GEOLOGY

"In all directions, many stones."

Samuel de Champlain,
Voyages

Map of New France (detail). Samuel de Champlain, 1612.

In All Directions, Many Stones

Jeff Meyers, LCMM

> As soon as we had reached the fall [we] went on shore to see whether we could pass this place; but we went some league and a half without seeing any prospect of being able to do so, finding only water running with great swiftness, and in all directions many stones, very dangerous, and with but little water about them...Having returned, and seeing the slight prospect there was of passing the fall with our shallop, I was much troubled. And it gave me especial dissatisfaction to go back without seeing a very large lake, filled with handsome islands, and with large tracts of fine land bordering on the lake…After duly thinking over the matter, I determined to go and fulfill my promise, and carry out my desire. Accordingly, I embarked with the savages in their canoes…
>
> *Voyages of Samuel de Champlain, 1604-1618*
> Grant (ed.), page 155.

Bedrock is the solid rock that underlies soil and other loose material on the landscape, providing the physical foundation for landforms and for the natural and cultural events that make up what we know as "history". In our minds, it forms the solid framework, the "terra firma" that seems to have always been here, unchanging and immovable.

In the summer of 1609, Samuel de Champlain accompanied Algonquin and Abenaki allies to enter the "River of the Iroquois" (today's Richelieu River) in a large rowing and sailing boat known as a "shallop". He was excited to explore the waters now known as Lake Champlain. When the party reached a stretch of impassable whitewater, however, Champlain stared in consternation at the bedrock and boulders that blocked his way. There was no possibility of his thirty-foot boat being able to pass through the "water running with great swiftness...in all directions many stones, very dangerous, and with but little water about them".

Champlain continued with his native allies, leaving the shallop behind in favor of one of the twenty-four swift and portable birchbark canoes on the voyage. While the rocky falls had nearly stopped him, Champlain traveled on with satisfaction. Perhaps the time staring at the stones and boulders gave him greater reason to wonder about the many rocks and rock forms that were frequently in his view for the remainder of his trip.

For centuries, geologists have examined the rocks that make up the land we move upon. With discovery after discovery they have come to realize that although the rocks around us may seem silent and immobile, in fact every crystal and layer of sediment echoes with a story of dramatic change. Bedrock tells a tale of time made up of moving oceans and shifting mountains, rivers, volcanoes, earthquakes, magma and ice. Landforms and the rocks and sediments that compose them are in a state of constant change.

Evidence of Ancient Seas

Champlain paddled by, peered at, or walked upon the evidence of geologic change every where he went in the New World. On Lake Champlain, the fleet of birch bark canoes passed by "four fine islands ten, twelve, and fifteen leagues long" and for mile after mile, his eyes could not have missed seeing the gray, layered rocks of low shoreline cliffs topped with northern white cedars. Countless chunks of this rock had broken off to form rocky beaches where lake waves lapped along the island shores. The same rocks covered the bottom of the lake into which he looked.

The bedrock seen along Isle la Motte, Cumberland Head, North and South Hero Islands, and Valcour Island formed about 500 million years ago when sediments deposited in an early precursor of our modern Atlantic Ocean that was forming a gap between the North American and Eurasian continents. (This ancient sea should be distinguished from the much more recent “Champlain Sea” that existed after the recession of the Pleistocene glaciers.) Shelf-like rock layers formed over millions of years as the sediments compacted and solidified into sedimentary rock formations. During this period the Vermont region was much closer to the equator and tropical latitudes. The region had a hot and humid climate and the sea was filled tropical marine life. The limestones and dolomites of the Champlain lowlands are formed largely by the calcareous hard parts of the marine species that lived during this period.

If Samuel de Champlain had climbed up one of the limestone ledges of Isle la Motte, he would have seen fossil coral reef structures chock-full of fossil organisms. Along the route of his lake travels he may have picked up fossil cephalopods (extinct relatives of squid), trilobites (extinct relatives of the horseshoe crab), brachiopods (an extinct phylum of shelled creatures) among others. Further down the lake, if he had stretched his legs at present-day Willsborough Point, he would have observed large fossil ripples in the rock – ripples with an asymmetry from trough to crest that indicate a strong local tidal current had once flowed there hundreds of millions of years ago.

Shifting Continental Plates

Why does so much of Lake Champlain bedrock contain fossils of coral and other marine life when the nearest such life today is thousands of miles away? It was not until the 1960s that geologists began to agree that the earth’s crust is not an unbroken sphere, but is actually composed of gargantuan, solid “plates” that “float” and drift in a semi-solid region below the earth’s surface. The drifting of these plates offers a convincing explanation for the puzzle: the continental plates are in constant movement. As they slide by, pull apart from, or smash into one another, tremendous forces are generated. Plate *colliding* with plate can lead to crustal folding that builds mountains. Plate *sliding* by plate can result in earthquakes; plate *separating* from plate can cause volcanoes or block faulting. The geologic history of the Champlain Valley is characterized by a repeating sequence of plate collision (mountain building events, also called “orogenies”) alternating with plate separation (down-dropping blocks and rifting of crust leading to valleys and new ocean basins).

Mountains Old and New

As he progressed down the lake, Champlain noticed in the distance “some very high mountains on the eastern side, on the top of which there was snow”. Since this was the beginning of July, many historians believe that it was probably rock—not snow—that he observed high on the top of what is today known as the Green Mountains. Champlain could not have imagined that there were once much loftier mountains here. Over one billion years ago a major mountain building event, the “Grenville Orogeny”, raised an extensive range of very tall mountains that once covered the areas of western Vermont and the Adirondack region.

Over a great deal of time, these mountains eroded away to nothing, leaving behind only their underlying “basement” rock. Before the next orogeny, crustal separation led to rifting and the formation of the “Iapetus Ocean” where the limestones described earlier were deposited.

About 440 million years ago, another plate collision event—the Taconic orogeny—first raised the mountains we know as the Green Mountains. This was a period of unbelievable landscape compression, and the bedrock at the mountain zones folded and folded again, crumpling and pushing bedrock both up in elevation and down into the depths of the earth. Another mountain-building event 100 million years later (the Acadian orogeny) added to and compounded the folding, raising the mountains again. The rock strata to the west of the growing mountains were affected as well. Layers of bedrock broke as a result of pressure in many places forming “thrust faults”. In some locations, older layers sheared off and rode up over younger layers of bedrock. Thrust faults occur in many Champlain Valley locations and account for a chain of small but prominent mountains along the Vermont shoreline of the lake (Cobble, Arrowhead, Pease, Philo, and Snake Mountains) as well as major waterfalls at the Lamoille, Winooski, Otter Creek, and other tributaries.

Champlain also saw to the south “other mountains no less high than the first, but without any snow.” These were the Adirondack Mountains, a circle of geologically very young mountains, but made of the same billion plus-year old rocks as ancient as the basement rock of the Green Mountains and the Canadian shield. The Adirondack rock originally formed at great depth from molton rock that cooled very slowly. Igneous in origin, these rocks were covered by many kilometers of overlying mountains and were therefore exposed to extreme pressure and heat that reconstituted their original mineral arrangements to form new mineral assemblages. Adirondack rock is therefore metamorphic rock. The ancient mountains overlying Adirondack rocks gradually eroded down to nothing, and they were then covered by the same sedimentary layers that surround the Adirondacks and which compose most or all of the Champlain Valley.

In relatively recent geologic time, the Adirondack region uplifted to form a mountainous dome. Erosion removed the sedimentary layers from the region and eventually created a sort of “window” through the sedimentary rocks that allows us to observe the older basement rocks below. In 1609, the sculpted peaks of the Adirondack dome showed their distinctive profiles to those looking up to their summits from the waters of the lake. We now know them as Whiteface, Giant, the Dix range, and about forty other peaks that exceed 4,000 feet in elevation. Interestingly enough, these peaks are actually higher now than when Champlain observed them, for the Adirondacks are still slowly rising at a rate of about 3 millimeters per year. That’s 12cm!

Block Faulting

The party of canoes eventually paddled over the very deepest section of Lake Champlain where the depth surpasses 400 feet. Here it is actually nearly 700 feet deep to bedrock, as the lake is filled with huge volumes of sediment. They then passed in close proximity to a hunk of Adirondack anorthosite as they paddled by Split Rock Point on the lake’s western shore. This “island” of rock, however, is exposed at the surface not because of the uplifting of the Adirondack dome, but as the result of block faulting—the result of one of several periods of crustal stretching or rifting. This type of faulting is the result of major tensional stresses, which stretch and pull apart the earth’s crust. As the bedrock pulls apart, sections drop down while others raise up. Split Rock Point is an upfaulted block of anorthosite and metagabbro that stands not far from the downthrown, younger limestone of Whallon Bay. Successive block faulting associated with the stretching of continents and the opening of the Atlantic Ocean about 200 million years ago helped to form the canyons of Lake Champlain. A few miles south of Split Rock Point is a cliff known as the “Palisades”, also the result of block faulting. The party of canoes must have passed close by this impressive cliff that rises 150’ above the water and sinks about the same distance below.

Erosion

Today, the main lodge of the Basin Harbor Club stares across the lake at the Palisades. This building is exposed to strong winds and harsh winter weather of Lake Champlain. Left alone, without constant painting and maintenance, this and any other lakeside buildings would quickly decompose into a pile of rubble in a mere hundred years or so. Although it takes a much longer time, solid bedrock is also subject to weathering and eventually disintegrates into fragments. Weathering of bedrock occurs by both mechanical and chemical means. The action of water and ice exploits rock joints to expand and fracture rock sheets in a sort of natural quarrying process. For 10,000 years prior to Champlain's arrival, Native Americans in this region had been picking up certain fragments of rock—mainly quartzite and chert—to fashion them into projectile points and other tools with which to hunt, fish, work hides, and perform other tasks necessary to survival.

We see the results of weathering everywhere we look. Rock bodies are broken apart and modified into smaller and smaller spherical shapes. Wedging, chemical dissolution, and other actions form a blanket of loose, decayed rock debris known as regolith, a widespread, discontinuous cover over solid bedrock. In Vermont, there is not much regolith as recent glaciers scraped the landscape down to bedrock leaving instead a layer of glacial till over the bedrock. Over this layer of till small particles of rocks and minerals, plus amounts of decomposed organic matter have created soil. The type and thickness of soil depend on the underlying rock material, topography, climate, and the passage of time.

Champlain noticed "many rivers falling into the lake," his route probably passing within proximity or view of the Saranac, Ausable, Boquet, Winooski Rivers, Otter Creek and other major tributaries. Running water is by far the most significant agent of erosion. Rivers collect water precipitated on the surface and funnel it back to the ocean. As water flows, it picks up weathered rock debris. Champlain may have noticed the difference in water clarity between the deep, clear waters of the Lake and the murky brown waters at the mouth of each tributary where sediments—eroded from the surrounding landscape—entered the lake. Water moves rocks large and small, enabling the aspirations of explorers and continuously modifying the surface of continents.

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Lesson

The Oldest Thing

LCMM

Grade Level K-8

Content Areas Science, Social Studies

VT Grade Expectations VT H&SS 8: Students connect the past with the present by…

- Classifying objects from long ago
- Exploring objects and looking closely at similarities, differences, patterns, and change.

NY Standards NY Social Studies Standard 1: History Key Idea 2:

- Distinguish between near and distant past and interpret simple timelines.

Duration 50 minutes

Learning Goals **Students will learn to identify the approximate age of an object and sequence a collection of artifacts into chronological order.**

Description

1. For homework, have students look around their home and try to find the oldest thing that they can bring to school. (Be sure to emphasize that they must have parental permission.)
2. Have each student share the object s/he has brought. Have him or her describe what it is and how old they think it is.
3. As students share their objects, discuss if the object is natural or man made, where it came from, what it is used for, etc.
4. As each student shares his or her object, lay it out on a table from oldest to youngest according to the estimated ages.
5. Discuss how wide a time range is represented by the collection of objects and if there are any clusters of similar ages.
6. Discuss how we can organize time by observing the age of objects around us.

Assessments Informal assessment of participation and students' ability to describe the object they bring.

Materials/Resources Objects brought to class by students.

Special Considerations This activity will lead into a discussion of rocks, which are the oldest things anyone could bring. If none of the students happen to bring a rock in, the teacher should have one ready to put the age of other objects into context.

Geological Timeline

LCMM

Grade Level 4-12

Content Areas Science

VT Grade Expectations

VT H&SS5-6:10: Students show understanding of past, present, and future time by…
- Constructing time lines of significant historical developments in the nation and world, designating appropriate equidistant intervals of time and recording events according to the order in which they occurred.
- Interpreting data presented in time lines.

VT S5-6:47: Students demonstrate their understanding of Processes and Change over Time within Earth Systems by…
- Identifying examples of geologic changes on the earth's surface…

NY Standards

NY Social Studies Standard 1: History Key Idea 2:
- Distinguish between near and distant past and interpret simple timelines.

NY Science Standard 4: Physical Setting Key Idea 2:
- Explain how the atmosphere (air), hydrosphere (water), and lithosphere (land) interact, evolve, and change.

Duration 50 minutes

Learning Goals **Students will discuss Earth events and how they fit onto a geological timeline compared with human events.**

Description

1. Use a long chalk/white board, a roll of paper about 20-30 feet long, or a line in a hallway to designate the "Beginning of the Earth" on the left and "Today" on the right.
2. Label Beginning of the Earth approximately 4.6 billion years ago. (This may be controversial and it could be productive to begin with a discussion about various creation theories including science.)
3. Divide the distance in half and label 2 billion years ago.
4. Divide that distance in half and label 1 billion years ago, the age of the Oldest Surface Rocks in the Adirondacks. This is also the approximate age of the first living things.
5. Divide that distance in half and label 450 million years. This is the age of many of the rocks that make up the Green Mountains.
6. Divide that distance in thirds and label 150 million years ago. This is the age of the Dinosaurs.
7. Divide that in thirds and label 100 million years, First Humanoid Remains.
8. Divide that in tenths and label the last one 100,000 years, Modern Humans.
9. Divide that into tenths and label 10,000 years, the earliest Agriculture.
10. Divide that in half and label 5000 years ago, the earliest Civilizations and the beginning of Recorded History.
11. Discuss how human time compares with Earth time. Emphasize that when we look at ordinary rocks on the ground, or transformations in the Earth, we are talking about lengths of time that are vastly greater than anything in our own experience.

Geological Timeline (cont'd)

Assessments

Informal assessment of students' understanding of key ideas.

Materials/Resources

White/Black Board, Roll of Paper

Special Considerations

If you begin with a typical 20 foot chalk/white board, all of human history will be about the thickness of a chalk line on the right hand side of the timeline.

Categorizing Rocks

LCMM

Grade Level K-8

Content Areas Science, Language Arts

VT Grade Expectations VT S 46: Students demonstrate their understanding of Processes and Change over Time within Earth Systems by…

- Observing and describing the properties of rocks.
- Observing, describing and comparing color and texture of different types of rocks and soils.

NY Standards NY Science Standard 4: Physical Setting Key Idea 2:

- Describe volcano and earthquake patterns, the rock cycle, and weather and climate changes.

Duration 50 minutes

Learning Goals **Students will sort a collection of rocks into categories that they create based on their observations.**

Description

1. For homework have each student find three rocks that are interesting and portable to the classroom.
2. Divide students into work groups of 3-5 and have them combine their rocks into a single collection.
3. Discuss how organizing things into categories makes them easier to study and identify. Give examples of the kinds of categories we typically use (e.g. size, color, shape and texture.)
4. Have students arrange their collection into at least three categories. The group must agree on the placement of rocks and be able to articulate the criteria for each category in words.
5. When each group has arranged their rock collection have them report to the whole class the description of the categories they created. The teacher should record the categories titles on the board or overhead.
6. Ask each group if there were any rocks that were difficult to categorize and why.
7. After each group has reported out, discuss similarities and differences between the categories students generated and if any categories were particularly good for describing rocks.
8. Have the whole class choose the 3-4 categories that they thought were most descriptive.
9. Have groups reorganize their collection into the categories chosen by the class.
10. Discuss how their arrangement changed and if there were any rocks that were difficult to place in the new categories.

Assessments Informal Assessment of participation and understanding of key ideas.

Materials/Resources Rock samples

Special Considerations Discuss safety in handling the rocks in case there are any sharp or otherwise dangerous samples in the collection.

Identifying Rocks

LCMM

Grade Level K-8

Content Areas Science

VT Grade Expectations VT S 46: Students demonstrate their understanding of Processes and Change over Time within Earth Systems by…
- Observing and identifying components of soils and rocks.
- Observing and describing the properties of rocks.

NY Standards NY Science Standard 4: Physical Setting Key Idea 2:
- Describe volcano and earthquake patterns, the rock cycle, and weather and climate changes.

Duration 50 minutes

Learning Goals **Students will learn to categorize rocks into the three basic types by closely examining their characteristics.**

Description
1. Before the activity assemble a collection of 5-10 different rocks and number them with an ID tag. Commercial collections or found samples are fine as long as they represent sufficient variation.
2. Divide students into work groups of 2-4.
3. Review the three basic rock types, igneous, sedimentary, metamorphic, and the characteristics they will be looking for.
4. Distribute the rock identification worksheets.
5. Give each work group one rock sample and have students examine and identify it according to the identification characteristics.
6. On their numbered worksheet they should record what they think the rock is.
7. After each identification, rotate the rocks between groups until each group has identified each rock.
8. On the board accept all the identifications for each sample first.
9. Go back and discuss any disagreements and have students make a case for why they identified the rock as they did.
10. If students are interested, have them use a more formal identification key to identify the specific rock name.

Assessments Informal Assessment of participation and understanding of key ideas.

Materials/Resources Hand Lenses, Rock samples, Worksheets

Special Considerations Some students become very interested in rock identification. There are many great field guides and internet rock identification keys available for individual students or teachers who want to explore this area in more detail.

ROCK IDENTIFICATION

Name ___________________________________ **Date** ___________________________

IGNEOUS rocks are formed from cooling magma. They are made of large or small crystals that are spread evenly throughout the rock. They may be light or dark, but usually light gray to black. There may also be pink, yellow, or black crystals in large grained rocks. Bubbles sometimes form if the rock cools very quickly. Some types of igneous rocks are: granite, basalt, gabbro, pumice, obsidian.

SEDEMENTARY rocks are pressed or cemented together from the grains that weather from other rocks. They may be any color with very fine or large sandy grains. They often have very clear layers that are easy to break apart. Fossils may be embedded in the rock. Some types of sedimentary rocks are: limestone, shale, chert, dolomite, coal.

METAMORPHIC rocks are formed from other rocks when they are put under great pressure and heat. They can be any color from pure white to solid black. Often they have fine grains of mica that flake off. They may also have layers of different minerals that are wavy like ribbons through the rock. They are usually very hard and the layers do not break apart easily. Some types of metamorphic rocks are: Slate, schist, gneiss, marble, quartzite.

Directions: Read the descriptions of the three types of rock, above. Then under "Characteristics", describe your rock - is it dark or light? Bumpy or smooth or flat? Are there flecks of another color or texture in your sample? Then try to identify if it's Igneous, Sedimentary, or Metamorphic in "Type of Rock".

SAMPLE NUMBER	CHARACTERISTICS	TYPE OF ROCK
1		
2		
3		
4		
5		
6		
7		
8		

Rock Cycle

LCMM

Grade Level	K-8
Content Areas	Science
VT Grade Expectations	VT S 46: Students demonstrate their understanding of Processes and Change over Time within Earth Systems by… • Observing and identifying components of soils and rocks. • Observing and describing the properties of rocks.
NY Standards	NY Science Standard 4: Physical Setting Key Idea 2: • Describe volcano and earthquake patterns, the rock cycle, and weather and climate changes.
Duration	50 minutes
Learning Goals	**Students will learn about the Rock Cycle and the three categories by which rocks are typically identified.**
Description	1. Remind students that the Earth is very old and although it seems to change little over a human life time, it is in constant change in "Earth Time." Earthquakes, volcanoes, continental shifts, and the weathering of rocks are all occurring, but at a pace we rarely notice. 2. Distribute Rock Cycle articles and worksheets. 3. Have students read the article and take notes as they work. 4. Discuss student responses clarifying and adding as needed. Emphasize the three types of rock: igneous, sedimentary, and metamorphic as the way scientists classify rocks.
Assessments	Informal Assessment of participation and understanding of key ideas.
Materials/Resources	Hand Lenses, Rock samples
Special Considerations	Discuss safety in handling the rocks in case there are any sharp or otherwise dangerous samples in the collection.

ROCK CYCLE

To us the Earth seems unimaginably huge and solid. We jump on it, dig in it, drop bombs on it, and rarely see any change. A boulder we see laying on the ground in the woods may have been lying in that same place for thousands of years. Only the occasional earthquake, volcanic eruption, or flood reminds us that the Earth is constantly changing.

Although the Earth seems solid to us, the part we live on is actually very thin. The surface of the Earth, the crust, is like the skin of a balloon. Inside the Earth is molten rock called **magma** that is in constant motion. The cool crust floats on this sea of liquid rock and we rare see what is happening inside. When pieces of the crust rub together we feel an earthquake. When the crust cracks open the magma explodes or oozes out as the lava of a volcano. As magma reaches the surface it cools and hardens into new, young rock. Scientist call the new rock that forms from molten rock **igneous** rock. Most of the Earth's crust is made of igneous rock. Examples are granite, basalt, and obsidian.

It's not just the inside of the Earth that affects rocks. Rain and water wash over and rub against the rocks. Over a very long time tiny particles that make up the rock are worn away. This is called **weathering**. The particles are washed away with the water, flowing downhill until they settle in the bottom of a pool or stream. After a heavy rain you can often see erosion and gravel and sand left along the roadsides. A pond or lake will often look muddy because there are so many tiny particles of rock and soil suspended in the water. Eventually all these particles will fall to the bottom and build up a layer of mud and sand. Year after year this layer gets thicker and thinker. These layers of mud and sand are called sediments. The particles on the bottom are squeezed together because of the weight of the mud and sand on top. Over thousands of years the sediments are squeezed together so tightly that they form new rocks. These are call **sedimentary** rocks because they are formed from the sediments in the bottom of a lake or ocean. Sometimes tiny animals are buried in the sediments. They also harden and turn into rock which we call **fossils**. Limestone, sandstone, and shale are examples of sedimentary rocks.

Older sedimentary or igneous rock is often pushed down deep into the crust of the Earth. The deeper it is pushed the more it heats up from the magma below and the pressure from the weight above. If the heat and pressure become high enough, the structure of the rock will change. The material in the rock will become harder and sometimes crystallizes into a **metamorphic** rock. Metamorphic rocks include marble, slate, and schist.

In time all rocks weather away and new rocks are created. This process of continuous change is called a **cycle** and the **rock cycle** is one of the Earth's basic systems. We don't notice it much because it happens so slowly. The rock you pick up off the ground may be a billion years old and it may take another billion years before it is recycled into some other kind of rock.

ROCK CYCLE WORKSHEET

Name ______________________________ **Date** ________________________

Read the article on the Rock Cycle. Take notes on the three types of rock and answer the questions below.

What are the three types of rock?

1 ____

2 ____

3 ____

1. Type of rock ______________________ Formation process: ______________________

____

____

2. Type of rock ______________________ Formation process: ______________________

____

____

3. Type of rock ______________________ Formation process: ______________________

____

____

Define these terms:

"Weathering" ____

____

____

"Fossil" ____

____

____

Why is it called the rock "cycle?" ______________________________________

____

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Rocks of the Champlain Valley - Class Rock Collection

LCMM

Grade Level K-12

Content Areas Science

VT Grade Expectations VT S 46: Students demonstrate their understanding of Processes and Change over Time within Earth Systems by…
- Observing and identifying components of soils and rocks.
- Observing and describing the properties of rocks.

NY Standards NY Science Standard 4: Physical Setting Key Idea 2:
- Describe volcano and earthquake patterns, the rock cycle, and weather and climate changes.

Duration 50 minute Introduction then On-going

Learning Goals **Students will learn about the variety of rocks in the Champlain Valley by building a class rock collection.**

Description
1. Present as a lecture or have students read Rocks of the Champlain Valley.
2. Discuss a class project to build a rock collection and give instructions on how to collect samples:
    - Find pieces of rock that are freshly broken off a ledge. A ledge is a bed of rock that is sticking out of the ground, or the side of a mountain. It is not loose, but is still part of the bedrock below the soil. Pieces of rock that have been buried in the soil, or rolled in a stream or river are not good to collect. It is difficult to see what they are or what they are made of and you really don't know where they came from.. Collect clean fresh specimens.
    - Make a label that has the name of the rock and the location where it was collected.
    - Assign a number to each rock.
    - Record in a notebook the name, location where you found it, and number of the rock.
    - Paint a small white rectangle on each rock, and write the rock's number on it.

3. Discuss safety while collecting rocks:
    - Always wear safety glasses or goggles when breaking rocks.
    - Use only hammers that are intended for breaking rocks.
    - Do not climb on dangerous ledges or on quarry walls.
    - Never enter mine tunnels or caves.
    - If possible, always collect with an adult.
4. Identify and label samples as they arrive in class.
5. Display samples in a display case, clear plastic fishing lure boxes, or mounted on a board.

Materials/Resources Rock hammers, goggles, display boxes, labeling materials

Special Considerations Emphasize safety and the enjoyment of finding as many different kinds of rocks as possible. Remind students that size is not as important as variety.

ROCKS OF THE CHAMPLAIN VALLEY

The rocks of the Adirondack Mountains are among the oldest on the surface of the Earth. They are up to 1.3 billion years old. However, nearly all the rocks that make up the Adirondacks are metamorphic, which means they were made from even older rocks. The Adirondacks are also unusual because even though they are made of very old rock, the mountains are not as old. They were pushed up by heat and forces inside the Earth and some measurements show that they are still rising. The most common rocks in the Adirondacks are schist and gneiss. Rich iron deposits were also mined along the shores of Lake Champlain for many years and were an important early industry of the region.

The Taconic Mountains form the southern end of the Champlain Valley. They are very unusual because the rocks at the tops of the mountains are older than the rock underneath. Usually new rock forms on top of old rocks. But in the Taconic Mountains, the older rock was pushed by huge forces within the earth over top of the younger rock. So the mountain tops are rich in older slate and chert, overtop the shales and limestone beneath. The **slate** from the Taconic Mountains is among the finest in the world.

The ridge of the Green Mountains is also made mostly of metamorphic rock, but only half as old as the rocks of the Adirondacks. They were formed about 450,000,000 years ago from older sedimentary rocks at the bottom of an ancient ocean. There is schist, gneiss, serpentinite, and quartzite along the spine of the Green Mountains. Further east are intrusions of granite that formed when hot magma rose and slowly cooled between other rocks. The **granite** from the Barre quarries is famous throughout the world. There are also pockets of talc and gypsum in the Green Mountains that are important commercial minerals.

Between the Green Mountains and the Taconic Mountains is a narrow valley called the Valley of Vermont. This region is famous for its **marble**. Marble is a metamorphic rock formed from limestone and is used for building and sculpting.

Most of the valley on both sides of Lake Champlain is **limestone** and **sandstone**. Much of the limestone is rich in fossils that were formed at the bottom of an ancient ocean. One of the oldest known coral reefs in the world now rests above water on the island of North Hero.

The Earth's crust is in constant motion, bending and folding slowly over millions of years. The rocks and mountains we see today will continue to change slowly. Rocks tell the story of how the land was formed, how old it is, and maybe what will happen in the future.