Lesson 3: GeoSleuth Schoolyard

Overview

The main goal of this lesson is to get students familiar with the idea that geology is something tangible and that it affects the world around them. They should be inspired to ask questions about how geologic processes shaped the world around them and make observations to answer those questions. All of this on their schoolyard.

During the introductory activity, students learn that geology is a lot like detective work. Geologists infer the sequence and timing of events by collecting evidence and making observations, just like a detective. Students first make observations of a murder mystery. Then, they try to use simple principles to develop a story that is consistent with these observations. Many of the principles they use in the murder mystery are exactly the same as a geologist uses in determining the history of a landscape. Photographs relate the murder mystery to real geology.

Teachers can then take their students outside to explore their new found geologic interpretation skills. Because every schoolyard is slightly different, teachers will need to adapt this excursion to their own unique setting. The rest of the web site is a collection of example geologic features that might have analogs in the schoolyard. Teachers should browse the images and walk around their schoolyard looking for similar features. It also has links to background information and classroom activities about those features that serve as a jumping off point for teaching a wide variety of topics in earth science. A teacher could plan a single fifty minute field trip to the schoolyard to explore all the features, or use images from this section throughout their entire earth science unit.

Learning Outcomes

- Students relate geologic concepts to observations and processes that are familiar from the schoolyard.

Materials

A schoolyard and some creativity.

Time Requirements

Varies. Most of these features can be integrated into other lessons as short 15 minute field trips to the schoolyard to introduce a unit covering a topic in geology. Each individual topic also includes a variety of activities for further exploration that can take 1-2 class periods each.

Science Standards

Varies. Click on each feature to find out which standards it addresses.

Opening Activity

Geo-Sleuth Murder Mystery
To get students familiar with the idea that geology is something tangible, try out this activity. It introduces a series of fundamental geological ideas (geologic time including superposition & cross-cutting relations, observations v. interpretations, physical processes, and more). And, it's a lot of fun!

Click here for instructions and a short teacher's guide on this activity.

Before class, review the example schoolyard features shown in the table below. Then, go exploring your schoolyard for interesting features on your schoolyard. They might be quite similar to our examples, or they might be completely different. Every crack in the sidewalk can be a teachable moment because every crack is evidence of some physical process, so be creative! Note that many of the example pages have related classroom activities that you may want to consider doing before or after your field trip.

Take your students on a field trip to the schoolyard. The trip may take half a class period or much longer.

Instructions

- Guide them to some of the features you selected earlier.
- At each stop on the field trip, get students thinking about what they see. Ask them to begin by making detailed observations. For older students, this may include 3-5 minutes of "free time" to wander around and look closely at the pavement or other surface of interest. For younger students, you may want to sit the class in a large circle around the feature. Solicit observations from students, and correct them if they incorrectly give you too much interpretation about what happened (It's important to keep observations and interpretation separate!).
- Then, guide them slowly into discussing what they think the sequence of events was that formed this feature.
- Using printouts of photos from the web (either this site or others), show a geological analog. Explain how the schoolyard feature formed by a similar process to the real geological feature. Our glacial striations page shows a good expample of how processes on the schoolyard are similar to processes in nature.
- Then, explain how they might be different. A good example of differences comes from our fossil page. In the schoolyard, the tree that dropped its leaves when the concrete was wet is still alive. For fossils, sometimes the species is extinct and hasn't lived for millions of years. Further, the climate might have completely changed so that you get fossils of ferns in the desert.
- You can take a single field trip to many features, or take several field trips throughout the school year.

Examples

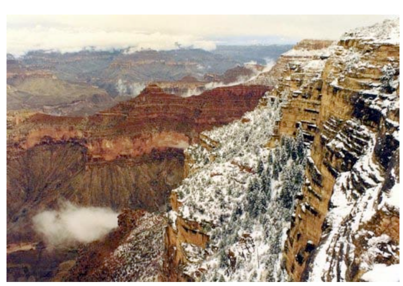
On a class trip out on to schoolyard, look for features like these. (Click on each image for a schoolyard example and one of a geologist in action).

Ages of Rocks

Dinosaur Tracks


Fossils


Glacial Striations


Layers on top of layers

Cutting across layers

Sinkholes

Lesson 3: GeoSleuth Murder Mystery

Overview

This murder mystery introduces both the nature of scientific inquiry and important geologic concepts in a very student-friendly, accessible manner.

Geology is a lot like detective work. The power of this exercise is that it exposes students to the main goals of geology and even some of the fundamental principles in a setting that they can understand -- a murder mystery. After the class explores the murder mystery, the teacher then shows a range of geologic photos that relate to features in the mystery.

I originally developed the exercise to begin the very first lecture of the semester in an college level introductory geology course for non-majors. More specifically, the course was taught at the community college level in a program inside San Quentin State Prison. Originally, we were apprehensive about teaching a murder mystery to students who may have committed a murder themselves. However, the students became very interested and excited in the exercise, enthusiastically participating. Once we established a list of agreed upon observations, they began arguing back and forth about theories and their interpretation of the evidence. The exercise was an overwhelming success. It has been tested from 4th grade through the college level, and can easily be adapted to any grade level. However, depending upon the age level of your students, a murder mystery may or may not be appropriate. Either way, don't glorify the violence. In fact, one possible scenario is that the man is not dead, but just spilled coffee, tripped and fell.

Top image: Cathy Grimaldi
Bottom image: Matthew d'Alessio, USGS

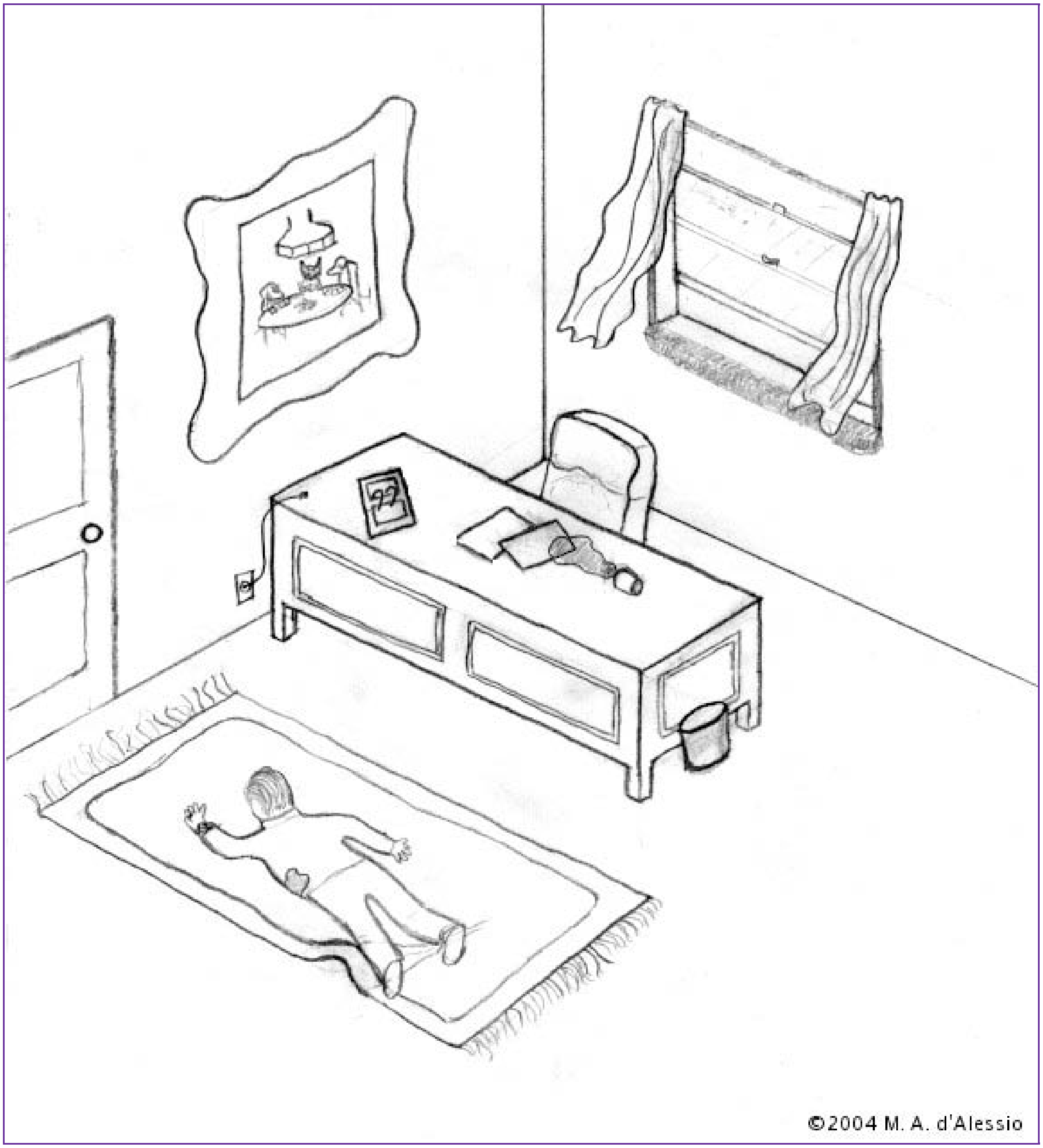
Learning Outcomes

- Geologists reconstruct the sequence of events that shaped the present-day landscape by making observations.
- Observations are different from interpretations. Observations are descriptions of things we see. Interpretations are stories about what happened that are based on the observations.
- Events that happened in the past are similar to events that we observe today. They follow the same laws of physics.

Presentation (either as overhead transparency or computer projector).
The activity is based around the GeoSleuth murder mystery drawing, shown below. You

have two options:

Materials	1. Recommended: Download a prepared presentation complete with the image, supplementary geologic images, and a teacher's guide. (Presentation: Powerpoint or Acrobat PDF ~ 3 MB; Teacher's Guide: Acrobat PDF, 1 MB). See the Downloads Page. 2. Abridged: Click on the image and print it on a transparency.
Time Requirements	One 50 minute class period



Introducing Get students excited that today they are going to do something a little bit different.

Introducing the Activity

Today, they are going to solve a mystery!

Instructions

1. Have students look at the photo for 1 minute silently by themselves.
2. Ask students to list observations about the image. Write them down on the board as students give them. Be very clear about the difference between observations and interpretation and don't write any interpretations on the board.
3. When you have collected all the observations, ask the class if everyone agrees with these observations.
4. Now the fun begins. Ask for students to volunteer their interpretation about the sequence of events that happened.
5. Let chaos reign for a few minutes as students argue competing theories.
6. Summarize the different interpretations, highlighting the geologic principles that each theory depends upon (shown below).
7. Show the geologic images from the Powerpoint presentation.
8. Put the murder mystery image up and go over the geologic principles again.
9. End class without giving them an answer about what really happened.

Closing the Activity

It's key to end the activity by returning to the GeoSleuth murder mystery photo. You should not, however, give students a definitive answer to the mystery. That's part of the nature of science -- there is never a right answer. There is only a "best answer," meaning one that is most consistent with the observations and most likely to be true. Different scientists often disagree about which answer is best, even when looking at the same data. This is because data are often incomplete or have large uncertainty.

Homework

Students can write their own murder mystery, carefully trying to integrate clues that will give the reader evidence of the sequence of events leading up to the murder.

Science Standards:

California

Investigation and Experiment ("Nature of Science" standards)

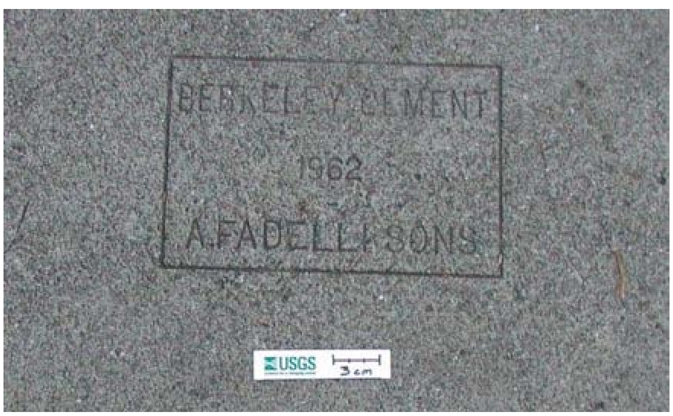
Gr3, Sc5. Gr4, Sc6. Gr5, Sc6. Gr6, Sc7. Gr7, Sc7. Gr8, Sc9. Gr9-12, Science Investigation. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. (See individual subitems for each grade).

Gr7, Sc4. Evidence from rocks allows us to understand the evolution of life on Earth. As a basis for understanding this concept:

Gr7, Sc4a. Students know Earth processes today are similar to those that occurred in the past and slow geologic processes have large cumulative effects over long periods of time.

Gr7, Sc4c. Students know that the rock cycle includes the formation of new sediment and rocks and that rocks are often found in layers, with the oldest generally on the bottom.

Gr9-12, Bio8g.* Students know how several independent molecular clocks, calibrated against each other and combined with evidence from the fossil record, can help to estimate how long ago various groups of organisms diverged evolutionarily from one another.

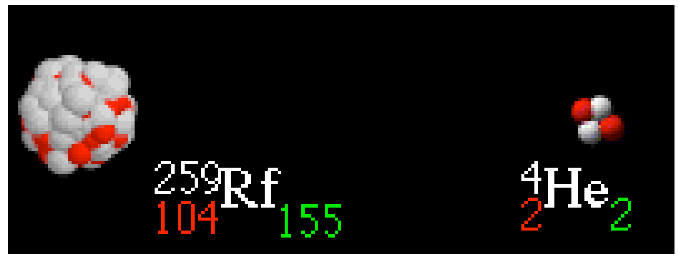


Click to Enlarge

Images From: *Matthew d'Alessio, USGS*
http://education.usgs.gov/schoolyard

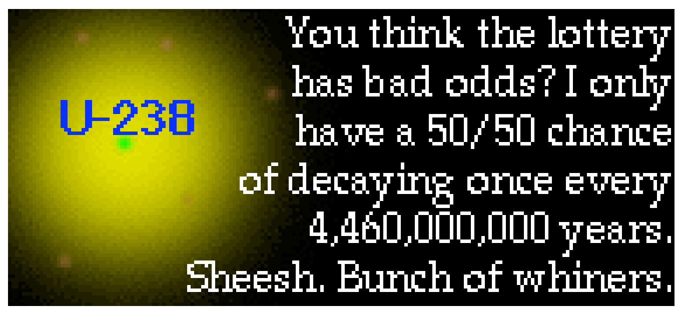
Location: Near Emerson Middle School, Berkeley, CA

About: When workers completed construction of these sections of sidewalk, they imprinted their company name and the year of completion. How many years ago did this sidewalk get built?



Click to Enlarge

Lawrence Berkeley Lab, US Dept. of Energy
http://ie.lbl.gov/quake/glossary/Glossary.htm



Click to Enlarge

Larry Sulak, Boston University
http://physics.bu.edu/cc104/half_life.html

Location: Radioactive material naturally occurs in very tiny amounts in most common rocks. (These amounts are way too low to hurt you, so don't worry!).

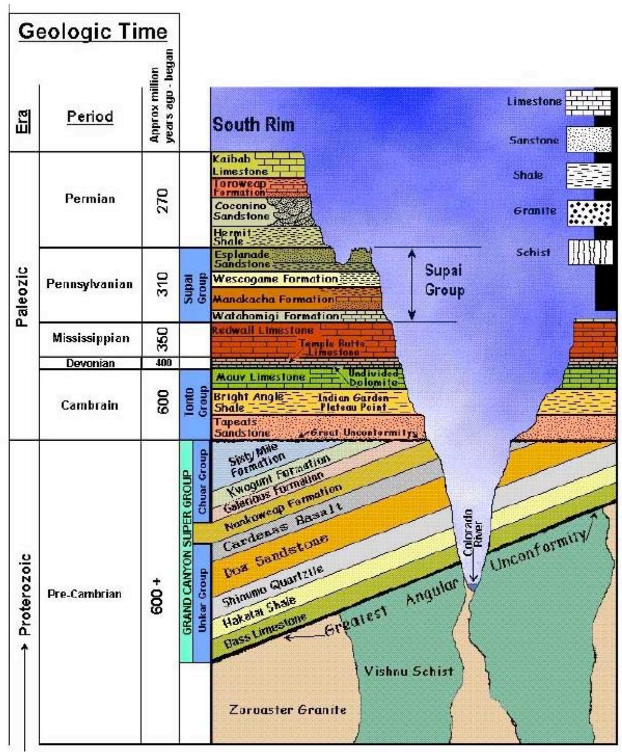
About: Rocks also have markers that help geologists determine their age. These markers involve radioactive decay of atoms. The exact process is complex, but all you need to know is that some atoms can change into other types of atoms (for example, Carbon can change into Nitrogen) by radioactive decay. Some radioactive materials decay more quickly than others (some take less than a second while others take billions of years!). If we know how fast the element decays, we can determine its age almost like reading it off the sidewalk.

[Click to Enlarge](#)

University of Missouri
http://www.missouri.edu/~umcspace/historic/buildings/union/1923/1923.htm

Location: Memorial Union, University of Missouri

About: Determining the when this building was built is very easy -- you just read it off of the cornerstone. Many important buildings for government, schools, and churches have a cornerstone showing the year of construction. Determining the age of a real rock is a bit more complicated.



[Click to Enlarge](#)

Charles Cowley, University of Michigan
http://www.astro.lsa.umich.edu/users/cowley/GCandMoon.html

Location: Grand Canyon National Park, Arizona

About: This cartoon of the Grand Canyon shows the names of individual layers. Along the left side, it also gives the approximate age of each layer in millions of years. In order to determine the age of an individual layer, a geologist must collect a sample of that layer and take it back to the lab. The geologist uses precise laboratory machines to analyze the relative abundance of radioactive atoms and atoms that form as a result of radioactive decay. Finally, the geologist can calculate the rock's age. This calculation requires knowledge of math, physics, and chemistry! Note how the oldest rocks in the Grand Canyon are on the bottom and the youngest rocks are on the top (more about layers).

Key Concepts:

- Most rocks have tiny amounts of radioactive material in them.
- Radioactive elements decay (they change into a completely different element -- for example, Uranium which is used in nuclear reactors changes into Lead, a very dense metal).
- Scientists use precise laboratory equipment to measure the amount of the new material that was created by radioactive decay.
- By knowing how fast certain elements decay, we can calculate the age of rocks (the number of years since the rock formed).

Links for further Exploration:

Introduction to concepts of geologic time (USGS publication: background reading material. Old, but a very good introduction)
History of Geologic Time (Background reading from the UC Museum of Paleontology)

Classroom Activities:

GeoAge (USGS Activity, Grades 7-12)

Mini-Activity

Have your students look for evidence of date stamps and cornerstones on their walk home. Depending upon your area, there may be quite a few.

Common Misconceptions: *Misconception*: Carbon-14 is the only dating technique
Fact: Carbon-14 is the most well known radiometric dating technique, but it can only be used to date objects younger than about 40,000 years. It also only works for objects that contain carbon. Many other radiometric dating techniques exist and are more commonly used for dating rocks many millions of years old. Many of these techniques are based on the decay of Uranium. For example, the first physical evidence of the age of the earth came from a technique analyzing the decay of Uranium into Lead.

Science Standards: **California**

Gr7, Sc4a. Students know Earth processes today are similar to those that occurred in the past and slow geologic processes have large cumulative effects over long periods of time.

Gr9-12, Bio8g.* Students know how several independent molecular clocks, calibrated against each other and combined with evidence from the fossil record, can help to estimate how long ago various groups of organisms diverged evolutionarily from one another.

Click to Enlarge

Image From: *Matthew d'Alessio, USGS*
http://education.usgs.gov/schoolyard

Location: Near Emerson Middle School, Berkeley, CA

About: You can tell an animal once walked here on this sidewalk when the cement was first wet. While many people and animals have walked over this spot since then, only one animal's prints are recorded. Why? We placed the white piece of paper in the foreground to give you a sense of how big the footprints and how far apart they are. The paper is about 10 cm across. Based on the amount of space between each footprint, was this animal as small as a squirrel, as big as a horse, or some size in between?

Click to Enlarge

Image used with permission from: *DinosaurHunter.org*
http://www.dinosaurhunter.org/weserber.htm

Location: Near Hannover, Germany

About: The tracks of iguanodontids and theropods are excellently preserved in this quarry in Germany. These trackways were formed 140 million years ago, when dinosaurs walked through mud on the sea or lake shore. We know it was a shoreline because the ripple-like pattern exposed in this picture is just like the patterns formed on modern beaches. Geologists carefully excavated these footprints so that they could learn how big the animals were and how they walked.

Click to Enlarge

Image From: *Matthew d'Alessio, USGS*
http://education.usgs.gov/schoolyard

Location: Near Emerson Middle School, Berkeley, CA

About: Closeup of animal footprint. Can you tell what type of animal it was? What evidence do you have to support your theory? The ruler shows the size.

Click to Enlarge

http://www.tpwd.state.tx.us/park/dinosaur/

Location: Dinosaur Valley State Park, northern Texas

About: Closeup of the distinct, three-toed birdlike imprint of a carnosaur, or meat-eater, which was the predecessor to the infamous Tyrannosaurus rex. Prints like this one were deposited along the shore of an ancient sea in limestones, sandstones, and mudstones approximately 113 million years ago. Note how big the footprints are compared to the students' hands!

Key Concepts:

- Sedimentary rocks start out soft and squishy ("unconsolidated").
- Animal tracks are only recorded while the rocks are soft.
- Sediments can become hard over time if exposed to higher temperatures and pressures or certain minerals that cement the grains together.
- Measurements of animal tracks allow scientists to learn about the size, walking technique, and lifestyle of ancient animals.

Links for further Exploration:

About the science:
Overview of Dinosaur Tracks
Photos showing process of Excavating Dinosaur Tracks
What we can learn from dinosaur tracks (Detailed Teacher Background)

Plan a visit:
Dinosaur Ridge, Colorado
Dinosaur State Park, Rocky Hill, Connecticut
Holyoke, Massachusetts
Clayton Lake State Park, New Mexico
Dinosaur Valley State Park, Glenrose, Texas
Moab, Utah
Red Gulch Dinosaur Track Site, Wyoming

Classroom Activities:

Tennis Shoe Detectives (Grades 2-4)
Make your own track site game (middle school. Some prep work, but lots of possibilities and loads of fun)
Stride Length and Speed (good integration with math, graphing, and hypothesis testing. Advanced middle school to High School?)
Extensive Study Guide on Dinosaur Tracks with Math exercises (middle-high school)
ThinkQuest Online Tutorial
Alaska Museum Track Size Activities (multiple exercises, elementary - high school)

Common Misconceptions: *Fact*: Humans and dinosaurs did not exist on Earth at the same time.
About the misconception: Some web sites claim that human footprints exist beside dinosaur tracks in areas like the one in the *Geologist in Action* photo above, but these are either misinterpretations or hoaxes. Teachers who have students that might have heard these stories at home might want to read: [In Depth Commentary]

Science Standards:

California

Gr2, Sc3d. Students know that fossils provide evidence about the plants and animals that lived long ago and that scientists learn about the past history of Earth by studying fossils.

Gr3, Sc3e. Students know that some kinds of organisms that once lived on Earth have completely disappeared and that some of those resembled others that are alive today.

Gr7, Sc4. Evidence from rocks allows us to understand the evolution of life on Earth. As a basis for understanding this concept:

Gr7, Sc4a. Students know Earth processes today are similar to those that occurred in the past and slow geologic processes have large cumulative effects over long periods of time.

Gr7, Sc4c. Students know that the rock cycle includes the formation of new sediment and rocks and that rocks are often found in layers, with the oldest generally on the bottom.

Gr7, Sc4e. Students know fossils provide evidence of how life and environmental conditions have changed.

Gr9-12, Bio8e. Students know fossils provide evidence of how life and environmental conditions have changed.

Click to Enlarge | | Move Mouse Over to See Labels

Image From: Matthew d'Alessio, *USGS*
http://education.usgs.gov/schoolyard

Location: Near Emerson School, Berkeley, CA

About: Here you can see the imprint of a leaf in concrete that fell onto the concrete just a few moments after it was poured. The concrete dried many years ago and has been very hard since then. Can you make an educated guess about what time of year (season) this concrete was originally poured? The ruler tells you the size of the leaf.

Click to Enlarge

http://www.earthscienceworld.org/imagebank/search/results.html?ImageID=h27hs1

About: A fossil fern in a natural sedimentary rock, with a coin to show you the size of the fossil. Millions of years ago, this fern fell in some mud. The mud was covered by more layers of mud causing it to eventually harden into a rock. The fern leaf decayed away, but this imprint of the leaf remained.

Click to Enlarge

Image From: *Matthew d'Alessio, USGS*
http://education.usgs.gov/schoolyard

Location: Near Emerson School, Berkeley, CA

About: This picture was taken during autumn when leaves fall. The tree by the sidewalk is currently losing leaves that look a lot like the fossil imprint in the sidewalk below it (near the white ruler, which is about 10 cm long). They are the same shape and about the same size. It's probably a good guess that this tree was here when the sidewalk was paved. In other words, you can tell which is older: the sidewalk or the tree!

Click to Enlarge

Spain Info Group
http://www.spaininfogroup.com/el_torcal.htm

Location: El Parque Natural del Torcal, Andalucia, Spain

About: A photo of a fossil sea creature (bottom of photo) in a dry desert environment. Unlike the schoolyard example of the tree and the leaf, real fossils sometimes come from environments very different than where you find them today. For example, this creature lived in a vast ocean, but do you see a vast ocean here today? What do you think happened? Not only does this place look pretty dry, but this photo was taken at an altitude of 1300 meters above sea-level (about 4000 feet). How did a sea creature get way up here? Geologists use fossils like this one to infer that two of the earth's plates crashed into one another and pushed up mountains.

Key Concepts:

- Sedimentary rocks start out soft and squishy ("unconsolidated").
- Fossils form when animals or plants die in the unconsolidated sediments and are covered by more layers.
- Sediments can become hard over time if exposed to higher temperatures and pressures or certain minerals that cement the grains together.
- Fossils are found in sedimentary rocks, but almost never in other rock types. (You need to start out with a soft material to make an imprint. Igneous rocks are very hot when they are soft/molten, so they burn up organic materia. Metamorphic rocks are exposed to such intense heat and pressure that any fossils are destroyed).

Links for further Exploration: University of California Museum of Paleontology (Loads of superb teacher resources and student-friendly links)

Classroom Activities: Mud Fossils (USGS Activity, Grades K-3)

University of California Museum of Paleontology (Loads of superb activities for K-12, with many activities emphasizing middle school)

Common Misconceptions: *Misconception*: Fossils are pieces of dead animals and plants.
Fact: Fossils are not actually pieces of dead animals and plants. They are only the impression or cast of the original living thing. The actual living parts decay away but their shape is permanently recorded in the rock as it hardens.

Misconception: Fossils of tropical plants cannot be found in deserts.

Fact: Fossils record ancient environments present at the time the rocks were deposited. The climate of a particular location can change because of a combination of 3 important factors: 1) Plate tectonics may cause land to move across much of the globe -- points that were once at the tropics may have moved to high latitude regions where the climate is dry. This motion can be tracked using magnetic signatures recorded in the rocks. Uplift from plate collisions can also raise areas from the bottom of the ocean up above beaches and to high mountains -- all different local climate zones; 2) The entire climate of the planet shifts. The planet has gone through wet and dry, hot and cold periods where the entire planet was different than it is now. Isotopic signatures in rocks record these changes; 3) Human accelerated climate change. Humans have impacted the local climatic conditions of small areas for several thousand years through agricultural practices. Deforestation and irrigation can cause dramatic local changes. Today, humans are causing changes through greenhouse gas emissions that may be big enough to change the entire global climate.

Science Standards:

California

Gr2, Sc3d. Students know that fossils provide evidence about the plants and animals that lived long ago and that scientists learn about the past history of Earth by studying fossils.

Gr3, Sc3e. Students know that some kinds of organisms that once lived on Earth have completely disappeared and that some of those resembled others that are alive today.

Gr7, Sc4. Evidence from rocks allows us to understand the evolution of life on Earth. As a basis for understanding this concept:

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Gr7, Sc4c. Students know that the rock cycle includes the formation of new sediment and rocks and that rocks are often found in layers, with the oldest generally on the bottom.

Gr7, Sc4e. Students know fossils provide evidence of how life and environmental conditions have changed.

Gr9-12, Bio8e. Students know fossils provide evidence of how life and environmental conditions have changed.

Click to Enlarge | Move Mouse Over to See Labels

Image From: Matthew d'Alessio, *USGS*
http://education.usgs.gov/schoolyard

Location: Emerson School Playground, Berkeley, California

About: If you look carefully at the ground, you can see a bunch of parallel lines. These formed when workers used brooms to distribute the tar of the blacktop evenly over the playground surface. The lines are a permanent record of the abrasion and scraping of the broom.

Click to Enlarge

U. S. Geological Survey
http://www.earthscienceworld.org/imagebank/search/results.html?ImageID=h0wn0f

Location: Glacier National Park, Montana

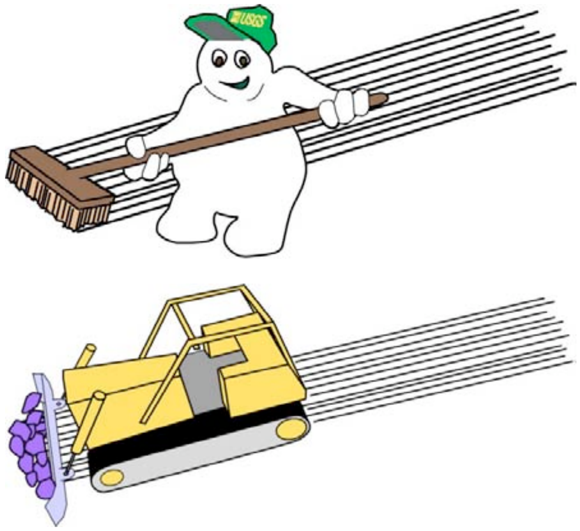
About: Glacial "striations" on bedrock. Rocks embedded in the bottom of a massive glacier scratched the rock underneath as the glacier moved along. Even though there is no ice present today, these scratched lines are evidence that glaciers were here in the geologic past. We can even tell which direction the glacier was moving by the direction that the lines point!

[Click to Enlarge]

Image From: *Matthew d'Alessio, USGS*
http://education.usgs.gov/schoolyard

Location: Emerson School Playground, Berkeley, California

About: A close-up of more broom-marks on a concrete walkway.



[Click to Enlarge]

Image From: *Matthew d'Alessio, USGS*
http://education.usgs.gov/schoolyard

About: The scratch marks on the schoolyard are formed by the process shown on top -- a broom dragged along over wet tar. You can imagine similar scratch marks from a bulldozer pushing rocks.

[Click to Enlarge]

Used with permission of Thomas Lowell
Department of Geology, University of Cincinnati
http://tvl1.geo.uc.edu/ice/Image/eropro/675-12.html

Location: Yale Glacier, in the Chugach Mountains near Prince William Sound, Alaska

About: A closeup of the scratch marks. Look at how the lines all go the same direction.

[Click to Enlarge]

Copyright Marli Miller, University of Oregon
http://www.earthscienceworld.org/imagebank/search/results.html?ImageID=hdedwg

Location: Exit Glacier, Alaska

About: A massive glacier slides downhill, pushing rocks out of its way like a bulldozer as it goes. When it eventually melts, there will be scratch marks left behind underneath it.

Key Concepts:

- Glaciers are made of ice and rocks that get trapped in the ice.
- Glaciers flow downhill because of gravity.
- The moving glacier acts a lot like a bulldozer, stripping away layers of rock and moving them off to the side.
- Rocks embedded in the bottom of the glacier scrape along the newly exposed bedrock and leave behind line-shaped scratch marks. (We call these "glacial striations").
- The direction of the scratch marks tells us the direction that the glacier flowed.

Links for further Exploration:

About the science:

[Background reading for teachers] No pictures, but detailed textual description of Glacial features and the importance of glaciers.

[Glacier Image Library] Very detailed, well organized, high quality images of glaciers.

Classroom Activities:

[Glacial Scratching] [Middle School] Students make mini-glaciers and use them to make scratch-marks on a piece of wood.

[Glacial melting demonstration] [Grades 3-8] Easy, cheap demonstration of what happens when a glacier melts.

[Web Quest 1] [Middle School]
[WebQuest 2] [Middle-High School]

Science Standards:

California

Gr4, Sc5c. Students know moving water erodes landforms, reshaping the land by taking it away from some places and depositing it as pebbles, sand, silt and mud in other places (weathering, transport, and deposition). -- (glacier ice is also moving water)

Gr6, Sc2. Topography is reshaped by the weathering of rock and soil and by the transportation and deposition of sediment.

Gr6, Sc2a. Students know water running downhill is the dominant process in shaping the landscape, including California 's landscape. (glacier ice is also moving water)

SchoolYard

Geologist in Action

Click to Enlarge | Move Mouse Over to See Labels

Image From: Matthew d'Alessio, *USGS*
http://education.usgs.gov/schoolyard

Location: Near South Hall, University of California, Berkeley

About: Zoom into the picture above and you can see four different layers of pavement on top of one another. The small white ruler (which is about 10 cm long) sits on the lowest of these layers. It is very common for layers of pavement to be placed on top one-another because it is cheaper and easier to simply cover up the old pavement than it would be to rip it out. Over time, the layers in this picture have eroded away so that layers that were once covered are now exposed.

Click to Enlarge

http://www.earthscienceworld.org/imagebank/search/results.html?ImageID=hmwng6

Location: Grand Canyon National Park, Arizona

About: The classic "layer-cake" structure of the Grand Canyon. The oldest layers are deposited first. Over time, the layers are buried as new sediment gets deposited on top of the existing layers. Using radiometric dating, scientists have determined that the Kaibab limestone that forms the top layers in the photo is 270 million years old. The Bright Angels shale that shows up as the thick dark layer towards the bottom of the canyon in this photo is 600 million years old. Here, the Colorado River has eroded lots of material while carving the Grand Canyon. Now, we can see all of the older layers that were once buried.

[Click to Enlarge](#) | Move Mouse Over to See Labels

Image From: *Matthew d'Alessio, USGS*
http://education.usgs.gov/schoolyard

Location: Near McCone Hall, University of California, Berkeley

About: The darker material on the left lies on top of the lighter colored pavement. The darker pavement was added later to cover up the lighter pavement that was cracking (some cracks are visible directly behind the white ruler, which is shown for scale).

[Click to Enlarge](#)

USGS - HVO
http://hvo.wr.usgs.gov/kilauea/update/archive/2003/Feb/5-14.html

Location: Chain of Craters Road, Hawaiian Volcanoes National Park, Hawaii

About: Hot lava slowly flows over a road in Hawaii. The road was there for decades before the lava flowed over it. National Park rangers work in the background to move a building to rescue it from the flowing lava. Volcanoes can stay active for millions of years, with each new flow of lava covering up an older flow. The same thing happend to this road in 2003 -- the road in the picture was built on top of a lava flow that buried an older road in the 1960's that was built on top of a flow several hundred years old.

Key Concepts:

- Newer rocks are deposited on top of older rocks. The newer rocks cover up the older rocks.
- For sedimentary or volcanic rocks, the oldest layers are therefore on the bottom and the youngest layers are on the top. We call this "The Principle of Superposition" (super = top).
- Erosion can help expose older layers that were once buried.
- Geologists reconstruct the order in which layers were deposited by their relative position (which ones are on top of which). We call this a "relative dating" because we don't know the exact date and time of the event, but only what happened before or after it. Detectives also use relative dates when they reconstruct a sequence of events to help solve mysteries.
- While the Principle of Superposition is generally true, think about cases when it might not be true. For example, plate tectonic forces can deform and contort rock sequences so much that they sometimes get turned upside down. Or, sometimes underground magma rises upward from the earth's interior and gets deposited beneath other rock layers (we call these rocks "intrusive igneous" rocks because they intrude into the existing rocks, and granite is a common example).

Classroom Activities: [GeoSleuth Murder Mystery](#)

Science Standards:

California

[Gr4, Sc4a.](#) Students know how to differentiate among igneous, sedimentary, and metamorphic rocks by referring to their properties and methods of formation (rock cycle).

[Gr7, Sc4a.](#) Students know Earth processes today are similar to those that occurred in the past and slow geologic processes have large cumulative effects over long periods of time.

[Gr7, Sc4c.](#) Students know that the rock cycle includes the formation of new sediment and rocks and that rocks are often found in layers, with the oldest generally on the bottom.

Click to Enlarge | Move Mouse Over to See Labels

Image From: Matthew d'Alessio, *USGS*
http://education.usgs.gov/schoolyard

Location: U. S. Geological Survey, Menlo Park

About: The stripe of light-colored pavement in this picture hasn't always been there. Originally, the pavement was all one color, but then there was a problem with the sewer line. To replace an old sewer line, workers dug a trench that cut across the old pavement, and then filled it back in with a lighter colored asphalt. The lighter stripe is younger than the darker material around it. When in the sequence do you think they painted the words "STOP" on the ground? How can you tell?

Click to Enlarge

http://activetectonics.la.asu.edu/ramon/Images/Grand_Canyon/

Location: Grand Canyon National Park, Arizona

About: Blocks of rock that look like stripes cutting across existing layers are also common in nature. Here, the reddish-brown layers accumulated over time. After they were laid down, hot magma pushed its way through the layers towards the surface. The dark "stripe" is where some of that magma solidified before reaching the surface. The fact that the dark layer seems to cut so cleanly through the layers is evidence that it came along after they were deposite (It is not possible to cut layers before they exist!)

Key Concepts:

- Newer rocks are deposited on top of older rocks. The newer rocks cover up the older rocks.
- For sedimentary or volcanic rocks, the oldest layers are therefore on the bottom and the youngest layers are on the top. We call this "The Principle of Superposition" (super = top).
- When one type of rock cuts through other rocks, it had to form after the rocks that it cuts. (You can't cut a cake until you have baked a cake).

Classroom Activities: GeoSleuth Murder Mystery

Science Standards: **California**
Gr4, Sc4a. Students know how to differentiate among igneous, sedimentary, and metamorphic rocks by referring to their properties and methods of formation (rock cycle).

Gr7, Sc4a. Students know Earth processes today are similar to those that occurred in the past and slow geologic processes have large cumulative effects over long periods of time.

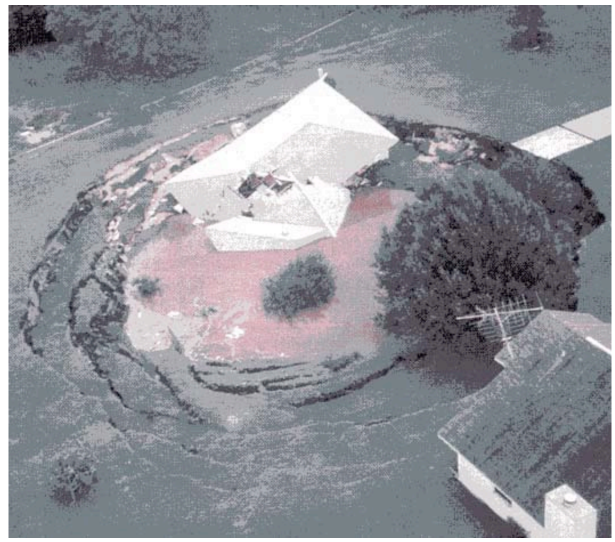
Gr7, Sc4c. Students know that the rock cycle includes the formation of new sediment and rocks and that rocks are often found in layers, with the oldest generally on the bottom.

Click to Enlarge | Move Mouse Over to See Labels

Image From: *Matthew d'Alessio, USGS*
http://education.usgs.gov/schoolyard

Location: Near the University of California, Berkeley

About: This road is in need of repairs! Fractures around the edge of this pothole form concentric circles, a lot like rings around a bullseye on a dart board. Near the center of the pothole, there are a lot more fractures and the pattern is harder to see. The pothole formed when a portion of the road compacted or subsided, causes the surface of the road to collapse and fall into the hole. To get a sense of the size of this feature, you can see the painted stripe of a crosswalk in the background, and a small white ruler about 10 cm long near the center-left.



Click to Enlarge

Image Credit: *USGS*
http://www.earlham.edu/~scheuer/sinkholes.htm

Location: Near Crooked Lake, Florida

About: Here, circular shaped fractures form the margins of a massive sinkhole that catastrophically caused this house to collapse. Sinkholes are natural features that are relatively common in areas with abundant limestone near the surface. Note how the sinkhole is filled with water, hinting at what caused this catastrophe.

Key Concepts:

- Certain types of rocks like limestone dissolve easily in water.
- Over geologic time, networks of underground caves and cavities can form as the naturally flowing groundwater slowly dissolve these rocks.
- Sinkholes are natural features that form when portions of these caves collapse.
- Humans can cause sinkholes to form more rapidly. Rapid pumping of groundwater for drinking and irrigation can cause draw all the water out of these underground cavities. The water actually provides support for the roof of the cave, so when water is pumed out the underground caves can collapse. This is one way sinkholes form.
- Circles of fractures often form around the edge of sinkholes when they collapse. The circular shape forms a "bullseye" pattern around the center of the collapse zone as the material

above the cavity falls down into it much like sand falling down the hole in an hourglass. [Image of hourglass with circular depression at top]

Links for further Exploration: About the science:
USGS Overview of Sinkholes USGS Circular 1182 [PDF]

Classroom Activities: Stockertown Sinkhole Dilemma (Role Playing, grades 6-9)

Common Misconceptions: *Misconception:* Groundwater flows in vast underground lakes
Fact: Groundwater usually flows through tiny spaces between individual mineral grains.
Many students have the wrong mental image of groundwater systems -- they frequently picture water flowing in vast underground lakes and rivers. This is not the case for most of the earth! In most rocks on earth, groundwater fills the billions of tiny spaces between individual mineral grains or in narrow fractures within rocks -- a lot like the pore spaces in a sponge. Sinkholes are the rare exception to this sponge-like groundwater system and they actually do form when large cavities develop underground. You can use the existence of sinkholes to help clear up the common misconception by telling students that if groundwater existed in underground lakes everywhere, we would see sinkholes in a lot more places. See this brief summary.

Misconception: Groundwater and surface water are separate systems.
Fact: Water from the atmosphere, surface (rivers, lakes, etc.), and groundwater are all connected via the hydrologic cycle and get naturally "recycled" over and over again. Actions people take that impact one of the parts of the system (such as overpumping of ground water) will eventually affect the rest of the system.

Science Standards:

Pennsylvania
Gr10, 3.5B: Evaluate the impact of geologic activities/hazards (e.g., earthquakes, sinkholes, landslides).

Florida
Gr7 Understands the action of ground water to form aquifers, caverns, and sinkholes.