This Lake Alive!

An Interdisciplinary Handbook for Teaching and Learning about the Lake Champlain Basin

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Main Lake

Ojihozo Creation Myth

as told by Joseph Bruchac

Kina. Listen. Long ago, when Tabaldak, the Owner, had finished making things, some of the dust of creation was still on the Owner's hands. So Tabaldak began to brush that dust away. It sprinkled down upon the earth. Where it fell upon the earth, the earth began to move about. It began to shape itself. It shaped itself a torso. It shaped itself a head. It shaped itself shoulders, arms and hands; it shaped itself hips. Then that earth which shaped itself sat up.

Awani gia? said Tabaldak. Who are you?

Ojihozo nia, said that earth which shaped itself. I am Ojihozo. I am the One Gathering Himself Together.

You are very wonderful, said Tabaldak.

Nda, said Ojihozo. No. You are the one who is wonderful. You are the one who sprinkled me.

Then Ojihozo looked around. All around was the beauty of the newly created earth. And Ojihozo became eager to get up and see it. But, like a small child eager to walk before he can, Ojihozo did not notice that he was not yet ready to walk. He had not yet shaped legs and feet. He was still connected to the earth.

So Ojihozo tried to stand. He pushed very hard to one side and he did not move. He pushed harder and harder, so hard that the earth was pushed up into mountains. Those mountains today are called the Green Mountains. But still he could not stand. Then Ojihozo pushed very hard to the other side. He pushed so hard that the earth rose up into mountains on that side, too. Today those mountains are called the Adirondacks. But still he could not stand.

Now Ojihozo reached out his long arms. He reached all the way to the mountaintops to either side of him. Then he pulled, trying to pull himself up. His fingers gouged down the channels of the rivers. Otter Creek, the Winooski, the Lamoille and all the other rivers were formed then. But still he could not stand.

Then Ojihozo saw that Tabaldak was looking at him. Tabaldak looked at him with that look of patience a parent shows when a child does something wrong but that parent is determined to let the child learn through his own mistake. Ojihozo looked at himself then. He saw that he was still connected to the earth. He did not have legs or feet yet.

Then Ojihozo reached down. He shaped legs and feet for himself. Then he stood. And when he stood, he left behind him a great hole in the earth. The waters flowed in and made that hole into a big lake. It is called Bitawbagok, The Waters In Between, by the Dawnland People, though on the maps it is called Lake Champlain. If you look at a map, you can see the shape there of a sitting person, his legs toward the north. That is the shape of Ojihozo.

Then Ojihozo walked around. He walked around for a long time seeing many things. But when he was done, he returned to the beautiful lake and the beautiful mountains he had made. This was where he wished to stay. He sat down upon a small island and changed himself into stone. He sits there to this day, watching over the mountains and the lake.

So the story goes.

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Mt. Mansfield

The Geologic History of the Lake Champlain Basin

Our State Fossil

by Tai Dinnan, Grade 4, Charlotte Central School, Charlotte, Vermont

The bones of the Charlotte whale were found while digging the Rutland and Burlington Railroad in 1849. Workers thought they belonged to a horse or cow so they kept on digging until a curious local farmer, John G. Thorp, questioned their find. He thought the bones were unusual and called Zadock Thompson at the University of Vermont. Zadock brought the bones to UVM to examine and identify them.

Unfortunately, the bones were dipped in “animal glue” to preserve them from desiccation, which made it impossible to prove the exact age of the skeleton. We do know that “Charlotte” lived during the time span of the Champlain Sea, 10,000 to 12,500 years ago. Today the skeleton of “Charlotte” is on display in the Perkins Museum of Geology at UVM where visitors are welcome to see her. The Charlotte Historical Society has placed a historic marker near the site where the bones were found. You can go and see it at the railroad crossing on Thompson’s Point Road.

A few years ago, Jeff Howe from the Perkins Museum decided the bones should be the state fossil. He asked for help from the Charlotte Historical Society and students from Charlotte Central School to bring this idea to the state government. Charlotte representative Hazel Prindle introduced a bill to declare “Charlotte” the official State Fossil. C.C.S. students then traveled to the state capital, Montpelier, to meet with a special committee and Governor Howard Dean. The state legislature later passed the bill and Governor Dean signed it into law at a ceremony at the Charlotte Central School on June 7, 1993!

The Charlotte whale was a White whale. Other names for it are Beluga, White porpoise, and Sea Canary. It was a toothed whale and is recognized by its grayish white color. It lived about 10,000 to 12,500 years ago. It is not known exactly what its habitat was, but now Belugas live in the colder Arctic Ocean, the North Atlantic, and the North Pacific. They prefer shallow waters and rivers. These whales eat fish including char, sand lance, capelin, pollack, cod, and salmon, plus shrimp and octopus. Belugas are 3 to 5 meters long and weigh about 1.5 tons while the calves measure about 1.5 meters at birth. The Beluga has up to 11 teeth in each side of its upper and lower jaw (at least 32 total) and lacks a dorsal fin which makes it easy to identify. Along with their camouflage, Belugas have the ability to turn their heads from side to side. They also are able to look over and under their shoulders to protect themselves from predators such as polar bears and killer whales.

Scientists do not know exactly how Charlotte died. They think it either died out at sea or it died of hunger in shallow water. It was buried over time and was undiscovered for thousands of years.

Introduction

The Geologic History of the Lake Champlain Basin was written by Jeff Howe for this publication. Jeff Howe oversaw the renovation of the Perkins Geology Museum at the University of Vermont (UVM) and served as the director/curator of the museum from 1992 to 1994. Much of the research that Jeff did—that is used in this essay—was funded by a grant given by the Lintilhac Foundation to the Perkins Museum. These funds and the creative work of Jeff Howe are responsible for the fine resource the museum is today. Jeff Howe is currently the Director of Museum Programs at the Delaware Museum of Natural History in Wilmington, Delaware.

Barry Doolan, Chairman of the Geology Department at UVM, reviewed this chapter and provided help with the graphics.

The Geologic History of Lake Champlain

1.3 billion years ago	**Ancient Adirondacks** This mountain range was formed.
450 million years ago	**Iapetus Ocean** This ocean was a shallow tropical sea. Its shells and organic debris were cemented in limestone.
440–350 million years ago	**Green Mountains** This mountain range was formed.
5 million years ago	**Ice Age** Glaciers carved the soft sedimentary rock in the Champlain Valley.
21,000 years ago	**Glaciers** Glaciers started melting northward toward New England.
14,000–15,000 years ago	**Lake Vermont** A large, deep lake was formed as the glaciers melted then blocked the outflow of water.
13,000 years ago	**Champlain Sea** The sea replaced Lake Vermont when ocean water from the north flooded the basin. The sea supported varied marine life, like the Charlotte whale!
11,000 years ago	**Lake Champlain** The lake was formed when the area was cut off by glacial rebound, sea water was flushed out.

The Geologic History of the Lake Champlain Basin

THE EVOLUTION OF THE LAKE CHAMPLAIN BASIN

Lakes of all shapes and sizes are situated all over the world in different environments. Some lakes are small and round and sit high in the mountains. Other lakes are huge and cover vast areas of land. Lake Champlain is long and narrow and is surrounded by mountain ranges on both sides. How did that come to be? To understand how the Lake Champlain Basin was formed, we need to go back a billion years...

Long ago, North America was covered by huge sheets of glacial ice. The Ice Age was a time when massive glaciers formed in the north and slowly moved southward. They eventually reached the area of the Ohio River, Cape Cod and New York City. The glaciers that covered the Champlain Basin covered land that was one billion years old. But these glaciers are only a recent part of a long geologic history of the Champlain Basin. To understand how the basin came to be it is necessary to return to a time when the land we now know as Vermont and New York did not exist.

The Ice Age is also called the Pleistocene Era, which lasted from 2.5 million to 10,000 years ago.

The age of the earth is approximately 4.6 billion years.

A billion years ago the earth was much different than it is now. There were no plants or animals on the land. The only life on the planet included a wide variety of microscopic plants, bacteria and a few primitive animal forms. As simple as these life-forms were, they had been evolving for over two billion years. Photosynthesis by microscopic plants over those years gradually changed our atmosphere from one that contained noxious gases, such as methane and sulfur dioxide, to one that was rich in oxygen. It was this oxygen-rich atmosphere that allowed other more complex life-forms to evolve.

THE ADIRONDACK MOUNTAINS

Geologists are not exactly sure why, but over the past one million years the Adirondacks have actually been rising!

The Champlain Basin as we know it did not exist a billion years ago. However, mountain-building events had formed a huge range of mountains that were as large as the Himalayas are today. These were the original Adirondack Mountains. Geologists know that the Adirondacks were once over 20,000 feet tall because the rocks that are now exposed could only have been formed at the base of a pile of rocks that deep. Erosion over the last one billion years has removed the overlying rock.

Today the highest peak of the Adirondacks is Mt. Marcy.
Mt. Marcy is 5,344 feet high.

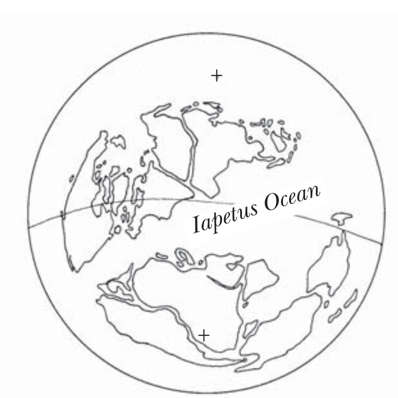
In many places in the Adirondacks, metamorphic rocks, formed from enormous heat and pressure, yielded fine specimens of minerals such as garnet, anorthosite and diopside. Because of these rocks, the Adirondacks are very popular with rock enthusiasts today, in addition to being a favorite vacation spot for skiers, hikers and nature lovers. For over 500 million years, the Adirondacks eroded in silence, finally being reduced to a range of low hills, lower than the Adirondack Mountains we see today.

THE IAPETUS OCEAN

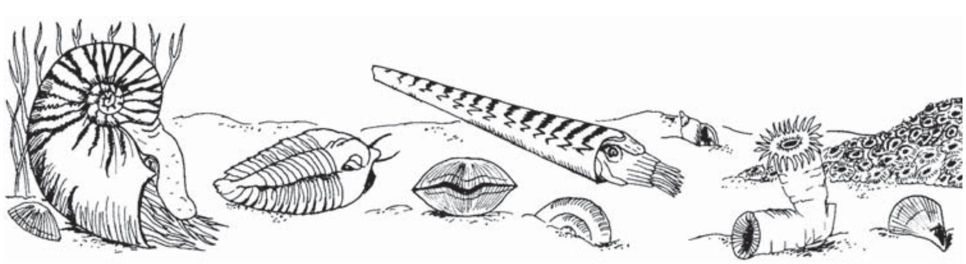
The ancient shoreline of the Iapetus Ocean extended from the land that is now the state of Georgia to Newfoundland. It lasted for over 200 million years—the same amount of time as the present day Atlantic Ocean has existed.

About 600 million years ago, another catastrophic event caused the surface of the earth to rupture, or "rift," in the approximate area that is now the Champlain Valley. As the rift grew in width and the opposite sides slowly moved apart, the space in between was filled by sea water, forming a warm, shallow ocean.

The ocean that formed in this area was called the Iapetus Ocean. It was full of rapidly evolving life, including trilobites, cephalopods, bryozoans and gastropods and primitive corals. On Isle La Motte, an island in northern Lake Champlain, the remains of a rich reef from the Iapetus Ocean can still be seen. The reef shows many fossils. Although once at the bottom of a warm ocean, the fossils on Isle La Motte are now in the middle of a farmer's cow pasture. Many locations around Lake Champlain yield fossils of things that once lived in the Iapetus Ocean.



the world 400 million years ago



THE GREEN MOUNTAINS

Because the surface of the earth is constantly in motion, the Iapetus Ocean slowly began to narrow, eventually closing completely. In the final stages of closure, the land masses on opposite sides of the ocean collided. This happened slowly over millions of years and it caused the ground to crumple, fracture and fold. This movement formed another huge mountain range, the Appalachian Mountains, which were not quite as high as the original Adirondacks, but still magnificent in size. The Green Mountains, which now cover the state of Vermont, were formed as part of this Appalachian range. They were formed some 450 million years ago and have also eroded to just a fraction of what they once were.

Much of the rock color in the Green Mountains is due to the metamorphic mineral chlorite. Biologists might say the Green Mountains got their name from the color of the trees. Geologists on the other hand, could say the mountains got their name from the color of the rocks. What do you think?

THE CHAMPLAIN THRUST

It took a tremendous force to create the Green Mountains. An outstanding example of this power is the Champlain Thrust, which runs along the northeastern shore of Lake Champlain from St. Albans to south of Burlington. As the Green Mountains were forming, enormous forces deep in the earth caused a huge slice of rock to break free and be forced upwards above rocks that were much younger in age. This “thrust fault” can be seen most spectacularly at Lone Rock Point near Burlington. Lone Rock Point is famous and geologists and geology students from all over the world come to observe and study this fault formed by compression.

Champlain Thrust at Lone Rock Point

A hiatus is a period of time for which no evidence of activity exists.

Why do we find fewer fossils of creatures that lived in mountainous regions where erosion is rapid than those that inhabited low river valleys where much sediment is deposited? In other words, why do we find more fossil fish than fossil mountain goats?

The Perkins Museum of Geology at the University of Vermont has the second most complete collection of Brandon Lignite samples in the world. Harvard University has the biggest collection.

THE GREAT HIATUS

From the formation of the Green Mountains 400 million years ago until the "recent" glaciation, there is very little record of events here in the Champlain Basin. This gap in the story is called the Great Hiatus.

Although no clear record marks this time period, ample evidence in other parts of New England suggest that a great deal was happening in this region. The age of dinosaurs and the formation of the modern Atlantic Ocean both happened during this time. The entire Champlain Basin was highly mountainous and undergoing extensive erosion. Sediments from this erosion were carried away and deposited in other places, far from the Champlain Valley. This erosion removed much of the "old" surface, leaving low rounded hills. Dinosaurs may have roamed over what is now Mt. Mansfield and Whiteface Mountain, but the fossil traces, if there were any, have eroded away over time.

THE BRANDON LIGNITE

The only known window into the Great Hiatus is the Brandon Lignite, a tiny deposit of iron-rich clay and lignite (a crude form of coal) found near Forestdale, Vermont. In the Brandon Lignite, scientists have discovered the remains of plant seeds and fruits about 25 million years old. These indicate that, at that time, this area was much warmer, perhaps like the climate in South Carolina. Geologists are not certain how the Brandon Lignite escaped being destroyed by erosion and glaciation. They have suggested that a small piece of the area was pressed into the soft clay below it and protected.

PLATE TECTONICS

Although the idea of plate tectonics has been developed in only the last 30 years, it is regarded as one of the most significant ideas in science, equal in importance to the discoveries of Galileo and Madam Curie. Rather than a discovery made by one scientist, it was developed by geologists working together worldwide. Plate tectonic theory is still being developed and continues to be modified as new evidence becomes available. This is the way that science operates: by continually redefining what we think to be true as new discoveries are made.

As early as the 1500s, when the first reliable maps of the earth were drawn, geographers noted that the coastlines of Africa and South America fit together almost perfectly like two pieces of a giant puzzle. There was no good explanation at the time for how entire continents might move apart such a great distance.

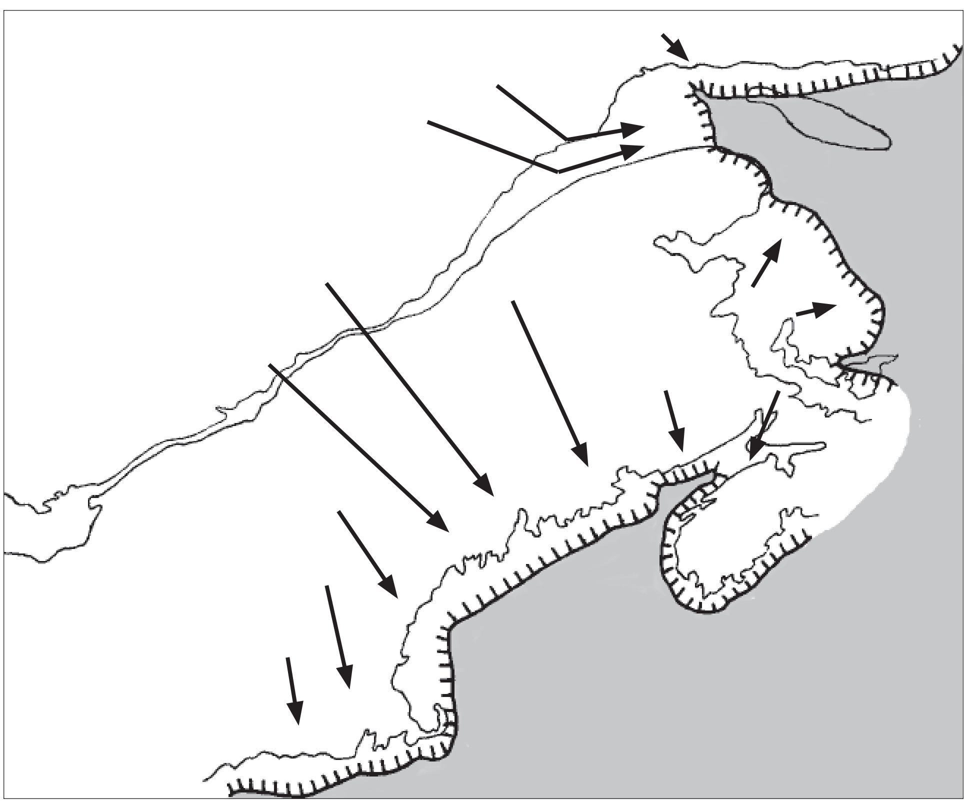
In the 1960s, scientists began to gather evidence from the bottom of the ocean that suggested that the crust of the earth is composed of large "plates" that move about slowly on molten rock. Along boundaries where these plates collide, their edges crumple, forming mountain ranges and volcanoes. When the edges of the continental plates pull apart, they form depressions that fill with sea water. These depressions can grow over time into large oceans. When plates slide alongside of each other (as they do in California), they cause frequent (and often destructive) earthquakes.

THE PLEISTOCENE—THE AGE OF GLACIERS

The earth has had many Ice Ages throughout its history, but the most recent, and the one that most affected the Champlain Basin, began about 2.5 million years ago. This period, from the formation of glaciers until their final disappearance about 10,000 years ago, is known as the "Pleistocene."

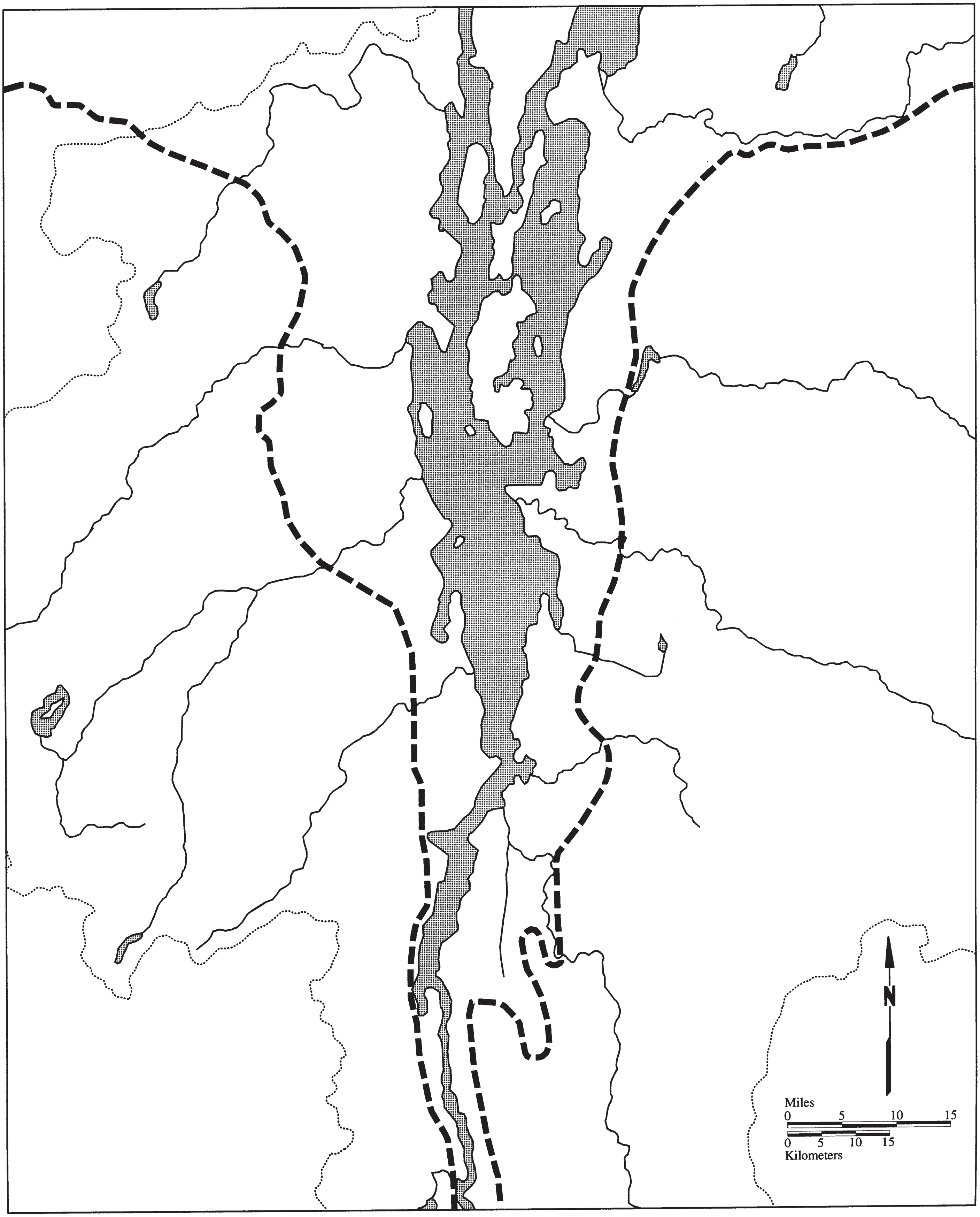
Glaciers form when the climate of the earth becomes such that more snow falls in a given winter than can melt the following summer. If these conditions exist for hundreds to thousands of years, snow piles up to enormous depths. When the weight of the overlying snow becomes great enough, the glacier begins to move outwards at its base, very similar to the way a pile of applesauce spreads at the bottom as more spoonfuls are added to the top.

This buildup of snow is what occurred in the northern latitudes of the earth during the Pleistocene Age. A center of snowfall in northern Canada produced a glacier that slowly migrated southward into New England. A lobe of this glacier penetrated between the Adirondacks and the Green Mountains, filling the valley and finally covering all of the mountains as well! At one time the thickness of the glacier in the Champlain Valley was over a mile high!!



18,000 years ago, glaciers covered most of New England.

Lake Vermont



Credit: *Northern Cartographic. Used with permission.*

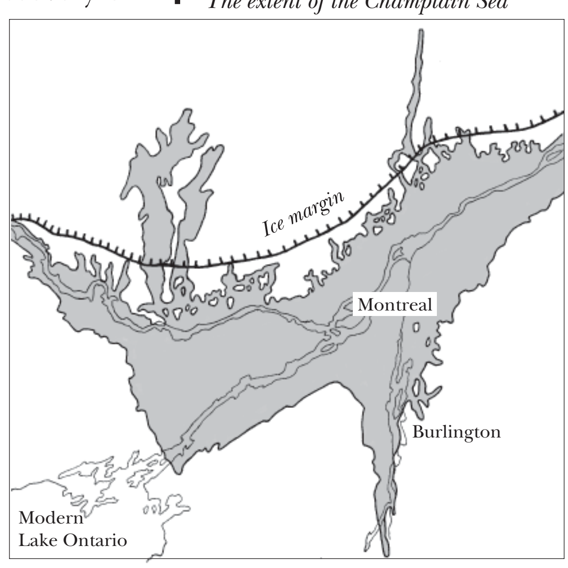
LAKE VERMONT

About 20,000 years ago, the climate of the earth changed again and the glaciers began to melt. As they retreated northward, enormous quantities of meltwater thick with sand and silt poured off the glaciers and flooded the land at their bases. As the ice melted through the Champlain Basin, meltwater was blocked to the north by the glacier and to the south by huge dams of rock, mud and jammed ice. A deep freshwater lake was formed, much deeper than present-day Lake Champlain, and it covered many hundreds of square miles in Vermont and New York (Canada was still covered by ice). This lake had many stages but is generally referred to as Lake Vermont.

THE CHAMPLAIN SEA

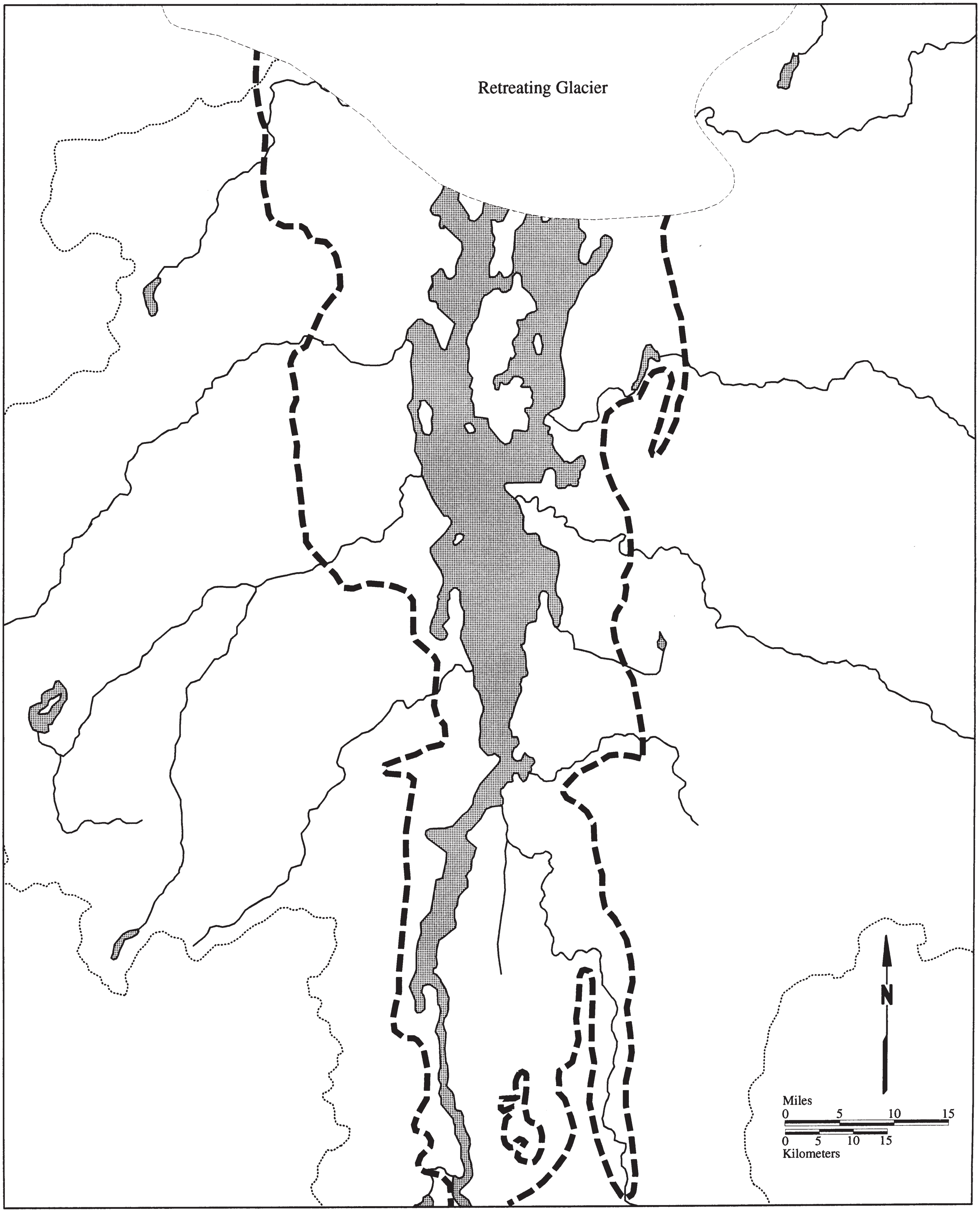
As the glacial ice continued to melt northward, it brought changes to this region. By about 13,000 years ago, the ice lobe had melted back to northern New York and Vermont, exposing land that had been covered by glacial ice for many thousands of years. The ice that had prevented Lake Vermont from draining melted and the lake level dropped many hundreds of feet. The general warming of the climate caused glaciers to retreat worldwide, causing the level of the oceans to rise from the increased meltwater. Thousands of feet of ice had covered the Champlain Valley. The weight of all this ice had depressed the land below the level of the sea for many years. This lowland was quickly flooded by the rising sea. Freshwater Lake Vermont was replaced by an extension of the ocean known as the Champlain Sea. It was no longer a freshwater lake but very much like a large inland bay, connected to the ocean by the valley that today contains the St. Lawrence River. The discovery of the skeletons of over a dozen white (or Beluga) whales from this time period, as well as the remains of other ocean fossils such as seals, salmon, herring and mussel shells, are evidence that this area was once part of the ocean. These fossils have been found in portions of New York, Vermont, Ontario and Quebec, all areas once covered by the Champlain Sea.

The extent of the Champlain Sea



On land, the valleys were clogged with sediment runoff from the melting ice. Sand and gravel ridges remained to mark former sites of the ice. Plants that could grow in the cold and Ice-Age mammals, such as the woolly mammoth and caribou, followed the retreat of the glaciers. From the south and west came the first humans, following the herds of grazing animals into new and productive lands. Archeologists call these people Paleo people.

The Champlain Sea



Credit: *Northern Cartographic. Used with permission.*

LAKE CHAMPLAIN

As the Champlain Valley continued to rebound from the weight of the glacial ice, the surface of the Champlain Sea rose until it attained an elevation greater than that of sea level. When this occurred, the salty water of the Champlain Sea began to flow slowly northward to the valley of the St. Lawrence and back to the ocean. As the rivers surrounding the basin continued to flush it with freshwater, the Champlain Sea slowly gave way to the freshwater lake that we know today as Lake Champlain. Lake Champlain has existed in its approximate present form for at least 9,000 years.

THE FOSSIL HISTORY OF THE LAKE CHAMPLAIN BASIN

A fossil is the remains or an imprint of a once-living organism that has been preserved in the rock.

The different kinds of fossils found in the Champlain Basin offer many interesting clues to plant and animal life in the past. A fossil is seldom composed of the original bone, teeth or plant fiber of the organism, but instead is composed of rock material that has slowly, over many, many years, replaced it. If the remains of an animal or plant are deposited quickly in soft mud or sand, they are protected from rapid decay in the atmosphere. Over time, the original material is replaced by dissolved minerals in the ground, eventually producing an exact copy, called a fossil. Sometimes a print of a plant or animal is left behind and is slowly filled in with more sand or mud. When the filled print hardens, it becomes a "cast" and looks just like the original shell, leaf, footprint or animal skeleton. Casts are also fossils.

Fossils of the Champlain Basin represent three distinct periods in time. Each of these periods is separated by vast stretches for which we have no fossil record.

THE EARLIEST FOSSILS

The oldest fossils that have been found in the Champlain Basin are those of creatures that lived in the warm, shallow Iapetus Ocean that covered this area over 450 million years ago. At this time, the land was barren and windswept, with no animals (or even plants!) living on it. All life on the earth at this time was confined to the oceans.

The Brandon Lignite
Earlier, we discussed the Brandon Lignite. The fossils here are important because they provide a rare window into a time for which we have no other record. The Brandon Lignite site is no longer active and fossils cannot be collected.

The fossil remains of trilobites, cephalopods, gastropods, bryozoans and graptolites are often found in the black shales and limestones along the shores and islands of Lake Champlain. In rocks that were deposited in areas that were beaches in the ancient sea, evidence of ripple marks, animal tracks and worm burrow holes can still be seen, similar to those seen on modern beaches.

PLEISTOCENE FOSSILS

In 1848, the tusk and two teeth from a woolly mammoth were discovered near Mt. Holly, in south-central Vermont. Mastodons and woolly mammoths lived in cold and rugged tundra environments and followed the retreating glaciers northward. The remains of numerous mammoths found in both New York and Vermont suggest that these animals once lived in the region surrounding Lake Vermont. The remains of caribou, hare, fox and deer have also been found. There is also evidence to indicate that the Paleo people who followed the large animals also inhabited this region shortly after the glaciers retreated.

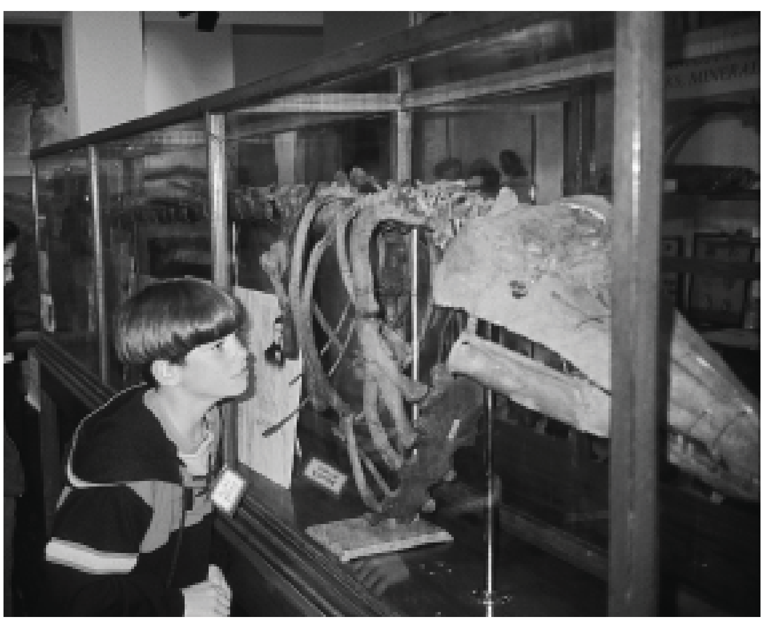
These bones can still be viewed at the Perkins Museum of Geology at the University of Vermont. Interestingly, they were discovered by the same railroad crew that discovered the bones of a whale one year later near Charlotte.

The Charlotte Whale

In August of 1849, railroad workers were laying the tracks of Vermont's first railroad near Charlotte. As they worked they came upon the bones of a strange animal buried in over ten feet of sticky blue clay. Thinking the bones to be those of an old cow or horse they continued to dig until a local farmer, who knew very well what cow and horse bones looked like, asked them to stop.

They notified Professor Zadock Thompson of the University of Vermont. Professor Thompson came to the scene to observe the strange bones and to carefully collect as many pieces as he could find. Thompson was a self-taught naturalist with few books and was operating in what was at that time a northern wilderness, far from the museums and colleges of Boston and New York City. Despite these hardships, he was able to reconstruct the skeleton, and after consulting with scientists in Boston and Paris, declared the bones to be those of a white (or Beluga) whale! This caused quite a sensation. How do you get the bones of an ocean-going whale buried beneath ten feet of clay in a field in Charlotte, Vermont, which is hundreds of miles from the nearest ocean?

Since that time, over 15 other whale fossils have been found in New York, Ontario and Quebec. We now know that the whales swam in the Champlain Sea and were buried in the sediments when they died—most likely of natural causes. At the time of Zadock Thompson, however, this idea was very new and controversial. Pictures of the "Champlain whale" appeared in geology textbooks as early as the 1860s. In 1993, a bill declaring the Charlotte whale the "Official State Fossil" of Vermont was signed into law by Governor Howard Dean.



Since the Charlotte whale is "only" about 10,500 years old, and its bones have not yet been mineralized, some people question whether or not it is really a fossil. Others argue that because the Charlotte whale represents the preserved remains of an ancient life-form that is no longer present in the area, it can rightfully be classified as a fossil. Do you agree?

CURRENT RESEARCH *on the* LAKE CHAMPLAIN BASIN

Today, much of the paleontological research in the Champlain Basin involves tiny microscopic fossils that can only be viewed with a microscope. These fossils, foraminiferans (or "forams" as many scientists call them), represent the shells of one-celled animals very similar to the amoeba. Scientists that study them are called micropaleontologists.

To study these tiny fossils, researchers drop weighted coring tubes from boats in Lake Champlain to collect samples of the sediments on the lake bottom. Back in the lab, scientists carefully remove the core samples, weigh them and label them, and then remove the sections that they want to study. The muds and clays of the sample are dried and sifted to remove the mineral and clay grains, leaving the forams. By carefully noting the types of forams they find, the composition of their shells and how deep they were found, micropaleontologists can reconstruct the changes that have taken place in the lake and the climate over time.

Geologists continue to study the rocks, minerals, fossils, folds and faults in the area to enrich our understanding of the area's past history. There is much work yet to be done, because there is so much story yet to be told and so many questions that remain. Perhaps you will make the next great discovery!

The Geologic History of the Lake Champlain Basin

Activities

These activities provide possibilities for the "non-geology teacher" to explore rocks with kids. Many geology activity books provide similar and more extensive ideas for activities.

Jeff Howe reviewed the following activities and offered these comments for teachers to consider:

To attempt to understand the enormity of geologic time, have your students count silently to themselves, as fast as they can, for exactly one minute. When they have finished, go around the room and see how far each student counted. Obtain a class average. On a calculator (or by hand) have one student multiply how far the class counted in one minute by 60 minutes and then 24 hours and then 365 days to determine how far you could count in one year. Continue with the math to determine how long it would take the class, counting as fast as they could, taking no time to sleep or eat, to count all of the 4.6 billion years in the Earth's history. The answer is around 30 years!

On a topographic map of New England, connect all of those areas in the Champlain and St. Lawrence lowlands that are the same approximate elevation as the base of Mt. Philo. Although glacial rebound was uneven throughout the region, this exercise will provide a rough approximation of the shoreline of the Champlain Sea. Compare your map to a map of the Champlain Sea. Note that Burlington and Montreal would be underwater.

Ask students to imagine conditions that would prevent fossils from being preserved in this area for many millions of years at a time. HINT: Either no organisms were present, no preserving conditions were present, or the evidence was removed by erosion.

There is no "right answer" to this question but the suggested scenarios appear valid to geologists. Fossils are not preserved because of the lack of preserving conditions and ongoing erosion. Pose the question to students and solicit other possible scenarios.

QUESTIONS

• What are some of the important events and changes that have led to the formation of the Champlain Basin?
• What caused these changes to take place?
• What methods do geologists use to discover how the earth changed so many years ago?
• What do fossils tell us about the Champlain Basin? Why are some fossils older than others?
• What is a glacier? How does it form? Why are there no glaciers in the Champlain Valley today?

KEY RESOURCES

• The Nature of Vermont *by Charles W. Johnson*
• NatureScope: "Geology: The Active Earth"—*National Wildlife Federation*
• Written in Stone *by Chet Raymo and Maureen Raymo*
• The Roadside Geology of Vermont and New Hampshire *by Bradford Van Diver*
• The Roadside Geology of New York *by Bradford Van Diver*
• "Paleontology of the Champlain Basin"—*available from office of the Vermont State Geologist*
• Natural History of Vermont *by Zadock Thompson*
• The Big Beast Book: Dinosaurs and How They Got That Way *by Jerry Booth*
• The Perkins Museum of Geology at the University of Vermont—*field trip*
• Button Bay State Park—*field trip*
• Mt. Philo State Park—*field trip*

Word Bank

Adirondack Mountains
amoeba
bryozoan
cast
cephalopod
Champlain Sea
Charlotte whale
chlorite
erosion
foraminiferan or “foram”
fossil
garnet
gastropod
glacial rebound
glacier
graptolite
Green Mountains
hiatus
Iapetus Ocean
Ice Age
igneous rock
lobe
Lake Vermont
mammoth
metamorphic rock
methane
microfossil
oxygen
photosynthesis
plate tectonics
Pleistocene
rift
sedimentary rock
sulfur dioxide
thrust fault
trilobite
tundra

Activity: The Rock Connection

TEACHER NOTES *and* INFO

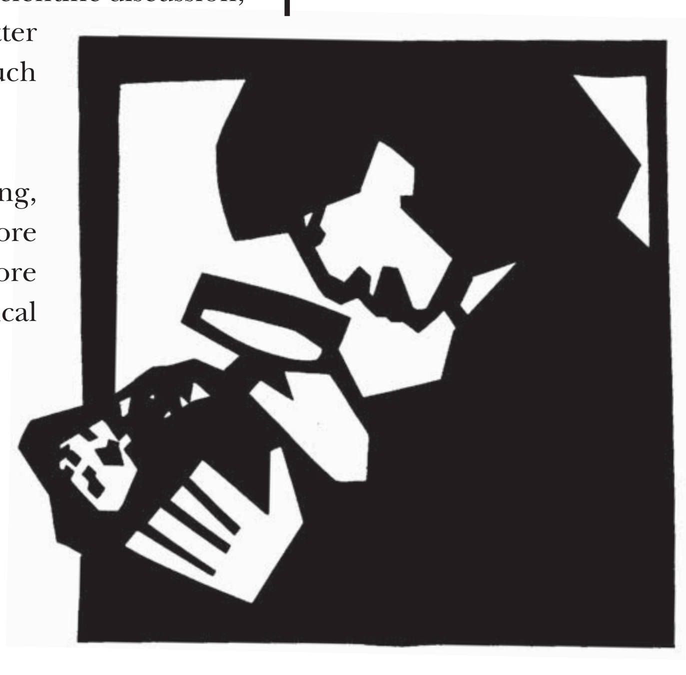
The next three activities are designed to let students informally explore rocks. They will learn some basic vocabulary, guess (hypothesize) how the rocks were formed and what they are made of, and record various observations. The activities can be done as a series of explorations or as single activities. It is helpful, however, to start with "Rock Talk" as an introduction to basic geological concepts and terms. It can then be used as a reference for the other activities. There is some overlap in the purpose and outcomes of the activities.

Tell students (give them two weeks' notice) that they will have to find and bring in a rock. They must find it (not buy it), and it must be local. Tell them it will, if they choose, be broken.

It is helpful to have a class set of magnifying glasses when students are observing their rocks. Students can set up stations with their rock samples.

A lot of science starts to happen as students start to bring their rocks into class and share observations and knowledge. I just recently integrated geology into my study of Lake Champlain. It was not a subject of which I had any previous knowledge and I didn't feel very confident. Having the students bring in their rocks was a great comfort. The rocks generated a lot of scientific discussion, excitement and sharing of information; this was a lot better than depending on the teacher for information—and much more beneficial!

These activities focus on the student as scientist: observing, recording, asking questions and hypthesizing answers before all the information is known. Later activities give more attention to exploring and understanding basic geological facts and concepts.



Activity: Rock Talk

Using an overhead projector, review with the class the information on the handout "Rock Talk" (see next page). Students will begin with a blank worksheet like the one below (with only vocabulary words in bold). Have them fill in the blanks with terminology they understand as you work through the questions and discuss the answers. Students can refer to their completed worksheets as they examine and think about their own rocks.

All the Talk about Rocks

What's a Rock?

Minerals ______________________________

Crystals ______________________________

Rocks ______________________________

How are Rocks Formed?

Igneous ______________________________

Sedimentary ______________________________

Metamorphic ______________________________

How are Rocks Identified?

Luster ______________________________

Hardness ______________________________

Cleavage ______________________________

Streak ______________________________

Rock Talk

What are Rocks? How Do They Differ From Minerals?

Minerals - Nonliving compounds of elements that are only found in nature. They are the building blocks of rocks. They can form crystals.

Crystals - Solid substances with atoms arranged in an orderly pattern, which usually form flat surfaces. There are seven crystal “systems” based on shape.

Rocks - Solid mixtures of one or more minerals. They make up the inorganic portion of earth.

How are Rocks Formed?

Igneous - Formed when magma or molten rock from deep inside the earth cools. Sometimes forced by pressure (volcanoes).

Sedimentary - Formed near earth’s surface by wind, water and weather. Erosion moves sand or soil over earth. When they settle together, they form layers.

Metamorphic - Formed when extreme heat, pressure and major shifting of the earth causes changes in igneous or sedimentary rocks. They look folded or squeezed.

How are Rocks Identified?

Luster - How does light react with its surface? Is the rock glossy? metallic? dull? pearly? shiny? chalky? greasy? Can you make up a name that describes it better?

Hardness - Scratch it and see! Can you scratch it with your fingernail? with a penny? with a nail? Can you scratch a piece of glass with it? Do your rocks scratch each other? Which one is the hardest? Which is the softest?

Cleavage - (ALWAYS WEAR SAFETY GLASSES WHEN BREAKING ROCKS!!!) How does it split? Does it break along flat planes or does it break irregularly? Are you sure? (Look carefully.)

Streak - Rub your rock on a streak plate provided by your teacher. What color is the powder? Is it the same color as the rock? Why?

Activity: **Classifying Rocks**

Other Ideas

- *Students can learn to identify their rocks blindfolded: pass the rocks around in a circle and ask students to hold on to the one that they think is their own.*

- *Have a rock swap with other schools.*

- *As a "pre" activity, students can sort a large collection of rocks according to different attributes. This is different than testing attributes and can be done informally to start observing rocks closely.*

There are many different ways to classify rocks. In this activity, have students put all their rocks into one collection. Then they can proceed to classify the entire collection into different categories. Some possible categories are suggested below. You may also want to do this activity in small groups or arrange work stations.

1. Classify all rocks by color. Record your findings by making a colored rock chart.

2. Classify all rocks by texture such as: rough, shiny, smooth, cracked. Think up more categories and compare your results.

3. Classify all rocks by weight. Verify your findings by using a scale.

4. Think up ways to classify your rocks in different ways. Compare your results. Surprise us!

Activity: **Rock Mystery**

Ask students to write in their thinkbooks about how they think their rocks came to be. They will not necessarily come up with the right answer, but educated speculation or forming a hypothesis is an important part of science.

Ideally, see if you can arrange a visit from a local rock hound or a visit to a geologist or a geology museum. Have students bring their rocks and test their hypotheses.

To encourage them to further examine and evaluate their rocks, have students complete a worksheet like the one below.

"I don't have any clue about how my rock was formed but I'll take a guess. Maybe my rock was formed from extreme heat or pressure. Maybe my rock is metamorphic."

Miranda Bushey
Grade 5, Milton

My Rock

1. Draw your rock here:

2. Using words, describe your rock. Include sentences about its size, weight, color, shape and hardness. Pretend you are describing your rock to a person who cannot see or feel.

3. What is the single most prominent characteristic of your rock? (Shape, color, size, etc?)

4. How do you think your rock was formed?

Activity: Characteristics of Rocks and Minerals

You will need:
- hammer or tool to break rocks
- sock or covering to prevent shattering
- magnet
- 5-10X magnifying glass
- rock and mineral guidebook
- streak plate or unglazed porcelain penny
- steel scissors or a file
- rock collection with samples of:
  igneous-volcanic rock *(basalt, obsidian, tuff and pumice)*
  igneous-plutonic rock *(granite and gabbro)*
  sedimentary rock (*sandstone, limestone, shale conglomerate, and coal)*
  metamorphic rock *(slate, quartzite, schist, marble)*
  This rock collection should also include semi-precious samples such as pyrite, hematite, agate, calcite, copper, silver, turquoise, a selection of crystals *(quartz, amethyst, fluorite, calcite, etc.),* and at least one geode.

TEACHER NOTES *and* INFO

Attributes of rocks can be tested with a rock kit that you borrow, buy or assemble yourself. If you go to a rock store, let the staff know you are collecting for educational purposes. Maybe they will give you a discount. A real rock collection works best for testing, but you can also use the rocks that students brought in. You may not get many different kinds of rocks, though. The "tests" that you will be running are the same that geologists use to classify rocks. They also conduct many other tests.

STUDENT ACTIVITY

If you have enough materials, arrange cooperative groups. Each group will need a sampling of rocks, testing tools and a chart of attributes (see "How Would You Describe It?"). Depending on the age group of your students, you may want to set up a supervised station for the rock breaking. It's always great to have a parent volunteer for this type of lesson. If you don't have enough materials, set up stations with a collection of rocks and tools. In this case, each student (or pair of students) would have a copy of the chart.

Review with students how to test for the different attributes. Pick a rock and demonstrate (without naming the rock aloud). **Example:** quartz

COLOR - *Quartz is usually colorless or white, but it may be pink, smoky gray, yellow, or purple if it contains impurities.*
STREAK - *Quartz should leave a white streak.*
LUSTER - *Quartz has a glassy luster because it shines a little like glass.*
HARDNESS - *The steel probably can't scratch the quartz, so it is considered a hard mineral.*
NAME - See if students can name the rock. Use mineral guides at this point.

This activity can be adjusted to have students individually test the attributes of their rocks and then work in cooperative groups to identify their rocks.

STUDENT HANDOUT - "How Would You Describe It?"

How Would You Describe It?

Attribute	Rock 1	Rock 2	Rock 3	Rock 4
COLOR - Observe and record the color of the rock.				
STREAK - What color does your mineral leave when streaked or scratched across a streak plate or unglazed porcelain? ***Note:*** *Sometimes it will be hard to distinguish the streak of hard minerals.*				
LUSTER - How does your mineral reflect light?				
HARDNESS - If you can scratch a mineral with your fingernail, it is **very soft**. If you can scratch it with a penny but not your fingernail, it's **soft**. If you can scratch it with steel scissors or a steel file, it's **medium**. If the scissors or the file won't make a scratch, it is **hard**.				
NAME - Can you name the rock? (Use mineral guides.)				

Activity: **Walk the Big Walk**

TEACHER NOTES *and* INFO

This activity shows geologic time relevant to the creation of Lake Champlain. Since this is a very hard thing to grasp, "walking the years" as a series of steps helps. The steps give a scale that the students can relate to. You need a large space such as a parking lot or a playing field to do this in.

Make big signs with the following information:

1. Earth formed 4,600,000,000 years ago.
2. Adirondack Mountains formed 1,100,000,000–1,400,000,000 years ago.
3. Iapetus Ocean opens 600,000,000 years ago.
4. Green Mountains formed 450,000,000 years ago.
5. Atlantic Ocean opens 200,000,000 years ago.
6. Glaciers advanced over North America 100,000 years ago.
7. Champlain Sea formed 12,000 years ago.
8. Lake Champlain formed 8,000 years ago.

Explain that one step equals 50 million years. Pick a starting point and have a student hold a sign and "move back in time." The spacing of students on this large timeline gives them a reference point to talk about geologic time.

1. Earth formed = 90 steps.
2. Adirondack Mountains formed = 25 steps.
3. Iapetus Ocean opens = 12 steps.
4. Green Mountains formed = 9 steps.
5. Atlantic Ocean opens = 4 steps.
6. Glaciers advanced over North America = sideways step.
7. Champlain Sea = balance on big toe.
8. Lake Champlain = balance on little toe.

Other Ideas

• Use the information in this article about the events since the disappearance of the glaciers and have students design another walking timeline (with another scale of their creation). Include human habitation and the presence of woolly mammoths!

• Although the number of "steps" in this activity is convenient, Jeff Howe suggests that students divide whatever distance is at their disposal (parking lot, soccer field, hallway) by the requisite number of years. This allows them to construct their own path, using good math skills along the way.

Credit: *Activity adapted by Lisa Borre of the Lake Champlain Basin Program and Charlotte Mehrtens of the UVM Geology Department from the BIG BEAST BOOK by Jerry Booth. Used with permission.*

Rubies Pearls

Activity: Fossil Print

YOU WILL NEED:
- petroleum jelly
- plaster of paris
- plastic margarine containers and covers
- spoons for mixing
- chosen object with which to print fossil
- straws cut in one-inch lengths (optional)

STUDENT ACTIVITY
Beforehand, students need to choose an object with which to make their fossil print. It could be a shell, piece of coral, bone or the hard part of a plant.

1. Lightly grease the inside of the plastic cover with petroleum jelly.
2. Lightly grease the object that will be used to make a print.
3. Mix plaster of paris in the plastic container. (Mixing directions are on the package.)
4. When ready, pour into the covers quickly.
5. Set the object in the plaster.
6. Put pre-cut straw pieces in the plaster which, when removed, will make a hole. When dry, place a string though the hole to hang.

One hour later, or the next day:
1. Pull up the object.
2. Pull up the straw.
3. Pull off the plastic cover.

Activity: Geology You Can Eat

You will need:

- three flavors of gelatin—maybe raspberry, lime and lemon
- graham crackers
- whipped cream
- banana
- clear glass pan, 8” x 12” and at least 2” deep
- measuring cup
- plate
- paper towel

TEACHER NOTES *and* INFO

The language of this activity is directed toward young learners. I found it so enticing that instead of changing the format to match the rest of this text, I left it as is. If you are going to do the activity, it makes sense that the “cooks” have a copy of the directions.

STUDENT ACTIVITY

To get a good look at what happens to rock strata, it is a good idea to make your own. You could do it with sand, silt, and seashells, but then you’d have to wait around for thousands of years before you could see the results.

A much quicker way is to use flavored gelatin. It’s easy to make, it’s a lot less messy, and when you’re done looking it over and experimenting with it, you can eat what’s left for dessert!

First, mix up a batch of limestone, more commonly known as lime gelatin. We’ll say that this stratum formed when the area was under the ocean. To create the limestone, put the gelatin in a measuring cup, add boiling water, and stir. Add a little less water than called for in the directions on the box. Let your limestone cool in the mixing cup for about 15 minutes; then pour it into the pan. Place the pan so it is level in the refrigerator and leave it until the gelatin is completely set.

Next, make a stratum of sandstone, the kind that forms from sand deposited by a river. Fossils are often found in this kind of stratum, so we’ll need some fossils, too. In this case, the sandstone will be raspberry gelatin and the fossils will be pieces of banana.

Cut the banana into small chunks. Mix the gelatin in the measuring cup as you did before and let it cool for about 12 minutes. Mix in the banana. Pour this mixture into the pan on top of the “limestone.” Make sure the limestone is completely firm, so the two layers don’t mix together. Place the pan back in the refrigerator until it is cold and firm.

Our next stratum will be a thin layer of coal formed when the area was part of a huge swamp. In this case, crushed graham crackers will be our coal. So crumble up five or six graham crackers and sprinkle them on top of the sandstone.

Next, mix up half a box of the lemon gelatin. This will be another layer of sandstone. Pour it on top of the graham crackers and return your growing formation to the refrigerator for more cooling.

For our final layer we need a siltstone. Make the rest of the lemon gelatin and let it cool in the measuring cup. Then stir in about 1/2 cup of whipped cream or topping. Pour this mixture evenly over the top of your formation. Put the whole thing back into the refrigerator.

One thing you'll notice is that the banana fossils are hidden away under a number of other layers. How will they ever be found? Fortunately, things don't stay put in nature. Rock strata may not be as soft as gelatin, but they do stretch and bend and even break, just like gelatin layers, when they are subjected to the heat and pressure generated by the earth.

Once your formation has set, take a look through the side of the dish. You've created in an afternoon a series of strata that would take millions of years to form in nature.

There are a number of different ways that the fossils can work their way to the top of the pile. Cut a 4" x 4" square of the formation, and you'll see how this might happen.

Where are the oldest gelatin strata? Right. On the bottom. And the youngest? On top.

Uplifting - There are tremendous pressures building up inside the earth. These pressures form mountain ranges, and at the same time they twist flat strata of rock into all sorts of bizarre shapes. Slide a knife under the center of your gelatin square and lift. The strata will bend so far and finally break. Once the pieces are standing on end, you'll see something interesting—one edge of the sandstone with the fossils is now on the surface.

If a couple of miniature paleontologists happened to wander across this area right now, they'd probably discover some great banana fossils!

Overthrust - There's another way that strata can get mixed up. Cut another square of gelatin. Gently and evenly push in from opposite sides of the square so that the center rises up and one half flops over on the other half. When this happens in the earth, geologists call it an overthrust.

Notice that the older strata are no longer under younger ones. In fact, half of the youngest stratum is on the very bottom. Geologists must study rock strata very carefully to determine their relative ages.

Faulting - The surface of the earth is full of big cracks called faults. Sometimes the land on one side of the fault will be uplifted, or raised, above the land on the other side. This is another way that fossils can work their way to the surface.

You can demonstrate the effects of faulting with another square of gelatin. Slice the square into two parts with a spatula. Then use the spatula to lift up one half. If it is raised high enough, the layer containing your fossil bananas will be exposed.

Erosion - Fortunately for paleontologists, sedimentary rocks are constantly being worn away from above by rain and wind, so fossils are constantly being uncovered. We can show this with a cupful of warm water and another square of stratified gelatin.

Place the gelatin on a paper towel on a plate. Tilt the plate over a sink or bowl that will catch the water, and slowly pour a stream of warm water on one edge of your square. Gradually, the top layers will melt away, exposing the fossil (banana) layer.

The wind also erodes sediments. To show this, take a blow dryer, turn it to warm, and aim it at a square of gelatin. In a few minutes the top layers will begin to dissolve. Soon banana fossils will be uncovered.

Of course, in nature the rocks don't melt. They're just slowly broken down and carried away.

Notice how small pieces of banana flow out with the melting gelatin. This happens with real fossils too. When paleontologists find a few small bone fragments lying on the ground (which they call float), they often find the rest of the fossil by looking in the rocks directly above it.

Marker Beds - Coal beds like the one formed by your graham crackers are very important to paleontologists because they can be seen very easily. A gelatin geologist looking at your formation, for example, could always be sure that wherever she spotted graham crackers she would also be likely to find bananas in the next layer. Real fossil hunters often use the dark black coal beds as "markers" because they are easy to spot among all the light gray and brown layers. By knowing where the fossil-rich strata are in relation to the coal, they can zero in on the areas where they are most likely to find fossils.

Credit: *Activity reprinted with permission from the BIG BEAST BOOK: DINOSAURS AND HOW THEY GOT THAT WAY by Jerry Booth.*