Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
1984 Volume VI: Geology and the Industrial History of Connecticut

The Ground We Walk On

Curriculum Unit 84.06.08
by Margaret M. Loos

Introduction

As I live and teach longer, I am convinced that the youth of today is so engrossed in the here and now that they often lose sight of the rich lessons of the past and they can't yet recognize the promises of the future. The study of Earth Science as it is required in our curriculum allows us an opportunity to develop an understanding of the processes that account for their present environment, both natural and man-made. I hope that this study will stimulate their imagination and curiosity and inspire respect for that environment.

This unit will explore those processes of geologic change, both bed rock and surficial, in evidence in the New Haven harbor area. It is designed for students of earth science in the eighth grade. It should be adaptable for any middle school or high school level. I expect to teach it in four weeks, using one day of each week as an on-site day. At each site I will emphasize a major geologic process or concept. In class we will use teacher demonstrations and experiments designed for, and hopefully by, students, I hope those students will gain insight into the special qualities of scientists who make geology their career or avocational interest. I'm particularly interested in seeing whether my students can be "turned on" or find excitement in truly earth-shaping events instead of tolerating a science class. The site I have chosen happens to be the New Haven harbor area, but the information, strategies and activities which I will employ should be adaptable for many other sites in this region.

STRATEGIES

After introducing the students to some image producing pictures on the formation of the earth, such as *The Earth Is Born* , available at the Peabody Museum or the National Geographic's film on the formation of Surtsey, I would ask them to mentally create an image of a featureless meeting of sea, sky and earth. Then, *on site at Lighthouse Point* , I would ask them to erase for a time those features of the harbor that man has effected. Perhaps they could picture themselves as being on the first ship from the Old World to enter the natural harbor. By setting periods for silent "meditation" and individual observation, I would allow students to write down any questions they might like to answer for themselves or others about the large physical features of the landscape as they look into the harbor, or even the smallest observable features of the beach itself.

By developing the students' observational powers by these visits and by taking slides for a student-teacher produced slideshow, I hope to acquaint them with the constructive and destructive forces in operation now and in earlier times in our area. The features present in our locations, such as cliffs, beaches, marshes, and feeding rivers will be examined to uncover the possible explanations for their formation and to expand to the greater features of the Sound, Long Island, the Continental Shelf and continental and ocean plate actions. The effects of moving water will be emphasized. The variety of coastal features will enable us to relate them to maps, making map study and mathematic exercises based on map study more realistic. Several printings of maps of this section of Connecticut and of the harbor will disclose the changes on the harbor's borders effected by geologic processes or by man's use of those borders. The different usage of the land at the water's edge by private owners and the municipality, such as recreation, industry, transportation, and other pursuits will be discussed throughout the classes. Students will be asked to examine their own and the public's attitudes toward those choices.

Of course, in order to understand the concepts of the earlier formative periods in the harbor's history, bedrock geology will be studied. The recent activities of the volcanoes in Hawaii and Mt. St. Helens have been presented in magnificent filming and photographs for classroom displays. These demonstrate that the earth is eternally primitive. In order to clarify the building of the Iayers of the earth we will go from the lava of the volcanoes to the rock cycle, examining examples of local igneous, sedimentary, and metamorphic rock on our sites and develop a collection of these to add to the teachers demonstration collection. Glaciation effects will be examined in depth. The economic usage and environmental implications of our local rock formations will present up-to-date aspects of bedrock geology.

These are the strategies I believe I can use to explore and make more relative the study of geology for my eighth grade students. As much as possible each of these phases will originate in the observable and tangible and expand to develop vocabularies, concepts, activities and *imagination* with the goal of producing understanding of the past's influence, the present's impact and, hopefully, to lead to some skills for dealing with the future of the harbor's environment.

LIGHTHOUSE POINT SITE I: STUDY OF EROSION

As we stand on the beach at Lighthouse Point, some of the features that might catch our fancy, geologically speaking, are the coarse sands of the man-made beach, the massive granite boulders that form the borders of the beach and front the lighthouse, the actual material that makes up the lighthouse, and the great granite blocks cut to shape a breakwater. The newly poured asphalt of the added parking lots cover much, but not all, of the uneven terrain abundantly blessed with rocks of all sizes. As our gaze sweeps toward the New Haven harbor, the graceful curve of Morris Cove is broken as the modest cliffs of Forbes Bluff jut forward. Looking past the navy and Coast Guard facilities and recreational area of the East Shore Park we see the ribbon of the Quinnipiac River widen into a small, but active, harbor. A point of land eases into a long flat landfill area which supports the Long Wharf commercial enterprises, then a small bit of marsh, a cove and finally the West Haven beaches that reach to Bradley Point.

How did such an environment come to be? How do geologists explain these features? Students will not be surprised to hear that early explanations were based on man's self-centered view that the earth was a place prepared for man, existing for him alone and therefore, the reshaping of the earth could only be explained by the creator's reaction to man's actions—a great flood. However, man is a curious creature who looks for relationships, who wishes to understand his environment in order to control it. During the 1800's geologists' extensive observations and collection of information led to development of currently accepted theories about the geologic processes that built and carved the features of our earth and the geophysicists of the twentieth century gave further explanation and documentation.

The processes that shape the earth can be divided into the *constructive* , or uplifting forces, and the *destructive* , or wearing away forces, such as erosion, weathering, and submergence in our theater of study, the New Haven harbor. It is easier on our beach to deal first with the destructive forces which rearrange the earth we walk on. We find them in our field study as small models which can explain some geological phenomena of a much grander scale. For instance, after a heavy rain would be a particularly advantageous time to examine the processes of erosion carried on by moving water. When we consider the cycle of water on the earth we would think of *precipitation* , (snow, sleet, hail or rain, and condensation) the *transport of water* on the earth, and *evaporation* or return of the moisture to the atmosphere. This is the hydrologic cycle. [1] The transport stage is the most active in shaping the earth, principally in the process of erosion where material is transported by moving water. As the water runs off the higher shore rocks, down through layers of different sized rocks and sand particles, the heavier rocks remain solidly in place and the water is forced to flow in a different direction, perhaps carrying off a few particles of the rock. Smaller rocks are carried a distance, perhaps to become lodged against the larger. Some grains of sand are rearranged, some carried relatively long distances to be dropped off, and the finer particles are carried in suspension, or actually dissolved, losing their particulate character. The result is a rearrangement of the small strip of beach to form a small valley or valleys. We can identify some of the contributing factors as the resistance of the solid materials, the strength and magnitude of the flow of the stream, the gradation of the land over which it flows, and the physical and chemical makeup of the material the stream encounters. Sometimes we can determine the origin of the material by examining it. In addition the stream may deposit the material (*alluvium*) in certain formations, such as a triangle or delta. The stream may curve or form *meanders* , or be cut off in a series of short, or braided streams, or cut off as pools called *oxbows* . [2] We may use this model to explain the action of rivers in general. They also must have comparable abilities to transport and deposit *s* ediments. The diagrams on the following page illustrate some of the possible formations in river or stream valleys.

(figure available in print form)
(1) Original Valley
(figure available in print form)
(2) Branching
(figure available in print form)
(3) Braiding
(figure available in print form)
(4) Meander
(figure available in print form)
(5) Oxbow New Course

STAGES OF DELTA DEVELOPMENT

Symbols

Sediments

(figure available in print form)

Marshes

(figure available in print form)

(1) What changes occur in the sediments and marshes at each stage?

(figure available in print form)

(2) How would changes in amounts of precipitation and evaporation affect this process?

(figure available in print form)

(3) Examine some maps to find some delta formation in an atlas. Find the Mississippi delta.

(figure available in print form)

Another agent of erosion on the beach (and other environments) is wind. When the sand surface is dry and a strong wind is blowing the sand grains seem to leap quickly for short distances and to form a light film moving across the beach. This is called saltation. The sand surface seems to creep along. Although this is more common with finer sands, it can be discussed on the beach and sands from other beaches (including black sand) can be displayed. Sometimes enough sand will accumulate in a spot as a small mound and will start rolling down hill making a smooth slipface or a tiny sand dune. We may surmise that these processes to change the features of a beach are determined by the strength of the wind and the size of the particles and the type of terrain.

Students may learn (either on the field trip or in the classroom) that the agents of transportation in erosion are:

1. Water in the forms of rivers, waves or currents.
2. Gravity, from small slippage to avalanches.
3. Wind, from the movement of one grain of clay to massive dust storms. [5]

Since the size of the sediment particles is an important factor a gradation of these sizes gives an opportunity to learn measurements ranging from those discernible and measurable on a metric ruler to microscopic particles. They are, gravel—greater than 2mm, sand—from 1/16mm to 2mm, silt—from 1/256mm to 1/16mm, and clay particles—less than 1/256mm. [6-]

The processes we have observed or discussed in erosion are:

1. Saltation, on the beach
2. Suspension of materials in moving water
3. Solution, dissolved material in moving water
4. Traction , dragging or pushing of material by moving water

In examining the beach we may find ripple marks, burrowing, different shaped deposits and beds, and maybe, in perfect conditions, mud cracks. They should all be discussed for future reference. Animal and plant life give opportunities for material for side projects and to give evidence that their remains must contribute organic material to the sediments. The salt present in the water of the sound also makes an addition to the sediments.

MORRIS COVE SITE 2: SOME COASTAL PROCESSES

Traveling toward the harbor, we encounter the pleasant crescent of a small beach lying between the jutting rock formations of Lighthouse and Forbes Bluff. This beach is produced by the irregularities in the coastline and the availability of sand between the outcrops of bedrock. Waves bend to conform to the shape of the coast and their energy concentrates on the areas that project out the farthest to meet them. The amount of cutting the waves do on the shoreline depends on the makeup of the materials that they encounter and the energy of the waves. High energy waves occur in winter or storm conditions and low energy waves occur in summer or gentle waves. Sand is deposited in summer conditions and the beach is built up, and it is removed in winter conditions.

(figure available in print form)

A. Erosion is usually greatest on projecting land.

(figure available in print form)

B. However, the material of the projecting land is very resistant.

Evidence of the energy level of the waves that encounter the shoreline can be interpreted by the nature of the beach that is created. The high energy waves can remove the fine sediments and leave a steep slope, and the low energy waves generally leave a gentler slope and do not remove the fine sediment. Therefore, the gentler the waves the finer the beach sand. The amount of erosion caused by the waves at Lighthouse Point and Forbes Bluff is limited because of the resistant nature of the rock formations there, but ordinarily any projecting coastline would experience the greatest erosion. Beaches such as that at Morris Cove continue to recess but residents eager to retain their land build man-made barriers in an attempt to withstand the wave effects. Students should examine these barriers to see what happens to the sand deposits when an interference to waves is presented.

If we watch waves break on the beach we may guess that the energy of a wave is mostly expended there, but what can we discover about the effects of the waves on the material under them? It is important to point out that waves are actually movements of energy and not of the actual molecules or particles of water. The molecules themselves only travel in a circular path theoretically half as great in diameter as the wave's length. If we can examine a flat area of coastline or obtain pictures of it at low tide we can gather evidence of the wave action there. If the path of the waves' circular movement never touches bottom they leave no ripple marks. If the waves are not breaking, but moving in gentle movement (oscillating waves) they leave symmetrical ripple marks and if the crest of the waves override their low points or troughs, they leave asymmetrical ripple marks.

(figure available in print form)

No movement in bottom sediment

(figure available in print form)

Ripple marks symmetrical

(figure available in print form)

Ripple marks asymmetrical [7]

If we place some floating objects on the water a short distance from shore at Morris Cove we may be surprised to see that the water does not carry them directly into the shore, but moves them parallel to the beach a distance. This movement is created by the interaction of the waves' onshore and offshore movements and is termed a longshore current. It can be observed on a grander scale where surfers ride the waves. Also any student who has ever floated on the waves knows he will reach the beach a good distance down shore from the point offshore where he began to float.

FORBES BLUFF SITE 3 : BEDROCK AND THE ROCK CYCLE

If we enter Fort Hale Park and walk back toward Lighthouse Point a short distance we will find a rock lined shore under cliffs interrupted by some lower ground. If it has rained recently students will see water flowing from cracks in the rocks. They should be encouraged to make a list of their observations, for instance, these rocks have cracks which appear in regular patterns, and they appear to break off the cliffs from these junctures. The piles of rock which match the cliff rocks and lie at the base contrast their sharp edges with the rounded smooth surfaces of the rocks that underlie them, The rocks display colors and textures. Students may well have been satisfied with the processes responsible for the changing of beaches and stream beds and other coastal effects which we have studied so far. However, we would hope that they would be curious as to how these cliffs or the masses of granite on the breakwater or even those greatest rock formations on the horizon, East and West Rock ridge were deposited. At first, eighth graders when confronted with rocks will say, "They're only rocks.", but when asked to look more carefully they can differentiate between them in terms of size, shape, color, smoothness, sharp edges, etc. The more they look, the more they see. Five minutes of silent study of a rock may allow them to observe that the particles in the rock may be all the same size or vary in size, color, and crystal formation. This is a good time for students to learn the definition of a rock as " *an aggregate of minerals which forms an integral part of the earth* " [8] . The study of rocks is *petrology* and the name Peter means "rock".

BEDROCK

If we watch a film strip or movie showing the scientific view of how the earth was formed, we see a layer of basement rock which underlies the crust of the earth. Under the oceans it is formed of *basalt* and under the continents this bedrock is termed *granitic* . The granitic material has a lighter density than the basalt and, therefore, the continents rose above the waters. The bedrock is divided into plates composed of oceanic or continental bedrock which have been colliding since the beginning. Influenced by the layer under the plates, the *mantle,* the collisions have disturbed and reshaped those plates. Scientists are agreed that there are three major layers to the earth (based on seismic wave studies) the *core* , which extends from the center of the earth to about 1,800 miles below the surface, the *crust* , which extends between 18 to 25 miles beneath the surface, and the *mantle* , between the two. [9]

THE ROCK CYCLE

A. *Igneous Rock* The rocks of Forbes Bluff represent the first class of rocks in the rock cycle, *igneous* . Igneous rocks are formed from a molten state and solidification. [10] (The concept that a rock can melt and flow can be impressed by the films or photographs of today's active volcanoes. A lab demonstration of the changes of state, solid to liquid to gas should be given.) As the material cools the resultant rocks will vary in appearance from ash, glass with no granular arrangement (obsidian) to relatively coarse textures with crystals evident (pegmatite). High fluidity allows the chemicals in the molten material to circulate (as ions) and combine with each other to form larger crystals in time. The amount of the different chemicals, the cooling time, and the space available determine size of the crystals. Some igneous masses are found deep in the earth. If the masses are many miles thick they are called batholiths, (Greek: bathys-meaning deep and lithos-meaning stone). Smaller bodies of the deeply rooted rock (a few thousand feet to 10 miles across) are termed *stocks* . In addition, at a site of former volcanic activity the *necks* of the volcanoes may still exist as *igneous* deposits. Some of the characteristics of volcanic remains are present on both the East and West limits of our harbor area. Batholiths, stocks and necks are called *plutonic* because they are formed underground, and if they invade other materials as sills, dikes, etc they are termed *intrusive* rock. If ash or cinders are thrown into the atmosphere, the rock material is called *volcanic* or *extrusive.11*

(figure available in print form)

A question not completely resolved by scientists is what is the source of the energy that heats up rock so it is fluid? A recent theory suggests that natural radioactive decay is capable of releasing tremendous energy that could produce such melts. Geologists also propose that "what is probably the essential mechanism of crustal deformation . . . (is) very slow plastic movements at about the level of the upper mantle" [12] with rising and falling flows as well as horizontal ones where gravity and gradation of density of material could account for the vertical movement. These two theories are recent explanations for areas of geology that do not give surficial evidence.

At Forbes Bluff we may now infer that the rocks of the bluff are igneous, since they are highly resistant to erosion and the cracks in the rocks appear in regular patterns, a characteristic of cooling igneous rock. Also the columns of rock also break away where the cooling of the molten material has caused shrinkage in patterns like mud cracks or the top of a chocolate pudding. The process which accounts for the breaking off of the rocks can be demonstrated in the classroom. Students should prepare a glass soda bottle by completely filling it with water and replacing the cap. The bottle should then be placed in a plastic bag and put in the freezer of a refrigerator until the next class. (The weekend is a good time.) The bottle should be found to have cracked open, indicating that the water expanded in the process of freezing. This action is responsible for many changes that are caused by weathering. *Weathering* is defined as "the slow, but inevitable disintegration and decomposition of rock under the influence of air and moisture", [13] but it is implied that this is without transport.

B. *Sedimentary Rock* Good examples of the second form of rock are those we observed on the beach site. *Sedimentary rocks* are formed by the consolidation of weathered or eroded material of other rocks, or by chemical or organic processes. Some forms easily recognized are the multilayered shale produced by the depositions of clay particles. Silt produces siltstone, sand produces sandstone, and gravel in union with others of these produces conglomerate. All of these are produced from particles removed from preexisting rocks.

C. *Metamorphic Rock* is the third kind of rock in the rock cycle, and probably the hardest for students to understand, partly because it occurs deep in the ground and partly because the conditions are alien to the more familiar surface. Metamorphism means solid state changes in minerals and textures of earlier formed rocks which occur without melting. Heat pressure, and chemically active gases and fluids are the agents of metamorphism. If large masses of rock are affected without contact with batholiths and with the influence of high temperature and pressure it is called *regional metamorphism* . [14] Geologists term the metamorphism that is caused either by the heat effect of intrusive igneous bodies or metamorphism caused at the site of a shearing action or granulation at the site of a fault *contact metamorphism* . [15] A fault is a fracture (break) (in the earth's crust) along which there is demonstrable slipping of one side past the other.

In metamorphism some of the actual changes may be

1. Enlarged grains in the minerals, because they unite under pressure, examples include quartzite and slate.
2. Recrystallization, as in marble.
3. The formation of new minerals because of chemical changes, as in garnets.

A characteristic weathering effect in metamorphic rocks is exfoliation where parallel layers of metamorphic rocks such as slate fall off the face of the rock due to the expansion of the water when it freezes and pushes the layers apart.

At this time our students should be able to make educated guesses about the types of rocks found at our different sites which we have observed and collected. They should even be able to tell something about the conditions that produced them. For instance, the granite in the breakwater at Lighthouse has large granules either produced by slow cooling in igneous or enlarged in metamorphism. They are indeed metamorphic. The boulders at Lighthouse might be classified as igneous if their resistance were considered, and John Rodgers, the outstanding expert on Connecticut's geology says these boulders are "Granite, once molten rock that cooled slowly underground . . . As this exposure is close to the eastern border fault of the Mesozoic rift valley, it was cracked and shattered during the earthquakes along the fault. It was not then at the surface but has since been exposed by Cenezoic erosion." [16] Paleozoic, Mesozoic and Cenezoic refer to the three most recent eras of Geologic time.

Paleozoic means ancient life and the era covered 350 million years to the *Mesozoic* era, which means the era of middle life and covered 140 million years up to the *Cenezoic* era, which means recent life and covers the last 60 million years until now.

RETURN TO LIGHTHOUSE POINT SITE 4 : GLACIATION

Can we yet explain the numerous rocks of various sizes that do not match the rock masses there? They can be explained as sedimentary or other rocks deposited there by one means or another. If we expose a vertical cut several feet in depth in the area, we find the soil is typically dotted throughout by these rocks of all sizes and varying makeup. If we wash away the sand, silt or soil particles by running water we would create a pile of rocks similar to that on a rocky shore. This type of makeup overlying bedrock is classified as *till* . In the early 1800's Scandinavian and European geologists observed that this till and other features that accompanied it could be explained by the same actions that were produced by existing glaciers. Dana in 1872 clearly classified this material in the United States as *glacial till* as well. [17] In fact many of the geologic phenomena that exist in the New Haven area can be approached as evidence of glaciation. Glaciers did not occur very long ago in our geologic terms, just a mere 15 thousand years ago. That was in a very recent age called the Wisconsin age of the Pleistocene epoch of the Cenezoic era. (Ages make up epochs, epochs make up eras, and eras make up eons.) To give an idea of this time range, Dr. Gordon, of the geology department at Yale gives us a range of time for dealing with rocks, based on the radioactivity index for dating rocks.

1. Oldest rock—4,300 million years old
2. Oldest organized life's fossil remains—500 million years
3. Connecticut Rift valley formed—100 million years ago
4. Beginning of ice-ages—1 million years ago
5. End of glaciation—10 thousand years ago.

Glaciers formed when layers of snow built up because it failed to melt for a period of years and more and more snow accumulated and pressed down on the under layers, forming a great sheet of ice. Since the ice melts sooner at contact points with the underlying material, melting took place and the water caused the glacier to move and advance as glaciation continued. Before the glacier moved down over the Connecticut shoreline a shelf of the continent made of the same material as the mainland extended outwards, above, then under the ocean. It was formed of hills and plains which gradually became lower until they reached the former shoreline which is calculated to have been at least 100 miles farther out from its present line. That area was called a coastal plain. That old coastal plain was "drowned" or submerged under sea water since the ice-ages as the sea level rose. The lowering of sea level that exposed the old coast was the result of the formation of the glacier which incorporated a great deal of the ocean's waters. In order to understand that the effect could be so great students must know the great ice-sheets covered much of North America, Europe and Siberia, and geologists estimate that the ocean at that time was 300 to 500 feet lower. [18.]

The glaciers acted as great conveyer belts bringing rock fragments obtained from the soil and bedrock over which the ice passed. It could grind and drag across the land. "Particles of clay, silt, sand and gravel and many large boulders are (were) in this way broken loose and mixed with the lower layers of the moving ice." [19] The glacier that affected the Connecticut shoreline, the Laurentide Glacier, was estimated to be at least ten thousand feet thick.

When the ice reached its farthest advance point it may have remained there for thousands of years. It began to melt and evaporate faster than it spread and for the long period when the melt and rate of advance balanced out the glacier deposited a great deal of its load of materials forming a chain of islands including the North shore of Long Island, Block Island and Fisher's Island. Students should be shown pictures of presently active glaciers so they may visualize the tremendous amounts of materials they are capable of transporting, and the tremendous pressures they can exert. Evidence of the glacier's power to weather and erode are everywhere around us.

20.

(figure available in print form)

21.

(figure available in print form)

Some landmarks of glaciation that we can observe in our area are:

1. Glacial Plucking—When the glaciers deposited ice in the seams of igneous rock, rocks broke away in columns and pieces of those columns. Example: West and East Rock.
2. Glacial Till—(Already cited) A variety of mud, sand, pebbles, rocks, etc., overlying bedrock. Example: Areas around Lighthouse Point deposited during the melt period about 12,000 years ago when the climate warmed.
3. Kettles—At the time of the melt, the ice sheet wasted away. It lost thickness and blocks of ice separated. These isolated chunks would melt and the level of the land would drop as they did and form depressions in the terrain as hollows or lakes called kettles. Example: Beaver ponds (although this has been artificially deepened).
4. Erratics—Large blocks of unconforming rock. Example: The largest of these is located at the top of Fountain Street, but many are indicated in the Lighthouse area and we will examine some. (See surficial maps)
5. Striations and grooves—These are produced when material is dragged across preexisting rocks by the glacier. Many are indicated in Lighthouse area, but the longest (30 feet) is on the West Rock Ridge.
6. Terminal Moraine—A deposit of material at the site of the most advancement of a glacier.
   Example: The North shore of Long Island, visible on a clear day from Lighthouse. [22]

Some other features of a glacier's action are indicated on the drawing, but they are not present in our harbor study.

An Active Mountain Glacier of Canada

(figure available in print form)

(figure available in print form)

(figure available in print form)

Area of New Haven Harbor: Tip of the Rift Valley

THE HARBOR

If time and circumstances permitted several other visits to sites in the harbor itself and on its Western shore would be useful, but we will have to settle for our view of these areas, visual material, and maps for background.

A. *The Harbor's Formation* Our New Haven harbor, the single most recognizable feature of the Connecticut shoreline, was formed as a result of the drowning of the coastal plain after the ice-ages, and its low placement at the end of a rift valley. Geologists refer to that valley as the tip of the Triassic Lowlands. Triassic identifies the period during the Mesozoic era when this low section of our state resulted from a vertical movement along faults that existed to the East and West of the valley. The vertical movement caused the bedrock beneath this rift valley to sink. Earthquake activity can be responsible for such vertical movements. The valley itself is composed chiefly of larger amounts of red sandstone which justifies the area being termed weak lowlands. The valley also has prominent ridges of trap (igneous) rock formed by protruding edges of uplifted layers of resistant volcanic rock. [23] These were caused when three lava sheets intruded on the red sandstone layers. The lava could invade the earlier material because it was a very dense, molten material. Much later in our valley's history the sediments above the cool molten material were removed by erosion and West Rock Ridge and East Rock were uncovered. If the rift valley were wider at the tip our harbor would be wider, but the Eastern and Western Highlands are composed of materials highly resistant to the rivers which drain them and only slight submergence has taken place resulting in a small harbor.

Students may be interested to learn that at the time of New Haven's settlement the harbor reached to the Green or Mall and that if the sea level here were only 100 feet higher the shoreline would be at the foot of West Rock. If we dipped the land under more the ridges of trap rock to the East of West Rock would make a series of lovely islands. (See maps on next page.)

The lowlands at the edge of the harbor cover our entire area of study and are only five miles across, but they widen to about 20 miles across as they reach the Massachusetts border. The highest points in the Lowlands are only 100 feet above sea level, whereas the Eastern and Western Highlands have many places ranging up to more than 1,000 feet. Probably the whole of the rift valley between the two border faults was at one time filled with river and lake deposits. [24]

The lowlands are also often referred to as the Redlands and New Haven was at one time Rottenberg (Redrock).

B. *The Harbor's Waters* The Quinnipiac River, the Mill River which joins it near the harbor, and the West River are the chief contributors of fresh water to the harbor. These rivers deposit some sediments but they are not the chief source of the sediments in the harbor that would eliminate its economic advantages if they were not periodically removed. The natural reaction between fresh and salt water present at the mouth of rivers explains the chief source of sediments. We must discover by measuring the density of fresh and salt water that salt water is the denser and therefore salt water will sink when the two meet and a lighter layer of fresh water will ride on top of the salt. An area where this meeting occurs is called an *estuary* . Since the layer of salt water is heavier it can invade the fresh water. This contributes to the river being affected by the tides and therefore it is termed a *tidal river* . The Connecticut River is tidal as far north as Hartford but the tidal invasion into the Quinnipiac, etc., is slight. The salt layer is at the bottom of the harbor and deposits much of the sediment it moves into the harbor from the Sound. The harbor bottom is dredged regularly. If we consult our surficial map we can trace the channel that is maintained for the traffic of the large oil tankers and cargo ships that serve this part of the state. The contour lines in the harbor indicate the depths of the bottom. Besides discovering the channel for shipping we will also find an area of much greater depth on the recent surficial maps (1965+) near the Eastern shore of the harbor. This was believed to be the source of much of the fill material that was used for the landfill site of Long Wharf on the West shore.

C. The West Shore of the Harbor

We should consult our maps from earlier years to discover how the Long Wharf landfill section appeared before the man-made expansion. Much of the area may have been marshland, because there is still a small remnant of marsh West of the landfill. Marshes often fill in because the marsh grasses trap sand and sediments when the marsh is protected from the action of the sea. However, in our area it appears that the face of the marsh was eroded and material removed. Normally that would result in the marsh invading the inland area but man has, in fact, prevented this action by landfill, highways and construction. There really is no natural shoreline left in this section. However, if we consult the map we see a very low-lying arm of sand reaching into the harbor from the Western end. It is very low because it consists of sand that has been moved and deposited by shore drift. It is termed a *spit* . This process can create new land, in the form of spits and as islands when they are cut off by water.

D. *The Horizon* , *Long Island*

A last observation on the formation of the harbor itself is that Long Island Sound did not exist as a body of water prior to the glaciation. We've learned that Long Island was formed by the glacier, but subsequently the water level rose when the glaciers melted, and Long Island was partly drowned. The glacier had by this time retreated farther inland leaving a fairly flat depression between Long Island and the mainland which was filled when the sea level rose, thus supplying the waters for the Sound. The sea level dropped again and Long Island was left across the Sound from New Haven harbor. The sea level is now rising at the rate of 3 mm a year which translates into a continual annual drowning of a foot of shoreline per year.

CONNECTICUT AS A WHOLE UNIT

We have now traveled around our harbor in class and in fact. In order to see the area in perspective we have incorporated a great deal of geology for background. However, some aspects of the geology of the whole state of Connecticut are fascinating and surprising. It's funny but one of the observations that young students make when confronted with a map of the world is that Africa looks as if it will fit like a puzzle piece in the indentations of the North and South America. Geologists have presented a theory that we call Wegener's Pangea to explain this and other noticeable relationships. Wegener proposed that a supercontinent existed that probably included all of the continental masses which exist today. [27] When it divided into several masses that part that subsequently made up most of America, we now refer to as Proto-America. It was bounded to the East by an ocean, not the Atlantic, but a different body of water, the Iapetos, East of Proto-America a small continental mass, Avalonia existed. If we can imagine these all being sandwiched into each other we would find the materials of Proto-America in our Westland Highland section. A great period of geologic change "eliminated Iapetos from New England, transforming what was left of it into continent and thus soddering the small continental mass of Avalonia onto the mainland of North America." [28] A strip of volcanic islands seems to also have been incorporated into the coastline. A new bedrock map of the state is being prepared and the chief classifications designated are Proto-American, Newark (another name for our Lowlands), Oceanic (Iapeton) and Avalonian.

(figure available in print form)

PANGEA 200 Million Years Ago

(figure available in print form)

The World Today

It is important to realize that geology has ongoing processes roughly divided into constructive and destructive. Those that build up the crust and those that are wearing it away. Connecticut is not in a stage of uplift. It has had active periods of mountain building in the past but now erosion processes have dominated for a long period creating *peneplain* , an almost flat lowland, "the nearest thing to complete victory for the leveling processes. [29]

The simplest prediction to be made on the basis of the geology of our harbor might be that it will continue to undergo erosion and submergence. We've had some light earthquake activity in this region in the last ten years, but conditions for crustal uplift and mountain building are not obvious, but I'm the teacher who told her students that volcanic eruptions didn't seem to occur much in the continental United States three days before Mt. St. Helens blew its top.

ACTIVITIES ON-SITE

---

1. *CHECK LISTS*

Each field trip would have a short list of some features to look for on that trip plus small experiments. The activities would, of course, vary with the conditions we find on that particular day. For example, on the beach transport of water is easier than any other place and students can create streams with channels of different shape, materials and other characteristics. Materials will be identified as students work with them but the most important observations should be of processes. Flora and fauna associated with the different sites should be pointed out.

2. *COLLECTIONS*

An ongoing collection of specimens should be accumulated for the class and individual collecting will be encouraged. These will be added to teacher demonstration materials. The rocks should be identified as well as possible and marked as to their collection site and the processes which might have produced them noted, for instance, discoloration due to weathering, cracks and sharp edges, etc.

3. *MAP STUDY*

Maps will be used on sites to find structures, elevations, conditions and changes in the sites since the map was developed. Mapping may also be done by teams of students for small areas (perhaps five feet by five feet) at Lighthouse. Students could approximate heights from sea level. Grids would be prepared ahead in class.

4. *PHOTOGRAPHY*

Each student should be allowed to document the mapping and to choose to make a slide of some feature of interest for a film strip of treasures of our unit. Later, in class, she would write a narrative to accompany her slide or slides. The Teacher's camera, if necessary, would be used. Also, any particular conditions encountered on the sites on individual days should be recorded.

5. *SPECIAL TRIP*

If possible, we should take advantage of the special facilities of *Schooner, Inc* . The most exciting would be the harbor trip on the ship, but lectures are also available through Schooner. Also, a visit to the Sound school would be rewarding in relating so many aspects of the harbor to its geology.

ACTIVITIES IN CLASS

1. *MAP STUDY*

A. Observation of World maps should be made to introduce latitude and longitude to refer to in detailed maps. Also, students should be allowed to play with the idea that the present continents might be shifted to form much of a giant jigsaw puzzle with some pieces missing. Perhaps they might formulate a theory of what could have happened to the missing pieces.

B. The maps of the ocean floors, particularly the mid-Atlantic Ridge, would help explain some of the stresses in the crust, the spread of the continents and help envision volcanic, earthquake, and uplift forces in general. These can be contrasted with continental areas where erosion and other destructive forces have been dominant.

C. Many activities may be centered on map study. Students may compare maps prepared for different purposes. They can see changes that have occurred between different renditions of the same mapped area over the years. The changes in our harbor are marked in the course of its mapping. Features of maps such as scale, kevs, contours and bench marks, grids, and color coding can be analyzed and used.

2. *EXPERIMENTS*

A. Experiments and demonstrations can be designed by teacher and/or students on such concepts as porosity, density and specific gravity, erosion resistance, water seeking its own levels, wave action, etc. Many of these are finely detailed in Vuke. (See Bibliography)

3. *TIME LINE*

A. This should be made on a roll of adding machine paper, using careful scale and placing significant geologic ages and changes of the harbor area's development to present a visualization of the magnitude of geologic time. Resource material should be available on a library table.

LESSON PLAN 1

USING A TOPOGRAPHICAL MAP

I. *OBJECTIVES*

1. To learn to relate 3 dimensional features to their representation on maps. (2-dimensional)
2. To use actual contours to measure height and depth.
3. To relate directions on maps to actual directions.
4. To interpret information through a key.
5. To deal with scale, ratios and distance by relating knowledge of man-made features to the distance between them on the map.

II. *INFORMATION*

Maps are fun. They are available for the New Haven Quadrangle in both the topographical and surficial forms. The topographical map allows us to add elevation to two dimensional surfaces. Therefore we can discern many features described throughout the unit, both land and water forms and the relationships between them. Although some maps may only have *hachuring* lines indicating slopes, ours are prepared with contour lines which connect areas of equal elevation. Every fifth line is darkened or colored differently for easier calculations. The reference point of contour lines is usually sea level. Bench marks giving actual elevations are indicated. The borders of the map contain the information for position on a grid and the latitudes and longitudes involved. Many natural and man-made features are indicated on these maps and interpreted by a key. The topographical map can be compared to the surficial which depicts the makeup of the land surface through a color-coded key. The surficial is especially useful in our unit. Other maps should be presented to show the many functions maps serve and for students to use to find particular information.

III. *EXERCISES*

1. Locate 10 actual structures, 5 natural, and 5 man-made on the topographical map.
2. Find your neighborhood and note if there have been changes there since the map was prepared.
3. Trace contours of your neighborhood and of the harbor area. Indicate the actual elevations

or depths on each fifth line that is darkened or in different color on your map.

4. Make a list of what you can learn from your map and the class will make a composite from these.

LESSON PLAN 2

GLACIATION

I. *OBJECTIVES*

1. To design an experiment to display the features of a stream of melting ice relating to the erosion and deposition of material.
2. To develop the students' powers of observation.
3. To teach the recording of accurate observation.

II. *PREPARATION*

Students should place a mixture of crushed ice, chunks of ice, rocks, sand and clay in a long plastic box which has had a layer of sand evenly dispersed on its bottom. Some of the materials might be colored sand and the colored rocks used for aquaria bottoms. These would serve as marker material, and movement can be measured better. The box should be examined at hourly intervals during the melt and the next class day to see the final deposition.

III. *OBSERVATIONS AND DATA*

At each examination the observations should be recorded and measurements of the distance traveled by marked material recorded. A drawing of the box and position of material should be made on the next class day.

IV. *RELATED QUESTIONS*

1. Did our "glacier" behave differently on the bottom? How?
2. What relationships can we discover between the size materials and their deposition?
3. What effects do we find the "glacier" had on the sand?

This experiment can be repeated with a funnel trickling water into and through the bottom of the material. Can we make any implications concerning melting under the glacier and its effect on glacial movement?

V. *RELATED EXERC* ISES

The drawing of the active glacier should be used to learn of the different structures and phenomena that accompany glaciers. Students should relate the experimental evidence with actual glacier products. (The drawing was constructed using the Athabasca Glacier as a model.)

LESSON PLAN 3

DENSITY

I. *OBJECTIVES*

1. To illustrate the process by which one material will float on another because of lighter density.
2. To handle materials to feel the differences.
3. To measure specific gravity of a solid.
4. To learn to compare densities of liquids.
5. To experience use of scientific equipment such as triple balance beams, graduated cylinders, beakers, etc.

MATERIALS OF DIFFERENT DENSITY

Materials Water, vegetable oil, glycerin, alcohol, cork, hard rubber stopper, pieces of wooden splints, strips of aluminum and copper, 2 liter beaker.

Procedure

1. Pour each of the liquids into the beaker slowly so layers are not too disturbed. Students may try to predict which will sink below the water and which will rise.
2. Drop each of the solid objects into the liquids carefully. Will they all sink to the bottom?
3. Write observations in notebook.
4. Draw beaker, layers and objects.
5. Let stand for a day and see if any of the layers changes.

SPECIFIC GRAVITY

Materials Two 100 ml graduated cylinder, 200 ml beaker, samples of nonporous minerals (or rocks) such as galena, quartz, feldspar, slate, pyrite, etc. small enough to be placed in graduated cylinder, triple beam balance.

Procedure

1. Use the triple beam balance to weigh (mass) a mineral or rock sample.
2. Measure 50 ml of water in graduated cylinder. Record measurement (50 ml)
3. Add rock sample carefully. Record volume of rock and water on line a.

Data and Calculations

a. Volume of water and rock =

b. Volume of water =

c. Volume of rock =

Specific Gravity = Density = Mass (of rock) Units

Volume (of rock) g/cm^3

DENSITY OF LIQUIDS

Materials Two 100 ml graduated cylinders, two 200 ml beakers, fresh water, salt water from Sound, triple beam balance.

Procedure

1. Mass beaker A and beaker B. Record masses.
2. Pour 100 ml of fresh water (measured in one cyliner) into beaker A. Weigh and record below.
3. Pour 100 ml of salt water (measured in other cylinder into beaker B. Weigh and record below.
4. Do calculations for density.

Data and Calculations

Mass of beaker A + water =
Mass of bealer A =
Difference = Mass of water =

Mass of beaker B + salt water =
Mass of beaker B =
Difference = mass of salt water =
Density = Mass of salt water
(of salt water) Mass of water

RELATED ACTIVITIES

Handle samples of tuff, pumice, obsidian, magnitite, quartz, corundum, etc. to experience materials of different densities.

Notes

1. John S. Shelton, *Geology Illustrated* (San Francisco Freeman Press, 1966), p. 128.
2. Robert L. Stanger and Otto E. Perkins, *Work-a-Text in Earth Science* (New York, Cambridge Book Co., 1967.) p. 74.

3. Ibid, p. 74.
4. Ibid, p. 75.
5. Arthur L. Strahler, *A Geologist's View of Cape Cod* , (Garden City, New York, Natural History Press, 1966), p. 34, 78.
6. Susan Vuke, *Processes of the Earth's Surface* , (Missoula: Mountain Press, 1980) p. 8.
7. Ibid, p. 88.
8. Shelton, p. 4.
9. Ibid, p. 422.
10. Ibid, p. 8.
11. Ibid, p. 14-20.
12. Ibid, p. 423.
13. Ibid, p. 116.
14. Ibid, p. 45.
15. Ibid, p. 45.
16. John Rodgers, "The Geological History of Connecticut", *Discovery* , Vol. 15 Number 1, 1980), New Haven (Peabody Museum of Natural History, Yale University Press, 1981.) p. 14.
17. Richard Foster Flint, *The Surficial Geology of the New Haven and Woodmont Quadrangles* , Quadrangle Report No. 18, (Hartford, U.S. Geological Survey, 1965.) p. 17.
18 Strahler, p. 6.
19. Ibid, p. 11.
20. Flint, p. 5.
21. Strahler, p. 21.
22. Shelton, pp. 32, 33.
23. Douglas Johnson, *The New England-Acadian Shoreline* , (New York: Hafner, 1967.) p. 76-78.
24. Rodgers, p. 10.
25. Flint, p. 5.
26. Johnson, p. 70.
27. Rodgers, p. 24.
27a. James A. Baggett, "Dinosaurs Ruled The World For 130 Million years—Why Did They Die Out?" *Scholastic Science World,* Nov 25, 1983 (Englewood Cliffs, Scholastic Inc., 1983).
28. Rodgers, p. 24.
29. Shelton, p. 154.

TEACHER BIBLIOGRAPHY

Flint, Richard Foster, *The Surficial Geology of the New Haven and Woodmont Quadrangles* , Quadrangle Report No. 18, Hartford, U.S. Geological Survey, 1965.

An indispensible source for understanding surficial geology, and especially the process and effects of glaciation in this area.

Johnson, Douglas, *The New England-Acadian Shoreline* , New York: Hafner, 1967.

This work is worth using for an explanation of the formation of New Haven Harbor and the New England shoreline in general. However, it is difficult to read.

Osterweis, Rollin G., *Three Centuries of New Haven* , New Haven: Yale University Press, 1953. A wonderful history of New Haven picturing the harbor in many places. The old maps are very useful.

Rodgers, John, “The Geological History of Connecticut”, *Discovery* , Vol. 15 Number 1, 1980, New Haven: Peabody Museum of Natural History, Yale University Press, 1981.

An invaluable resource for an overview of Connecticut geology. It is more interesting if the reader has a background in geology.

Shelton, John S., *Geology Illustrated* , San Francisco: Freeman Press, 1966.

This text provides the best visualizations of geological processes in the form of photographs that could possibly be found. It also covers the entire field in a comprehensive manner.

Shumway, Floyd, and Hegel, Richard, *New Haven* , *An Illustrated History* , U.S.A.: Windsor Publications, 1981.

This is a good source of clear, old maps and views of the harbor.

Smith, David I. and Stopp, Peter, *The River Basin* , Cambridge: 1978.

A nice, easily read explanation of the workings and systems of rivers. It introduces the reader to mechanics of river flow measurement and uses.

Strahler, Arthur N. *A Geologist’s View of Cape Cod* , Garden City, New York: The Natural History Press, 1966.

This small work presents structures and processes on Cape Cod, but they can be used very well as explanations of Connecticut beaches and shores. The diagrams and pictures are most helpful and the text is clearly written for the non-professional, even for students.

Vuke, Susan, *Processes of the Earth’s Surface* , Missoula: Mountain Press, 1980.

This book is a limitless resource for stimulating ideas on how to present geologic processes in the classroom, (particularly erosion). Excellent illustrations.

STUDENT BIBLIOGRAPHY

Baggett, James A., “Dinosaurs Ruled The World For 130 Million Years—Why Did They Die Out?”, *Scholastic Science World* , Nov. 25, 1983, Englewood Cliffs: Scholastic Inc., 1983.

The article relates the Pangea Theory to prehistoric life.

Bisacre, Michael et al., Editors, *The Illustrated Encyclopedia Of The Planet Earth* , London: Exter Books, 1979.

A comprehensive source for reference on the physical world. The Atlas includes descriptions of the geologic makeup of regions.

Gallob, Edward, *City Rocks City Blocks and The Moon* , New York: Charles Scribner’s Sons, 1973.

A delightful book showing geology in a city’s buildings and streets. Man’s uses of rocks are shown as well as geologic processes in action in the city. Low reading level.

Rhodes, Frank H., *Geology* , New York: Golden Press, 1971.

This is a field guide students should be comfortable with.

Stranger, Robert L. and Perkins, Otto E., *Earth Science Cambridge Work-A-Text,* New York: Cambridge Book Co., 1967.

A text-workbook with good basic information, organization and activities.