyyyyy much stiffer than a diving board, and, even though the last ice melted back about 10,000 years ago, the rocks in New England are still "bouncing" a bit (on the order of 1 millimeter/year only along the Maine coast, so don't try to sell tickets to watch sealevel change on this account). If you want to learn more about this activity, you might search the internet for "glacial rebound New England".

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After Nahant formed an island (or two or three) that poked up out of the sea and stayed there, there was probably not a sand spit initially linking Lynn and Nahant. As the land

rose (glacial rebound), the shallow-place-now-called-Nahant would have more of an impact on waves approaching the shoreline. Waves approaching Nahant slow down, and wrap around Nahant on both sides. This causes part of the waves to move parallel to the shore (down the beach from Swampscott towards the present causeway), which in the long run carries sand down the beach towards the traffic circle. In addition, the Pines River and the Saugus River both transport sediment out to sea, which is deposited in the shallow water in Lynn Bay. These two sediment sources combined to make **Nahant one of the world's best examples of a *tombolo*** – offshore rocks connected to the shore by a long sand spit. Before the roadway helped stabilize it, the sand might wash away in particularly violent storms, but wave action caused by Nahant's position offshore and the continued influx of sediment from the two rivers would rebuild it eventually.
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Nahant Geology Today

Geology isn't just history, although that aspect of geology is something that geologists have fun working out. Here are a few examples of the interplay between geology and life in Nahant. You can probably think of other examples as well.

Economic Geology. The Saugus Iron Works (see National Park Service website info at http://www.nps.gov/sair/) was one of the earliest metal foundries in America. The Nahant Gabbro was an important local factor in making it possible to refine iron from "bog iron ore" in swampy land near the Iron Works. (Iron smelting was possible here because of the proximity of iron ore from the swamps, charcoal from local trees, and a source of "flux" which is probably what the Nahant Gabbro provided.) Chunks of Nahant Gabbro were extracted from the area around 40 Steps Beach and shipped around Nahant and up the Saugus River to the Iron Works. (Thanks to Arthur Berretta for this information.) Although the Nahant Gabbro itself contains some iron-rich zones (look for especially dark chunks of Nahant Gabbro among rounded beach stones – you'll find these are especially heavy, for their size, due to higher % of iron-rich minerals like magnetite) – it is most likely that the Nahant Gabbro was used because of its abundant calcium-rich feldspar content permitted its use as a "flux" – material that helps the mixture to melt at a lower temperature, and that will combine with impurities that float to the surface of the melted rock and ore. The puddle of dense molten iron in the furnace sinks to the bottom of the "pot", while the calcium-rich "slag" floats on top and captures a lot of the impurities. You can pour out the molten iron to make nails, etc. and discard the slag.

Beaches and beach processes. You can study these every day at Nahant. Waves, tides, position (sheltered? exposed to open ocean?), and geology (rock cliffs? sand? till?) affect the shape and size of beaches, whether the beach has rock or sand, the movement of sand/ stones, erosion of rocks etc.

Fishing. If you scuba dive, you know that lobsters like to live in rocky areas. Sediment moving into Lynn Bay from the Saugus River and Pines River should have an effect on shellfish etc.

Environmental Geology. If water from the landfill on the Saugus River carries any contaminants into the river, it might affect shellfish and other life in Lynn Bay. If sealevel rises in the future by several feet as some people feel may happen due to global warming, Nahant may need water taxis or a higher road along the causeway.
Earthquakes. In the 1600's and 1700's, a few earthquakes in the Boston area, centered in the ocean off Cape Ann (Gloucester area) caused many chimneys in eastern Massachusetts to collapse. Geologists do not understand why those earthquakes occurred, and there is no way to predict whether they were one-time events or might be repeated. The fact that it has been over 250 years since the last good-sized one might be either good news or bad news. In places with many earthquakes each year (California, Japan), scientists can study the history of large numbers of local earthquakes to draw conclusions about causes and repeatability of earthquakes in those areas. In areas like New England, with only a few earthquakes each year, it is much more difficult to "mine" the historical earthquake records to figure out what is likely to happen next.
Groundwater Geology. Nahant soils are generally clay-rich so water doesn't flow as quickly through it as it does in, say, the sandy soils of Cape Cod. In much of Nahant (higher elevation parts of Big and Little Nahant) the soils seem to be thin – bedrock is close to the surface and water may not easily be able to move through rock unless it has many fractures. During heavy rains, the thin soils may saturate with water, causing the wet basements that are common on my street, at least.
Soil Creep. Each winter, when water in the top few inches of the soil in New England freezes, the ice expands and pushes the soil particles up. Each spring, the soil thaws and gravity pulls each soil particle downslope slightly. Over the years, this freeze/thaw cycle moves all soils on slopes downhill. My hope (and my downhill neighbors' hope), is that my basement is tied well enough to the rock and soil so that my house doesn't become part of their house on any timescale that either of us cares about.
Soil Formation. "Soil" is loose granular material with enough organics (bits of decaying leaves, etc.) that it can support the growth of plants. With each rainstorm, new water soaks through, helping to dissolve a bit of rock and create some more grains. Microbes in the soil help break down leaves, twigs and other decaying material. The skunk that lives in my back yard helps by digging holes in my yard that let in air and water a little more easily. These help the chemical and biological weathering processes that occur in soil. The upper few inches of a soil is a tremendously complicated natural factory, in which earthworms and microbes rule. (Worms turn over the soil, help aerate it with their burrows, etc.)
Scenery and that "Nahant Feeling". It wouldn't be the same without Geology... now would it?

Some Geology Projects

Study erosional glacial history of Nahant. Walk around town to see if you can find places where the upper, smooth surfaces of rock are exposed. Many of these will be in much the same shape as when the ice melted back, 10,000 years ago. Sometimes you can find “glacial striations”, thin grooves in the rock formed when a rock in the bottom of the glacier scraped into the rock underneath, showing the line along which ice moved.

Study depositional glacial history of Nahant. What sediments did the glaciers leave behind? (Look around for exposures of till sitting on top of bedrock surfaces. One or two places have been noted above, but you can find others.) Dig out a few of the rocks from these till layers and study their size and shape. Does it look like these could have been beach pebbles? Why/why not? *In a place that has been inhabited as long as Nahant, sometimes you will be looking at soil or rocks that people have brought in to level their property. It can be hard to detect this.*

Find exposures of the Nahant Gabbro, dikes, and fractures. (See notes for 40 Steps Beach area above.) Can you see why geologists say that the Gabbro came first, the dikes came next, and the fractures were last (most recent in time?). We call this “relative dating” in geology: sometimes you don’t know exactly when a certain event happened, but you can say something about what happened first, second, third... etc.

Study Beach Processes. (1) Spend time at an exposed beach like 40 Steps. Why are there many rocks here, rather than just sand? (Where would the sand go if there were large waves?) What happens to pieces of rock and sand when waves crash on them? Why are the rocks at this beach mostly rounded? Why are parts of the rock cliffs smoothly polished? (2) Compare these observations with processes at a sandy beach. Are the waves larger or smaller? Why are there fewer rocks and more sand? If you have a mask and snorkel, spend time right along the shore, and watch how the sand grains move when the waves break and move up and down the shore. You will definitely look like a geek doing this, but it is the only way to see how sand moves by wave action. (Maybe this is one to save for a vacation in the Caribbean. You will still look like a geek but nobody at home will know about it.) (3) Take a picture of the width and steepness of Lynn Beach during the summer at low tide (or high tide). Take another picture at the same tide during the winter, when storms may be a bit stronger. Is the beach steeper or wider at one time of the year vs. the other? Why might this happen? How about for other beaches in town? Record time of day, tide state etc. for each picture. (4) Take an empty water bottle with a cap to the beach and throw it in. (Take it out later so you don’t trash up the beach.) Track its movement along the shore (if any). If the wind is really strong and you think the bottle is acting like a sail, you can put some water in it until it just barely floats. Which direction were the waves coming from on that day? “Longshore drift” is an important mechanism of sand transport along beaches.

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Northeastern University's Marine Science Center at East Point: http://www.marinescience.neu.edu/