Grade 6
Earth's Structure, Processes and History – Part B

Adapted from
Oakland Schools Science Scope

Earth's Structure, Processes and History – Part B

About Our Scope Unit/Lesson Template

This template is designed to serve several teaching and learning principles considered as staples of state of the art science instruction. Here are the key principles in summary:

- It's critical to **elicit prior knowledge** as a unit or lesson begins.
- **Key questions** should drive student explorations and investigations.
- **Activity Before Concept** – Student inquiry-based explorations which give personal experience with phenomena and ideas should precede a presentation of science ideas.
- **Evidence is the heart of the scientific enterprise.** Students generate evidence and analyze patterns in data that help to construct scientific explanations around key questions.
- **Concept Before Vocabulary** – Attaching science vocabulary to concepts developed by student investigations yields more success than beginning a unit or lesson with a list of science vocabulary.
- **Talk, argument and writing** are central to scientific practice and are among the most important activities that develops understanding.
- **Application** of the ideas provides review, extends understanding, and reveals relevance of important ideas.
- **Assessment** of knowledge, skill, and reasoning should involve students throughout the learning process and be well aligned to the main objectives and activities of the unit.

The Scope Science template is designed to put these principles into practice through the design of the ***SCOPE LEARNING CYCLE FOR SCIENCE***. Each unit has at least one cycle. The components are listed below:

The Key Question for the Cycle	Each cycle has one, open-ended driving question that relates to all the content and skills of the unit. The Key Question is presented at the opening of the cycle and revisited at the cycles conclusion.
Engage and Elicit	Each unit begins with an activity designed to elicit and reveal student understanding and skill prior to instruction. Teachers are to probe students for detailed and specific information while maintaining a non-evaluative stance. They also can record and manage student understanding which may change as instruction proceeds.
Explore	A sequence of activities provides opportunities to explore phenomena and relationships related to the Key Question of the unit. Students will <u>develop</u> their ideas about the topic of the unit and the Key Question as they proceed through the Explore stage of the learning cycle. Each of the activities may have its own Focus Question or central task that will be more focused than the unit question. The heart of these activities will be scientific investigations of various sorts. The results, data and patterns will be the topic of classroom discourse and/or student writing. A key goal of the teacher is to reference the Key Question of the cycle, the Explore and Elicit of the students and to build a consensus especially on the results of the investigations.
Explain	Each unit has at least one activity in the Explain portion of the unit when students reconcile ideas with the consensus ideas of science. Teachers ensure that students have had ample opportunity to fully express their ideas and then to make sure accurate and comprehensible representations of the scientific explanations are presented. A teacher lecture, reading of science text or video would be appropriate ways to convey the consensus ideas of science. Relevant vocabulary, formal definitions and explanations are provided. It's critical that the activity and supporting assessments develop a consensus around the Key Questions and concepts central to the unit.
Elaborate	Each unit cycle has at least one activity or project where students discover the power of scientific ideas. Knowledge and skill in science are put to use in a variety of types of applications. They can be used to understand other scientific concepts or in societal applications of technology, engineering or problem solving. Some units may have a modest Elaborate stage where students explore the application of ideas by studying a research project over the course of a day or two. Other units may have more robust projects that take a few weeks.
Evaluation	While assessment of student learning occurs throughout the unit as formative assessment, each unit will have a summative assessment. Summative assessments are posted in a separate document.

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Contents

Unit 1: Earth's Structure, Processes and History – Part B

Unit Introduction

This unit attends to the Michigan Grade Level Content Expectations as they are gathered in Sixth Grade Unit 4 of the Michigan Department of Education Science Companion Document. Topically, the unit addresses concepts related to evidence for plate tectonics, the nature of plate boundaries, natural hazards, deep time and the geologic time scale, relative age dating techniques including the use of index fossils and on ancient environments reconstructed from evidence in the rock record. To organize the content of this unit the Oakland Schools Science Scope has established two learning cycles:

Cycle 1: Evidence for the Plate Tectonic Theory
Cycle 2: Exploring Earth History

The resources and opportunities to address these topics are of such abundance and quality that the unit has the tremendous potential to be a highly relevant, real world and investigation rich experience for students. As teachers look for ways to have students use real world data, apply interactive technology to real world questions and foster meaningful tasks for reading, writing, argumentation and mathematics and framed by the Common Core Curriculum Standards, the issues here provide abundant opportunity. The main limitation is the class time available given other content demands.

On the Common Core State Standards for English Language Arts and Literacy in Science

All science teachers will find the Common Core State Standards of ELA a tremendous asset for reaching learning objectives in science education. Reading, writing, argumentation and discourse are central proficiencies necessary for success in science. All teachers should become fluent with the document and will likely find it validating.

http://www.corestandards.org/assets/CCSSI_ELA%20Standards.pdf

These standards are best reached with science instruction that connects content to real world problems and experiments, complimented with scientific writing, challenging questions, processes for classroom discussion and debate and use of scientific text.

It is recommended that teachers require students to use an interactive science notebook to support learning in this unit. Here are some features and policies to consider:

- Use a bound notebook – cut and paste some other materials into it (quad-ruled notebooks are nice for graphing activities).
- The right facing page is for teacher content, the left is for student reflection.
- Leave four pages for a table of contents.
- Leave the notebooks in the room.

Learning Cycle 1: Evidence for the Plate Tectonic Theory

Introduction

Plate tectonics is the central organizing theory for the science of geology. It is both fascinating and, at an introductory level, easy to understand. In this unit, the precursor concept of continental drift is explored as students assume the role of experts in aspects of geology to explore and present key evidence. The science of rock magnetism provided the evidence that led to a consensus on the ideas related to a mobile crust. A string of new discoveries and models led to the development of the plate tectonic theory. In this unit, students explore the evidence by investigating global plate boundaries. As students develop a familiarity with earth's tectonic plates, they research and report on important events in the history of natural disasters.

Learning Objectives

Students will be able to:

- Understand and explain the evidence for continental drift.
- Understand and explain the evidence for plate tectonic theory.
- Correlate geographic features, earthquakes and volcanoes to plate boundary types.
- Model and analyze plate motions.

Key Question: How are geologic events and features explained in light of the plate tectonic theory?

Engage and Elicit

Activity 1 – Categorizing Plate Boundaries

Purpose
To categorize plate boundary types based on four types of global data (earthquakes, volcanoes, ocean floor age, and ocean bathymetry, also called underwater topography).

Activity Description
Small groups study global earthquake maps in order to categorize plate boundaries. As an elicitation activity, the main point is to see what students understand about plate tectonic theory. **Teachers should not correct student thinking at this stage.** Students will reveal a great deal through class discussion, and the teacher should probe for details and record student ideas for later reflection.

Focus Question
How can geologic patterns be grouped into categories of plate boundaries?

Duration
One class session

Materials
- Maps from the Discovering Plate Boundaries website: http://plateboundary.rice.edu/
  - Click on link to "Downloads"
  - Print in color the map of earthquakes (i.e., seismicity). The other global maps (volcanism, ocean floor age, ocean floor depth) are interesting and important but should not be included in this activity. It is best to printed on 8.5 x 11" laminated sheets. Be sure they information about the color coding is included.
  - Print the Plate boundary map for each student, with a clipboard (**Note:** Before copying, teachers should hand draw the eastern plate boundary of the Philippian Plate and the western boundary of the Juan de Fuca Plate onto the map. These boundaries are prominent in the data, but oddly their boundaries aren't present on the map.)
- Clipboard for each student
- Colored pencils

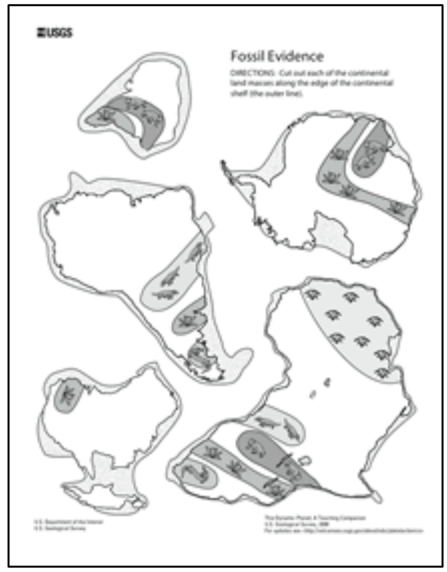
Teacher Preparation
1. Thoroughly read the front page of the website, the Quick Guide and Part 1 and 2 of the Teacher Guide PowerPoints.
2. Determine a printing solution to color print and laminate the four posters. In large classes, two copies of each type (totaling eight) would improve the flow of the activity.
3. Print and copy the student handout and plate boundary maps for each student.
4. Gather clipboards and colored pencils.

Classroom Procedure
1. Form groups of three students, and distribute a blank plate tectonics map to each student.

2. Explain the global plate tectonic map.
3. Provide each group with one color copy of the global seismicity map. Several groups will have the same type of map.
4. Have each group study the map and try to determine how many categories of plate boundaries there are in the world based on the dataset they are using.
5. Have the groups make a color-coded key for their map.
6. Have them color code each boundary on the earth.
7. Initiate a whole-group conversation by having small groups present their maps.
8. During the presentations, ask the class to identify some things we know about plate tectonics and list them on the board or some other method to keep the record. As the unit proceeds, some conclusions may be validated, clarified or corrected.
9. Key things to listen for include student understanding of the following:
   - The three main types of plate boundaries
   - The ring of fire
   - Hot spots
   - Evidence for plate tectonics
   - The difference between continental drift and plate tectonics.

Explore

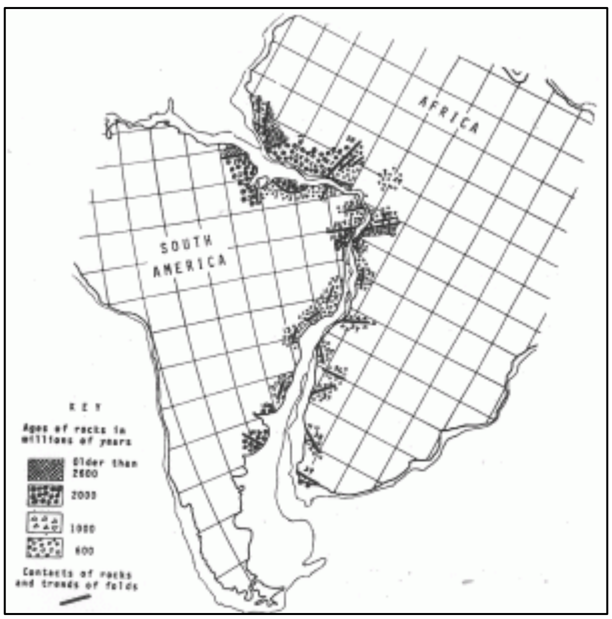
Activity 2 – Puzzling the Continents Together



Purpose
To analyze the evidence that intrigued Alfred Wegener in the earlier 20th century and led him to propose continental drift (the predecessor to the plate tectonic theory).

Activity Description
Student teams explore an assigned area of evidence, which they present and discuss in a format typical of real science communities. The teacher creates these three teams:

1. The Paleontologists: Fossil Evidence in the Southern Hemisphere.
2. The Geologists: Geologic and Fossil Evidence near the coasts of South America and Africa.
3. The Glaciologists: Glacial Evidence in the Southern Hemisphere.



Each team will have an activity to complete, and then they will plan a presentation at a science conference. After the presentations and a discussion, each student writes an article on the evidence for continental drift.

In addition to being an important core idea in geology, plate tectonics lends itself well to a study of the history of science and the development of plate tectonic theory. It has occurred fairly recently and has an amazing timeline of fascinating discoveries.

Focus Question
What is the evidence for the idea of Continental Drift?

Duration
Two class sessions

Materials
- Completed Maps – Fitting the Continents Together (for teacher use)

Atlas URL:
http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/Completed%20Maps%20-%20Fitting%20the%20Continents%20Together.docx

- *This Dynamic Planet* – a USGS pamphlet on plate tectonics: http://pubs.usgs.gov/gip/dynamic/
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/This%20Dynamic%20Planet%20Pamplet.pdf

For Team 1 – The Paleontologists:

- Student Paleontologist – Fitting the Continent Together
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/Student%20Paleontologist-SHemisphere%20Continents.doc
- USGS Wegener's Puzzling Evidence Exercise:
  http://volcanoes.usgs.gov/about/edu/dynamicplanet/wegener/
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_II/Wegener%20Puzzing%20Evidence%20Exercise.docx
- Student Directions:
  http://volcanoes.usgs.gov/about/edu/dynamicplanet/wegener/puzzlelegend.pdf
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_II/USGS%20Student%20Directions-Evidence.pdf
- Puzzle Pieces:
  http://volcanoes.usgs.gov/about/edu/dynamicplanet/wegener/puzzlepieces.pdf
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_II/USGS%20Puzzle%20Pieces.pdf
- Answer Key for Teacher:
  http://volcanoes.usgs.gov/about/edu/dynamicplanet/wegener/continentkey6.pdf
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_II/USGS%20Southern%20Continents%20Reconstructed.pdf
- Global Map for Students:
  http://volcanoes.usgs.gov/about/edu/dynamicplanet/wegener/worldtoday.pdf
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/Global%20Plate%20Tectonic%20Map.docx

For Team 2 – The Geologists:

- Student Geologists – South America and Africa (includes student maps)
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/Student%20Geologist%20-%20SAm-Afr.doc

For Team 3 – The Glaciologists:

- Student Glaciologist – Southern Hemisphere Continents
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/Student%20Glaciologist-SHemisphere%20Continents.doc

For Teacher Presentation:

- "The Global Distribution of Mountain Ranges" (a short article to model the presentation of a line of evidence)
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/Global%20Distribution%20of%20Mountain%20Ranges.docx

Teacher Preparation

1. Become familiar with the activity each team will complete.
2. Notice that the paleontology task will be more time consuming than the others. Here are some options to accommodate that fact:
   - Begin the first part in class to be sure students know what to do, but then assign the completion as individual homework.
   - Another possibility is to have the paleontologists do a small amount of research on their fossils or the concept of divergent evolution.
   - Don't assign the paleontology role at the beginning, but pass it on to faster students, if they have done thorough work on the first component.
3. Print and copy the materials, including the "Historical Perspective" section of the *This Dynamic Planet* pamphlet. This will be easier if you use the downloadable PDF file.
4. Carefully read the short article on "Global Distribution of Mountain Ranges" since the teacher will use this graphic to model a quality presentation.
5. Read up on the life of Alfred Wegener from the USGS pamphlet (*This Dynamic Planet*) to help set up the activities.
6. Gather and prepare materials. After the presentations and discussion, the activities the students didn't complete could be treated as homework.

Classroom Procedure

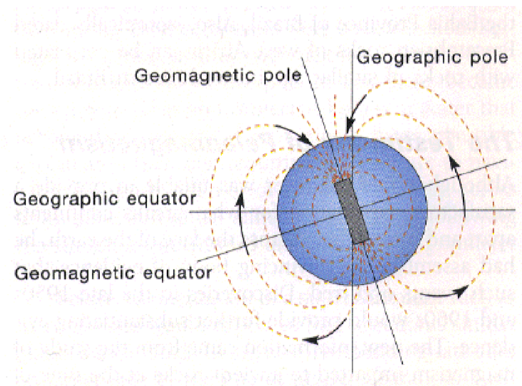
1. Explain key ideas about scientific theories to students. Here are some that are relevant to the topic of this unit:
   - When a grand theory like plate tectonics is created, it develops and changes over time, sometimes spanning generations.
   - Early ideas may be refined, abandoned, or integrated into a more sophisticated explanation.
   - A scientific theory is the highest level explanation in science. This belies the common misunderstanding that a theory is merely an opinion. A scientific theory provides explanations for thousands of observations, uses scientific laws and hypotheses, and provides a basis for new predictions that can be communicated in the form of a hypothesis or a research question.
   - Plate tectonics is the central organizing theory of geology. It was preceded by a hypothesis called Continental Drift.

- Theories are created over time by communities of scientists who read each other's writing and meet at conferences for presentations and discussions.

2. Provide a general overview of Alfred Wegener's life story.
3. Explain that in this activity, students will play roles in the geoscience community and that their job is to provide evidence for others to consider in support of continentals drift.
4. Provide materials and instructions for each team.
5. Provide time for each role to organize a brief presentation with graphics and key points.
6. Perform the Teacher presentation on the evidence from the global distribution of mountain ranges. A key purpose of the presentations is to show how one speaks when presenting scientific explanations. Ask students to listen to the teacher's word choice and manner while presenting. Model these traits:
   - Speak to the evidence, not just absolute conclusions. *(The reconstruction shows that it's possible for the mountains to align as a single belt.)*
   - Use words that show tentativeness of conclusions. *(The evidence supports the idea that the continents were once part of a super continent.)*
   - Orient the audience to the graphic(s) since they have no experience with them. (*This is the coastline of North America…*)
   - Relate the ideas to other ideas that have been discussed.
7. Have the student teams present to the class. Encourage the audience to engage in a discussion by providing questions, ideas, and connections to other evidence.
8. Challenge the presenters with the types of concerns 20^{th}-century physicists had about Wegener's idea. "What could make the continents move?" "How could they be 'drifting' around?" "What are they drifting on?" Tell students that while their evidence is interesting, a strong theory needs to include a "mechanism," which is a force and means for continents to move. These concerns are, in fact, what kept Wegener's idea from being accepted by the scientific community until later evidence emerged.
9. Assign a brief individual essay describing the evidence Alfred Wegener used to construct his hypothesis of continental drift based on the evidence generated by the student teams.
   - Provide a simple graphic organizer to help students put the four lines of evidence down before they write. Do not provide this during the presentations as they may be a distraction which can stifle genuine involvement.
   - Allow students to ask those from other roles to proofread and provide advice about the evidence from their expertise.
10. Close the activity by sharing the "Historical Perspective" section of the *This Dynamic Planet* pamphlet. Ask students to use the "Talking to the Text" protocol with the document. (In this protocol, students write comments or sketches in the margins. They can be questions, summations, statements or pictures.)

Explore

Activity 3 – Evidence for Plate Tectonics from Rock Magnetism



Purpose
To explore the nature of a physical dipole magnet and the similarities to earth's magnetic field.

Activity Description
In the 1940's and 50's, Wegener's ideas were discounted by physicists because he was not able to explain the force that put the continents into motion. However, the study of rock magnetism in the early 1960's provided a body of evidence that convinced geologists that Wegener was on the right track. It led to the discovery of sea floor spreading and the world's subduction zones. Along with the concept of a Tectonic Plate, conceived as a rigid, mobile and deep "lithosphere," those features explained the mechanism that skeptics required to accept the validity of Wegener's evidence. Still, the idea of mobile continents was abandoned in favor of mobile plates, which include ocean crust.

The evidence is overwhelming that the earth's magnetic field has reversed its polarity numerous times over geologic time. Magnetic polarity is recorded in iron-rich volcanic and sedimentary rocks. This discovery led to the development of a Magnetic Time Scale which, when found to be comparable to the symmetrical sets of magnetic stripes mapped upon ocean ridges, led to the theory of sea floor spreading, a cornerstone of plate tectonic theory.

The full details of this field of research are beyond the scope of this course, but it is necessary to impart some general understanding of rock magnetism to understand the evidence for and developmental history of plate tectonic theory. It would be adequate at this level to provide some experience with a handheld dipole magnet and compass to impart an understanding of the following:

- The shape of the magnetic dipole field
- That the earth's magnetic field has two poles, which are close to the true geographic poles
- On the earth's surface, compass needles align with the magnetic force field, causing them to point towards the poles
- The field results from the movement of the earth's liquid, iron-nickel outer core
- That because certain rocks can record polarity reversals, sea floor spreading was discovered by ocean floor research.

Focus Question
How have changes in Earth's magnetic field provided evidence in support of plate tectonic theory?

Duration

Two class sessions

Materials

- Exploring Magnetism Manual
  http://cse.ssl.berkeley.edu/SEGwayed/lessons/exploring_magnetism/Exploring_Magnetism/Exploring_Magnetism.pdf
- Materials as described, such as bar magnets, compasses, and iron filings, etc.
- Teacher background on how paleomagnetism lead to plate tectonic theory – video: Secrets in Stone:
  http://216.11.99.113/VBP/Oakland%20Schools/Secrets%20in%20Stone.wmv (or here: http://vimeo.com/28203736)
- Background on sea floor spreading and Harry Hess: http://pubs.usgs.gov/gip/dynamic/ (follow: Developing the Theory)
  - http://pubs.usgs.gov/gip/dynamic/developing.html
  - http://pubs.usgs.gov/gip/dynamic/stripes.html
  - http://pubs.usgs.gov/gip/dynamic/HHH.html
- Modeling sea floor spreading (a different activity, but includes good background content for teachers)
  http://www.ucmp.berkeley.edu/fosrec/Metzger3.html

Teacher Preparation

1. Become familiar with the first two activities in the document "Exploring Magnetism."
2. Consider adding a step to Activity 1, during which students flip the magnet to model the reversal of the earth's magnetic field.
3. Consider continuing to Session Two, where electromagnetism is explored. The basic circuit can be considered a model of the earth's swirling, electrical current, magnetic field-generating, liquid, outer iron-nickel core.
4. Become familiar with more of the history of plate tectonic theory by reading the "developing," "stripes" and "Herman Hess" sections of *This Dynamic Earth*.
5. In addition to the materials required for the Exploring Magnetism activities, gather a 4-10 inch bar magnet and hang it from the ceiling by a fishing string. Notice that in short order it will align to the earth's magnetic field, as does a compass needle.

Classroom Procedure

1. Begin the lesson by lightly spinning the hanging magnet. As the activity proceeds, students will notice the magnet always stopping in the same direction (pointing north).
2. Open the activity by explaining the demise of Wegener's ideas until new technology, developed during World War II, provided new physical and magnetic maps of the ocean floor.
3. Ask students how a compass works to elicit their understanding of earth's magnetic field. Record their ideas prior to the activity.
4. Initiate the activities as explained in the teacher guide.
5. Point out that the magnetic record in rocks not only records polarity of the field, but that the direction of the recorded field is controlled by the latitude at which the rock was formed. Later in the unit, this fact will contribute to an understanding of how past locations of India can be determined.

6. Provide students with excerpts from *This Dynamic Earth* and, as a class, create a time line of the development of plate tectonic theory. If the reading level seems too high, a standard textbook may have to suffice.
7. When a time line is developed, use it to address the focus question and reinforce the differences between the idea of continental drift and the plate tectonic theory. Take advantage of this topic to emphasize how science works. The *scientific community* required a more detailed explanation to accept continental drift. Wegener's explanation lacked a believable mechanism for continental movements. Discovery of rock magnetism led to the discovery of sea floor spreading, and later to subduction zones. These new revelations tipped the scales towards a *consensus* in the scientific community. Nonetheless, skeptics remained for some time.

Explore

Activity 4 – Voyage Through Time – A Plate Tectonic Flipbook

Purpose
To create a visual model (flipbook) of plate motions.

Activity Description
This activity has students create a flipbook which animates plate motions. It is a basic physical model which can be used to answer many questions. For example, it can be used for an analysis of India's plate motion and the opening of the Atlantic Ocean. Teachers and students can connect the model to the evidence explored in Activity 2. This is one of dozens of great activities from the prolific Dr. Larry Braile. The instructions are clear and demand some great analysis from students.

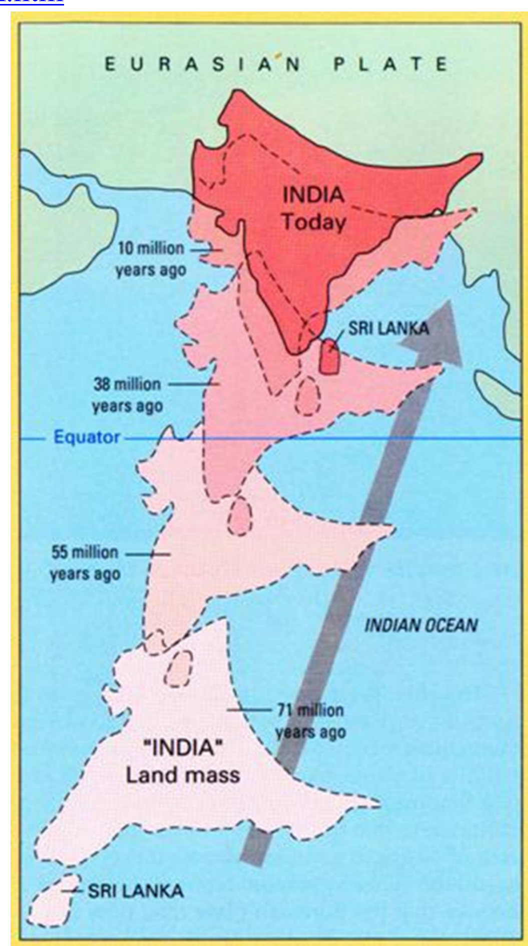
Focus Question
How can a visual model be used to explore plate motions?

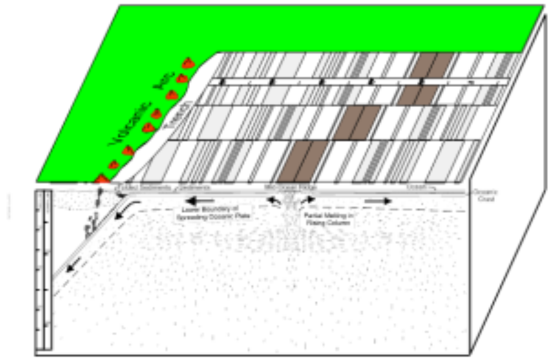
Duration
Two class sessions

Materials
Flipbook Activity Description from Dr. Larry Braile:
http://web.ics.purdue.edu/~braile/edumod/flipbook/flipbook.htm

Teacher Preparation
1. Print and prepare the flipbooks for students.
2. Become familiar with the graphing task in the activity.

Classroom Procedure
1. Provide and explain the use of the flipbook.
2. Emphasize that the flipbook is a physical model. Scientists create mathematical models of plate motions. Also, due to highly precise global positioning systems (GPS), plate motions can now be measured.
3. Conduct the activity as described. Use the discussion prompts and conduct the Extension activity where the movement of India is graphed.
4. Relate observations made with the flipbook to the evidence discussed in Activity 2.





Explore

Activity 5 – Modeling Plate Boundaries

Purpose
To explore plate boundaries using a physical model.

Activity Description
Using a shoebox and stencils, students assemble a three-dimensional box model of earth's mobile tectonic plates. This model actually resembles the plate boundaries in the northeastern Pacific region where British Columbia merges into Alaska. The Pacific Plate is moving northward relative to the North American Plate. Along British Columbia, the motion creates a transform fault. In central and western Alaska, it creates a subduction zone because the motion is convergent. The divergent boundary (ocean-spreading center) is comparable in location to the Juan de Fuca-Pacific Plate boundary, but the scale and geometry of the boundary is not a match. After the model is built, students are challenged to create a narrated video of the operation of the model.

Focus Question
How can plate boundary types be investigated using a physical model?

Duration
Two class sessions

Materials
- Sea Floor Spreading and Subduction Model
  http://pubs.usgs.gov/of/1999/ofr-99-0132/
- Glue sticks, scissors, box cutters
- "What on Earth is Plate Tectonics"
  http://www.nature.nps.gov/geology/usgsnps/pltec/ptnut.pdf
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_II/USGS%20PT%20Overview.pdf
- Digital camera
- Animations of Plate Boundaries
  http://www.iris.edu/hq/programs/education_and_outreach/animations/11
- Jules Verne Voyager Jr. (Amazing interactive website)
  http://jules.unavco.org/VoyagerJr/Earth
- Global Plate Tectonic Map
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/Global%20Plate%20Tectonic%20Map.docx

Teacher Preparation

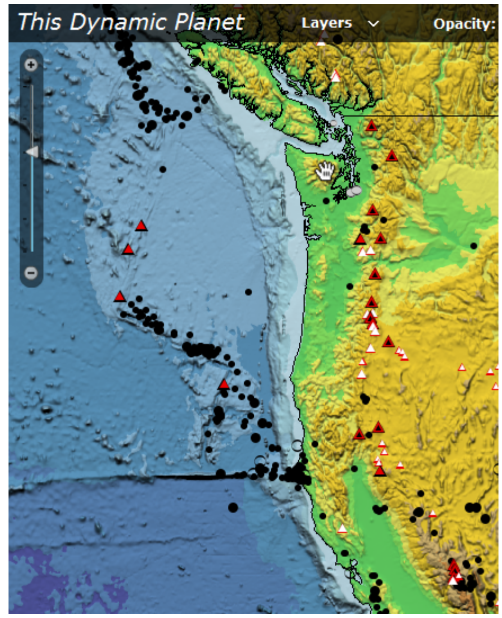
1. Gather a large batch of shoe boxes (6.5" x 13" by 5" deep). Some outdoor stores or shoe stores stock their shelves without boxes and will give the empties to teachers.
2. Prepare the stencils by printing the selection of pages from the PDF document "Sea Floor Spreading and Subduction Model." For safety concerns, teachers may want to cut the slits in the box top and the stencils.
3. Print and copy a global plate tectonic map.
4. Practice using "Jules Verne Voyager Jr." This online tool creates the maps you want to make. Here are some operational steps:
   - Leave "Select Base Map" at "Face of the Earth & Relief"
   - Change Add Features to "Tectonic Plates"
   - Change Add Velocities to "N. America" (this fixes North America and shows the relative motion of all other plates. All plate motion is relative and should be described in reference to something else).
   - Click on "Show Changes."
   - Note the relative motion arrows near plate boundaries. Are they divergent at spreading centers, strike slip at transform faults? Convergent at the world's trenches? If some places don't make sense, the explanation will relate to what plate is being held fixed.
   - See what happens when you hold the Pacific Plate as fixed, or Africa or other plates.
   - To zoom, just click in an area.
   - Note that multiple features can be put on the map by holding the Ctrl key down while clicking on features.
   - Explore other features such as ocean floor age or earthquakes.

Classroom Procedure

1. Open the activity by explaining that scientific models help scientists explore ideas and conduct investigations. Much of plate tectonics is researched using mathematical models, but in this activity students will use a physical model.
2. Demonstrate the operation of Jules Verne Voyager Jr. and point out how the motion vectors demonstrate.
3. Create teams of two or three students and tell them they will build a physical model of tectonic plates, and that they will create a descriptive video explaining the three types of plate boundaries.
4. Provide the materials so teams can build their model.
5. Support their efforts and point out strong examples.
6. Provide the document "What on Earth is Plate Tectonics" or any other source of information as background knowledge.
7. Present or provide access to the online animations of the plate boundaries.
8. After students read about the three types of plate boundaries, ask them to create a script to use for their video. In it, they should:
   - Describe the motion of the three types of plate boundaries.
   - Demonstrate the motion model using the model.
   - Point out several locations that are similar to the geometry of the model (for example, relate to western North America plate tectonics).

9. Select some of the student videos to show to the class. Encourage students to show their families their video, as well as Jules Verne Voyager Jr.

Explain



Activity 6 – Tour of the World's Plate Boundaries

Purpose
To address this cycle's Key Question and to develop a better understanding of global plate tectonic geography by exploring the world using interactive software that presents data sets.

Activity Description
This activity is an interactive lecture directed by the teacher. Several incredible tools are available. Each has its strength, and together they can be used to explore interesting locations and phenomena.

Focus Question
What are the plate tectonic explanations for features we see in the world?

Duration
Two class sessions

Materials
- A computer capable of presenting to the class
- Global Plate Tectonic Map
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/Global%20Plate%20Tectonic%20Map.docx
- Teacher Guide PowerPoint files from Discovering Plate Boundaries (Best for its notes on specific plate boundaries using the Discovering Plate Boundary maps (Activity 1)).
  http://plateboundary.rice.edu/tg.html
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/Teacher%20Guide-Discovering%20Plate%20Boundaries-2.pdf
- *This Dynamic Planet*: An interactive online map (best for fast, flexible zooming and panning) which shows detailed ocean-shaded contours (i.e., bathymetry). Quickly toggle on/off volcanoes and earthquakes in various categories, using the "Layers" pull-down near the top of the screen.
  http://nhb-arcims.si.edu/ThisDynamicPlanet/index.html
  http://mineralsciences.si.edu/tdpmap/
- Seismic Eruption Software: (Best for menus of global and regional views with pre-selected populations of earthquakes and volcanoes.) These are excellent at showing the nature of plate boundaries and hot spots. Call-out textboxes with information provide useful insights. Allows users to make 2 and 3-D views of interesting areas. PC only (no Mac version). Easy download and install.

www.geol.binghamton.edu/faculty/jones (scroll down to Seismic Eruption and download the self extracting file)

- Optional: Dr. Braile's supporting materials for Seismic Eruption: (provides some other ideas on how to use Seismic Eruption) (refers to the program by it's old name: "SeisVole")
  http://web.ics.purdue.edu/~braile/edumod/svintro/svintro.htm
  http://web.ics.purdue.edu/~braile/edumod/sv/2navig.pdf
- IRIS Earthquake Browser: (Best for quick online setting of color-coded earthquake ranges and depths)
  http://www.iris.edu/servlet/eventserver/map.do
- Other sources of background and images:
  - *This Dynamic Planet* – a USGS pamphlet on plate tectonics: http://pubs.usgs.gov/gip/dynamic/
  - Index of great plate tectonic graphics: http://mineralsciences.si.edu/tdpmap/printable.htm
  - Document with high quality schematics: http://www.sci.csuhayward.edu/~lstrayer/geol2101/2101_Ch19_03.pdf
  - UC Berkley's plate animations: http://www.ucmp.berkeley.edu/geology/tectonics.html
  - Promethean Flipchart about Plate Tectonic Theory (98 pages): http://www.prometheanplanet.com/en-us/Resources/Item/148991/theory-of-plate-tectonics#.U-res-NdWSo
  - Interactive Website from Smithsonian Institute about Plate Tectonics and Volcanoes:

Teacher Preparation

1. Review the PowerPoint from "Discovering Plate Boundaries," which describes interesting plate tectonic features globally. Teachers can adapt and use this premade presentation or simply learn from it.
2. Download, install, and practice Seismic Eruption Software on the presentation computer. Because of the preset views, this software, too, can show teachers what places in the world are interesting to explore.
3. Become familiar with the websites provided in the materials list and decide which ones you want to use.
4. All tools are not required, but teachers should invent and rehearse a tour. One is suggested in the Classroom Procedure section.

Classroom Procedure

1. Explain to students that they are to engage in a class lecture by participating in tasks, discussions and note taking.
2. Distribute another global plate tectonics map if students don't have the one from the modeling activity.
3. Tell students to take notes in the interactive notebooks and on their global maps.
4. Explain that a global plate tectonic tour will be led by their teacher.

Possible Script (using *This Dynamic Planet* and Seismic Eruption):

Divergent Plate Boundaries

1. First we will look for divergent plate boundaries that seem to be splitting apart continents. Turn to a partner and look at your maps. Where do you recommend we go:
   - Baja California—the East Pacific Rise has been overrun by North America, which has caused Baja to split from Mexico.
   - The Red Sea—The Arabian Peninsula is being split from Africa.
   - Great Rift Valley of Africa—will Africa be split apart?
   - New Madrid, Missouri—will North America split apart?
2. Pan and zoom to these locations. Explore the population of earthquakes and volcanoes at each type of plate boundary and discuss some generalizations that can be made, (e.g., subduction zones have the deepest earthquakes in broad linear zones, trending deeper toward the upper place).
3. Use Seismic Eruption maps to see the nature of volcanism and earthquakes.

Convergent Plate Boundaries

1. Now we will look for convergent plate boundaries. There are three types: ocean-ocean, ocean-continent, continent-continent. Turn to a partner and look at your maps. Where do you recommend we go:
   - Peru Chili Trench—the signature of an ocean—the continent subduction zone: Andes volcanic mountain range and earthquake belt deepening eastward.
   - Marianas Trench—some of the oldest ocean crust creating the deepest ocean trench.
   - Cascadia Subduction Zone—Is the North American Pacific Northwest at more risk than California?
   - Caribbean—what is the origin of the majority of Caribbean islands?
   - Himalayas—continent-continent subduction creating the largest mountains in the world. Is this a modern analogy for the Appalachian Mountains?
2. Pan and zoom to these locations. Explore the population of earthquakes and volcanoes. Use Seismic Eruption maps to see the nature of volcanism and earthquakes.

Transform Plate Boundaries

1. Now we will look for transform plate boundaries, most of which are part of the ocean spreading centers. They offset the divergent segments. Turn to a partner and look at your maps. Where do you recommend we go:
   - San Andreas Fault Zone—the simple horizontal motion occurs in a broad fault zone, not just one simple fault plane.
   - Queen Charlotte Fault—much like the San Andreas, but receives less press due to low population of British Columbia and Alaska.
   - Any ocean spreading center—these give the mid-ocean ridges that zipper (or baseball cross stitch look).
2. Pan and zoom to these locations. Explore the population of earthquakes and volcanoes. Use Seismic Eruption maps to see the nature of volcanism and earthquakes.

Hot Spots

1. Now we will look for hot spots. Turn to a partner and look at your maps. Where do you recommend we go:
   - Hawaii—The Hawaiian Islands show a trend in ages from the very young near the active hot spot (Island of Hawaii), aging to the northwest. Follow the hot spot track as far as you can. You will see a bend (dated at 43 million years), a more northerly trend to the western Aleutian trench (dated at around 83 million years).
   - Iceland—There is no hot spot track because the hot spot lies under the Mid-Atlantic spreading center.
   - Yellowstone—The Yellowstone hot spot track was produced as North America moved over the Yellowstone hot spot. Idaho's Snake River Plane is a valley of volcanic rocks that age progressively to the west. Some of western Oregon's mountains were once ocean volcanic islands like Hawaii is today.
2. Pan and zoom to these locations. Explore the population of earthquakes and volcanoes. Use Seismic Eruption maps to see the nature of volcanism and earthquakes.

Explain

Activity 7 – Graphically Organizing Features of Plate Tectonics

Purpose

To create a simple graphic organizer that organizes key concepts
related to plate boundaries.

Activity Description

Students make use of what they have learned in this cycle in conjunction with text resources to create a logical graphic organizer or concept map that depicts how earth structure, geographic features, and plate boundary types relate to one another. They are presented with a list of terms and sources of content, and challenged to create a graphic organizer. This can not only serve to solidify their conceptual understanding, but also as formative assessment instrument for teachers.

Focus Question

How can the key concepts of earth structure and plate tectonics be organized?

Duration

Two class sessions

Materials

- Student handout, "Graphically Organizing Features of Plate Tectonics.doc". This includes a scrambled list of vocabulary terms. The list in table includes the following:
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/Graphically%20Organizing%20Features%20of%20Plate%20Tectonics.docx

convergent	subduction zone	North American Plate
divergent	trench	Juan de Fuca plate
spreading center east Pacific	ridge	Cascadia subduction zone
rise	hot spot	San Andreas Fault
Pacific plate	inter-plate earthquakes	Yellowstone hot spot
lithosphere	inter-plate volcanoes	Iceland hot spot
crust	Mid Atlantic ridge	Hawaiian hot spot
mantle	asthenosphere	lithosphere

- "What on Earth is Plate Tectonics" (PDF summary document from US Geological Survey): http://www.nature.nps.gov/geology/usgsnps/pltec/ptnut.pdf
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_II/USGS%20PT%20Overview.pdf
- *This Dynamic Planet* – a USGS pamphlet on plate tectonics:

http://pubs.usgs.gov/gip/dynamic/
- Vision Learning page on earth's structure (somewhat technical, but excellent explanation):
  http://www.visionlearning.com/library/module_viewer.php?mid=69
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/Earth%20Structure-VisionLearning.docx
- UC Berkley's plate animations:
  http://www.ucmp.berkeley.edu/geology/tectonics.html

Teacher Preparation
1. Select appropriate text for students.
2. Print the list of vocabulary on a sheet to distribute.

Classroom Procedure
1. Provide the student handout and explain the task to the students.
2. Provide content resources from the Materials list above, or students' textbooks.
3. Have students begin task individually.
4. As they start, look for students who are setting up some logical categories. These would include: bathymetric features (ridges, trenches), plate boundary types, examples of plate boundaries, interpolate features (e.g., most hot spots), divisions of the earth.
5. To help others get on the right track, select some good examples of categories.
6. Let students continue on their own as they design a graphic organizer. It is fine to show some examples, which teachers can find in newer versions of Microsoft Word or online.
7. After a day, form groups to have them compare and evaluate their graphic organizers. Have students revise their graphic organizer based on input.
8. Visit the groups during this process to evaluate understanding and provide feedback for logical depictions. Listen for incomplete or incorrect understandings of the key concepts.
9. Allow groups to collaborate on a new, larger draft that can stand as a classroom poster.
10. Students could use printed PowerPoint slides (as six slides per page handout sheets) or envelop labels as boxes in their graphic organizer.
11. Have students participate in a gallery walk to view other solutions.

Elaborate
Activity 8 – Science Reporting on Natural Disasters

Purpose
To provide a technical explanation for natural disasters related to plate tectonic activity.

Activity Description
This is an Internet research project that puts the students into the role of a technical reporter. They choose or are assigned an historical volcanic or seismic event for which they research and provide a technical explanation that relates to plate tectonics. There are countless fascinating events to explore. Students could use some of the interactive technology that the teacher modeled in Activity 7 to gather images of the plate tectonic setting. Seismic Eruption actually has a number of events already configured for student use. In addition, it is easy to find historical photos of natural disasters. Students produce reports written in the format of an article.

Focus Question
What is the scientific explanation for an important natural disaster of the past?

Duration
Three class sessions

Materials
- Internet search engine
- Seismic Eruption software: Easy download and install (scroll down to Seismic Eruption and download the self-extracting file) www.geol.binghamton.edu/faculty/jones
- List of famous natural disasters (see Teacher Preparation)

Teacher Preparation
1. Construct the parameters of the project. Here is a suggestion

Role:	You are a journalist who specializes in science.
Task:	To research and write a science-based article on an important natural disaster of the past.
Product:	An article about a specific natural disaster that occurred in the past.
Criteria: 1. The article will describe the timing, location, and type of event (earthquake or volcano). 2. The natural disaster will be well described. The description should include: • Details of the event. • How it affected humans and the environment. • Some important quantities that measure the event and/or impact of the event. 3. The plate tectonic setting will be described. The descriptions should include: • Name and location of a relevant plate boundary. • Type of plate boundary and a description of the motion.	

4. Images will depict key ideas of the article. Important images would be:
    - Map that shows the location of the event.
    - Plate tectonic map showing plate names, plate boundaries, earthquakes and volcanoes (should they be in the region).
    - Photographs of damage to human infrastructure and the environment.

2. Develop a menu of natural disasters to elevate student awareness.
    - **Earthquakes**: Japan 2011, Alaska 1964, Northridge SAF, Haiti, San Francisco 1906, Chili 1960, Pacific Northwest—hypothetical event in 1700 (fascinating story), New Madrid, Missouri 1811.
    - **Volcanoes**: Hawaii, Iceland, Yellowstone, Mount St. Helens 1980, Mount Pinatubo 1991, Mt Pelée 1902, Mt. Krakatoa 1883, Mt. Vesuviu AD79, Nevado del Ruiz, Columbia 1985.

Classroom Procedure

1. Provide students the parameters of the project, which should be taken up individually.
2. Request a project proposal where students indicate what event they will research. Provide a class period to research possibilities and develop written proposal. The following content is recommended:

Your Task: Read up on three natural disasters and decide which one you will research for your article.

Your Procedures:
- List the three events you researched.
- What was most interesting about each? Which event will you research?
- Why did you make this decision?

3. When the articles are written, have groups of three share their articles with one another.
4. Hold a classroom discussion so students can share some remarkable findings from the project.

Learning Cycle 2: Exploring Earth History

Introduction

The Exploring Earth History cycle focuses on the evidence geologists use to discern earth history from the rock record. While scientists use a combination of relative and absolute age dating techniques, the emphasis for sixth grade focuses on relative age dating. It also begins to develop the challenging concept of deep time and the geologic time scale. Some excellent materials have been developed on these topics, which have been incorporated into our lesson sequence. In some cases, we recommend modification to better support the vision of science instruction promoted by the Next Generation of Science Standards.

Learning Objectives

Students will be able to:

- Comprehend the geologic time scale and relate times to key geologic events.
- Understand and use relative age dating principles and index fossils to deduce sequences of geologic events.
- Relate rock types and fossil evidence to ancient environments.
- Apply age dating principles to the study of specific geologic regions (Denver Basin and Michigan Basin).
- Write a geologic history for a common Michigan cobble.

Key Question: How is evidence used to discern earth history?

Engage and Elicit

Activity 1 – Sequencing Geologic Events

Purpose
To brainstorm events of earth history and propose sequences, durations, and time spans.

Activity Description
As an Engage and Elicit activity, the important aim is to have students surface their thinking about one of the most challenging concepts of science: deep time. Groups of four students are asked create a list of events in earth history that they are aware of. They write these on index cards. The teacher provides five new cards with events, and asks student groups to sequence the cards, note the duration they presume, and take on the challenge of spacing them. After groups compare their results with one another, they write summaries and generalizations on how the class thinks about deep time.

Focus Question
How do we think about events in the deep time of earth history?

Duration
One class session

Materials
- Cards with geologic events (print the first six slides—PowerPoint file—in handout mode, six slides per page).
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/Geologic%20History.ppt
- Index cards
- Colored pencils

Teacher Preparation
1. Print and copy geologic events from PowerPoint file, one set per group. Cut slides into cards.
2. Gather other materials for each group.

Classroom Procedure
1. Form discussion groups of 4-5 students and provide them with blank index cards and colored pencils. It will be important to have an even number of groups.
2. Instruct students to individually create a list of events in earth history that come to their minds. Provide a full five minutes. When they stop early, tell them to keep trying and remain quite.
3. Next, have students share their lists with one another and pick five together that they will write and illustrate on the index cards.
4. As they begin, look at their lists and provide for them 4-6 cards from the PowerPoint file.

5. Have students sequence the events. While they pursue this task, teachers should insert themselves into the conversation to make sure all participants are weighing in, and that the discussion is substantive.
6. After the groups are satisfied with their sequence of cards, challenge them to estimate the duration of time for and between the events. If they were to create a scale model of their timeline, how would it look?
7. At this point, it will be interesting to see how the thinking of various groups compares. Pair up groups and have them stand up and form two facing lines sequence in the same direction, ancient to modern.
8. While they face each other, have each group present their sequences person by person.
9. In a whole group conversation, have each pair report out on the similarities and differences between the groups. If there are differences, push the conversation to elicit student notions about earth history. Prompt students to defend their perspectives and challenge others.
10. Have the students sit during a whole-group discussion to try together to form some generalizations and a summary of how they think about earth history. This will be looked at again in the cycle to see how their learning may change their thinking.

Engage and Elicit

Activity 2 – How Old is the Earth? Part One

Purpose
To become clearer on how we think about deep time and earth history.

Activity Description
As described in the introduction of this cycle, many lessons will be from the brilliant teacher guide provided by the Earth Time Project. This activity is the first of three in a row. Others will follow later in the cycle.

This activity uses a strategy called a Quick Write and serves as another Engage and Elicit activity. The focus here is on the evidence showing how scientists know the age of rocks or fossils. The activity, a Quick Write, is thoroughly described in the Earth Time Educator Guide, which should be downloaded for teacher use in this cycle.

Focus Question
How do scientists know how old a rock or fossil is?

Duration
One class session

Materials
- The Earth Time Teachers Guide
  http://www.earth-time.org/EARTHTIME_Educators_Guide.pdf
- Chapter 1 of Earth Time DVD—available online
  http://www.earth-time.org/movs.html
- A rock or fossil

Teacher Preparation
1. Review the Earth Time Teachers Guide. It is a large PDF file organized much like this one, except it includes all student materials within the document. Notice the division between the middle school and high school curriculum.
2. Read through the first activity, "How Old is the Earth? Part 1," and review the online DVDs. In this cycle we will only use the first one.
3. Gather a rock or fossil that students may find compelling.

Classroom Procedure
1. Follow the detailed procedures provided in the Earth Time Teachers Guide.

Explore

Activity 3 – How Old is the Earth? Part Two

Purpose
To explore the immensity of geologic time, and the changes and events of earth history, by making a scale model of the geologic time scale.

Activity Description
This is the second Earth Time activity. Students build a scale model of geologic time using colored yard. Building and analyzing a scale model of Earth's 4.6 billion year history is an important and effective strategy for confronting students with the mind-bending concept. It is critical for making sense of the slow and enduring processes of biological and geological evolution. The details are well described in the Earth Time Teachers Guide.

Focus Question
How can a model of earth history be used to generate accurate generalizations about deep time?

Duration
One class session

Materials
- The Earth Time Teachers Guide
  http://www.earth-time.org/EARTHTIME_Educators_Guide.pdf
- Colored yarn, meter sticks, and other materials described in the Earth Time Teacher Guide

Teacher Preparation
1. Review the Earth Time Teachers Guide.
2. Read through the activity "How Old is the Earth? **Part Two." (Begins on page 22 of the document.)**
3. Gather the necessary materials.

Classroom Procedure
1. Follow the detailed procedures provided in the Earth Time Teachers Guide.

Explore

Activity 4 – Core Sample Storytelling

Purpose
To create a 3-dimensional model of the layered rocks in the Denver Basin.

Activity Description
This activity provides a concrete physical model of the deep and broad regional structure of the Denver Basin. The Denver Basin is rightfully the center piece of the Earth Time Curriculum. It spans more time than even the Grand Canyon and has fossils from wildly diverse paleo-environments. It is real world, yet structurally simple. With clay laid out to represent the rocks of the Denver Basin and straws used like drilling cores, students puzzle out the geologic structure of the basin. In doing so they create a *conceptual model* of the basin. This point is important to emphasize even though it's not made in the activity. Other than that the details of the investigation are well described in the Earth Time Teachers Guide.

Focus Question
How can we construct a conceptual model of a geologic basin using samples from cores?

Duration
One class session

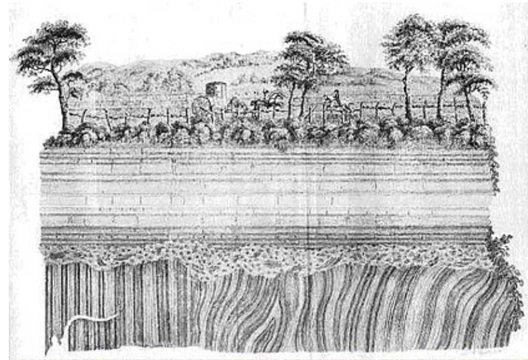
Materials
- The Earth Time Teachers Guide
  http://www.earth-time.org/EARTHTIME_Educators_Guide.pdf
- See the detailed Advanced Preparation section for this activity. It describes how the models must be made ahead of time and set in a refrigerator. It includes some recipes for Play Dough.

Teacher Preparation
1. Read through the first activity "Core Sample Story Telling." **(page 29 of the document)**
2. Prepare and gather the necessary materials which include making the models ahead of time. Play Dough can be purchased or mixed using provided recipes. Once constructed, the models must be placed in a refrigerator overnight.

Classroom Procedure
1. Open the activity by pointing out that with incomplete and remotely sampled data, scientists are left to build conceptual models of what lies under the surface. While we are using a physical model to explore the basin, our explanation or maps are conceptual models that represent a solution to the questions about the composition and structure of the basin.
2. Follow the detailed procedures provided in the Earth Time Teachers Guide.

Explore

Activity 5 – Relative Age Dating: What's Up?



Purpose
To determine the sequence of geologic events using relative age dating principles.

Activity Description
This is a well-organized activity that defines the basic relative age dating principles and provides exercises with which to apply them. The topic provides a great opportunity to convey the magnitude of the 17th and 18th-century discoveries of these principles by Nicholas Steno, William Smith, and James Hutton. Today their conclusions seem blatantly obvious, but in their time the conclusions were mind-blowing revelations. It's a challenge to inspire the students with that sense of awe that such discoveries bring; this topic has potential to offer it.

Focus Question
What sequence of events would explain observations in the rock record?

Duration
Two class sessions

Materials
- What's Up? An Relative Age Dating Activity
  http://www.geosociety.org/educate/LessonPlans/Relative_Age.pdf
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_II/Whats%20Up%20Relative%20Age%20Dating%20Activity.pdf
- Rock samples that match the rock types in the exercises
- Relative Time Scale by USGS
  http://pubs.usgs.gov/gip/geotime/relative.html
- Biography of Nicholas Steno:
  http://www.ucmp.berkeley.edu/history/steno.html
- James Hutton's Angular Unconformity
  http://en.wikipedia.org/wiki/Hutton%27s_Unconformity

Teacher Preparation
1. Print and copy the activity.
2. Read up on the history of geologic age dating and prepare some brief text on the topic, either from the sites listed in the material section or from textbooks.

Classroom Procedure

1. Provide students with the activity, and provide an overview that includes some questions in the vein of "what do you suppose people used to think?"
2. Students will need careful orientation to the symbols. Use the rock samples to help convey what the symbols mean. Students also will need to become familiar with how rock contacts (bedding, igneous contacts, unconformities) are symbolized and what they represent.
3. Carefully oversee their work and call for pauses to guide students through spots where some are having trouble.

Explore

Activity 6 – Overlapping Index Fossils: Who's on First?

Purpose

To determine a logical sequence of rock layers based on common index fossils.

Activity Description

This activity extends student skills in relative age dating to the use of index fossils, which can be used to correlate and date rock layers. An index fossil is any fossil that is useful for determining the relative ages of rocks. It was an English canal builder who first documented the revelation that fossils were associated with and limited to certain layers and could be relied upon for correlations. This activity does a nice job of developing the concept of overlapping fossils with a pre-exercise using a nonsense letter. Because students are looking at fossils, teachers are presented with the opportunity to begin the conversation about what fossils say about past environments (paleo-environments). Sepkowski's famous diagrams should be analyzed.

Focus Question

What sequence of rock layers can we discern from the occurrence of fossils?

Duration

One class session

Materials

- UC Berkeley's activity: Who's on First?
  http://www.ucmp.berkeley.edu/fosrec/BarBar.html
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Who%20is%20on%20First.docx
- Fossils (any that can be observed for interest)
- Sepkowski's "Three Great Marine Evolutionary Fauna" document
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/Sepkowski%20Marine%20Fauna.docx

Teacher Preparation

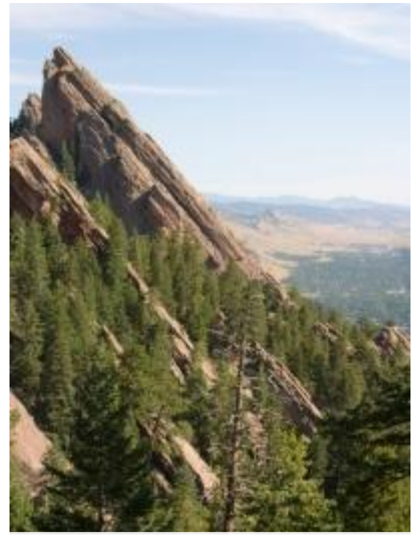
1. Carefully study the activity. At first it may seem confusing, but once familiar, it is simple.
2. Print and copy the activity.
3. Prepare sets of small colored cards using card stock. They will be easier to re-gather if each set is a different color.

Classroom Procedure

1. Follow the detailed procedures provided in the activity guide.
2. As the students get familiar with the fossil types on the cards, show the Sepkowski charts and ask for students' interpretations. These charts simplify countless details of marine species and create three great groups.
3. Display images of ancient marine ecosystems, such as a tropic coral setting.

Explore

Activity 7 – Geologic Time Scale and the Denver Basin



Flat-irons near Boulder Colorado
Image from Earth-Time.org

Purpose
To interpret the rock layers and fossils found in the Denver Basin.

Activity Description
This is a very well-resourced activity from the Earth Time Teacher Guide on page MS L4 – page 1. This activity is rare and effective because students gain familiarity with a real geologic basin, one that spans time from the Precambrian Era to the Quaternary and includes fossils from a great diversity of ancient environments.

To elevate the intellectual demand of the task and more accurately emulate the workings of the scientific community, several modifications have been made for our curriculum.

Focus Question
What is the geologic history of the Denver Basin?

Duration
Two class sessions

Materials
- The Earth Time Teachers Guide http://www.earth-time.org/EARTHTIME_Educators_Guide.pdf
- Materials are described in the Earth Time Teacher Guide
- Extra materials for the modification:
  - Wall-sized stratigraphic section redrawn on poster paper. Remove labels for rock formations. See MS L4 – page 25 (PDF page 71)
  - Laminated color paintings from the High School section, see PDF pages 241-250
  - Teacher set of questions from student worksheet to be used in whole-group facilitation (MS L4 – page 4, PDF page 50, step 9)

Teacher Preparation
1. Carefully read the procedure in the activity and prepare the fossil cards and the pages that describe each of the rock formation. Color print and laminate the sets. It may be necessary to print two full sets to accommodate large classes.
2. In addition to those images, our modification will require the paintings of ancient environments found in the High School section of the Earth Time Teacher Guide (PDF pages 241-250). These also need to be color printed, laminated, and cut into individual images, but one set will suffice.

3. Also for the modification, create a wall-sized depiction of the stratigraphic column on poster paper (MS L4 – page 25 (PDF page 71). Sketch in the contacts between the formation and the rock patterns. Do **not** label the formation with their names, as this will be the heart of the challenge for students.
4. Other detailed teacher preparations are available in the Earth Time Teacher Guide.
5. To help teacher facilitation, print out the student worksheet questions that may be used in class discussions (MS L4 – page 4, PDF page 50, step 9)

Classroom Procedure

1. The approach described in the Earth Time Teacher Guide has students correlate color photos of fossils to the description pages of the 20 rock formations. While the resources are phenomenal and unique, we have found the intellectual task is overly simple but befuddles students because of the numerous slippery, laminated sheets.
2. We recommend following the first part of the activity where students read the Student Handout (MS L4 – page 23, PDF page 69).
3. The activity modification follows:
   - Instead of giving each student or group all 20 rock formations, we recommend dividing the class into five groups and providing each with four consecutive formations.
   - The students' challenge will be to determine where on the wall-sized sequence their layers are represented. Then students will tape the photos of their formation and fossils on the wall near their formation. It will be interesting if more than one group assigns their rock and fossil to the same layer. Good discussions can ensue.
   - Then each group, in turn, will present the details of their assigned formations. Teachers will point out that sharing details is what happens in real geological scientific conferences. No scientist can be an expert in every aspect of geology, so they share results in meetings.
   - The teacher facilitates a group discussion, asking for students to describe the changes over time represented by the basin. The teacher can also deepen student understanding by using the questions from the student worksheet.
   - At this point, the teacher reveals the paintings of ancient landscapes. One by one, the original teams attempt to determine where the landscapes should be attached to the wall in order to be associated with the layers, fossils, and rock descriptions with photos.
   - All students attempt to write out a geologic history for the Denver Basin.
   - The student worksheet can be assigned as homework.

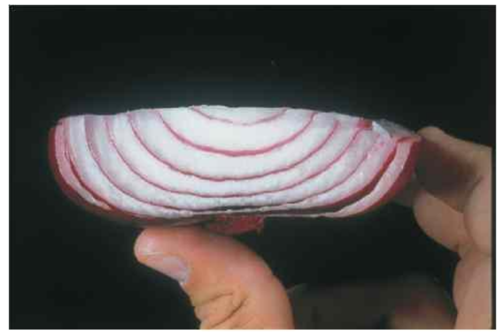


Image from Earth Time Project

Explain

Activity 8 – The Geologic History of Michigan

Purpose

To reinforce concepts of geologic time, age dating, and fossils by building a geologic time line of Michigan's geologic history.

Activity Description

As an Explain activity, student understanding of the concepts related to the previous activities can be used and reinforced. As with the Explain stage of the last cycle, this is an interactive lecture during which the teacher presents an image-rich slideshow and students respond. In this activity, they will be adding events to a time line they create on adding machine tape. Throughout the teacher presentation, the focus questions and main ideas of the previous activities will be reviewed.

Focus Question

How can age-dating techniques be used to understand Michigan's geologic history?

Duration

One class session

Materials

- Michigan Geologic History – Cranbrook Institute of Science:
  http://www.oakgov.com/peds/assets/docs/es_docs/geo_overview.pdf
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/Michigan%20Geologic%20History.pdf
- Geology Resource Guide – Cranbrook Institute of Science:
  http://www.oakgov.com/peds/assets/docs/es_docs/geo_resguide.pdf
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/Oakland%20County%20Glacial%20Geology.pdf
- Bedrock Geology of Michigan document (from UM):
  http://www.geo.lsa.umich.edu/teaching/Bedrock%20v6.pdf
  Atlas URL (poster sized PDF):
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/Bedrock%20Map%20-%20UMich.pdf
  Atlas URL (printable Word document):
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_II/UM%20Bedrock%20Maps%20of%20Michigan.doc
- Adding machine tape
- Colored pencils and rulers
- "Why Earth Science and 9 Big Ideas of Earth Science"

http://www.youtube.com/user/AGIeducation
- Materials from past activities of this cycle:
  - Geologic Time Scale on yarn
  - Core model of the Denver Basin
  - "What's Up? A Relative Age Dating Activity"
    http://www.geosociety.org/educate/LessonPlans/Relative_Age.pdf
    Atlas URL:
    http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_II/Whats%20Up%20Relative%20Age%20Dating%20Activity.pdf

Teacher Preparation

1. Gather materials.
2. Refer to the suggested sequence in the Classroom Procedure and devise and rehearse a presentation.

Classroom Procedure

1. Show Big Idea #2 from AGI's Educator YouTube channel. Use the pause button and slider to facilitate discussions about the content. This would be a good time to contrast relative dating from absolute age dating (using radiometric isotopes).
2. Explain that during a teacher presentation, students are to create a geologic time scale for Michigan.
3. Provide pairs of students with 1.6 meters of adding machine tape, colored pencils, and ruler. Present the challenge of making a scale such that 40 centimeters equals 1 billion years. Have students mark the beginning time as 3 billion years, about 1 decimeter from the left end. Mark the present as 0 million years, at 1 decimeter from the other end.
4. Have students mark off every 100 million years in the last billion. Using the yarn from the earlier activity, have students mark off the Paleozoic, Mesozoic and Cenozoic Eras.
5. Begin to present and review content about Michigan geologic history. As teacher presents the content, pause so students can develop their time lines. See suggested sequence below:
   - Review the slideshow (Michigan Geologic History – Cranbrook Institute of Science), and analyze each slide for timing of events.
   - Provide students with the "Bedrock Geology of Michigan" handout while the PDF file is projected from a computer on a screen. Review the three large regions of Michigan. If the text is beyond the reading level of students, the teacher can interpret while the students focus on the maps and dates of key events.
   - When discussing the Michigan Basin with students, there will be great opportunity to review past activities and skills. Show an onion cut in half as a simple model of Michigan's basin and compare it to the Denver Basin, noting that the youngest layers in the Michigan Basin are still in the Paleozoic Era.
   - Review and practice relative age dating principles. Make references to the Michigan Basin, which simply illustrates superposition and original horizontality. On the issue of horizontality, it's probable that the basin shape predated the accumulation of sediments. Therefore, the layers thin out near the margins.
6. Encourage students to illustrate and annotate their time lines.
7. Host a Gallery Walk so other teams can view the products of their classmates.

Elaborate

Activity 9 – Every Pebble Tells a Story

Purpose
To describe, in writing, a hypothetical history of a rock sample.

Activity Description
"Every Pebble Tells a Story" is an activity from Dr. Larry Braile, a prolific writer of geology lessons. As with the study of the Denver Basin, students are challenged to do what is the essence of the geosciences: construct a logical scenario of earth history from a given (but limited) amount of evidence.

In the activity, students are expected to suggest a set of geologic events that are likely part of the history of the cobble. It's helpful to realize that a set of cobbles gathered from the same location most likely have the same final episode of their histories, while being originally formed in wildly different environments and times. Starting from the most recent, Michigan cobbles may have experienced final rounding in a beach or river setting, after being ground into cobbles by the continental glacier that covered the region during the Pleistocene Epoch. All glacially transported cobbles would have traveled from the north, many as far as northern Ontario. Unless they were formed at the surface, which only occurs in volcanic rocks such as basalt, each rock was deeply buried and returned to the surface through uplift. That said, even volcanic rocks could have been buried after being erupted onto the surface. Upon their uplift, they all would have experienced erosion at the surface by the forces of wind, water, and ice.

Therefore, every story would have a similar ending, but each could have its own unique beginning. The specific origin may be discernable by a specialist, but for teachers and students it is adequate to speculate on reasonable possibilities, given knowledge of the rock type and rock forming processes. When we pluck through a pile of beach rocks, or those present in our typical landscaping, we are handling rocks that were once part of the roots of a towering mountain range the size of the Himalayas, resulting from the collisions of ancient continents. Others are remnants of "snowball" Earth, a theoretical glacial event that occurred a billion years ago. Still others could be related to our state stone, the Petoskey Stone, a coral limestone that formed when Michigan was a shallow marine basin near the equator some 400 million years ago.

The activity should follow basic knowledge of rocks and minerals, rock forming processes and the rock cycle. It also is necessary to use this activity after some study of plate tectonics. It is well placed as a capstone activity for a geology unit because discerning earth history from a hand sample or even an outcrop is a higher level task that utilizes knowledge and skill that will be acquired in this and the previous unit.

Dr. Braile's lessons are thoroughly resourced and it will be necessary to review his description and approach. We suggest two significant modifications:

1. We provide a process that uses statements of geologic events cut into strips from which students can gather ideas. These are called "Geological Event Strips." It is unlikely that a

K-12 student will have the background knowledge to write a geologic history of a Michigan cobble without such support. Therefore, we scaffold the task with a teacher-facilitated process using these statements.

2. We promote writing in a scientific voice using an organizational structure known as "Claim-Evidence-Reasoning (C-E-R)." Students should be proficient in writing with a scientific voice in forms typical of the discipline. Here too, the task is scaffolded with sample writing of varying quality.

Oakland Schools hosts a free online workshop for this activity that takes about five hours. It may be helpful to participate in the workshop before the first use of this activity.

Focus Question

What is the geologic history of the cobble I am holding in my hand?

Duration

Two class sessions

Materials

- Dr. Braile's activity description:
  http://web.ics.purdue.edu/~braile/edumod/pebble/pebble.htm
- A set of typical cobbles (e.g., granite, limestone, gneiss, sandstone, conglomerate)
- Steel nails, copper pennies, streak plates, magnifying glass
- Water in plastic beakers with paper towels
- Dilute hydrochloric acid (or vinegar)
- Managing HCl (for teacher use)
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Earth_Materials/Managing%20HCL.doc
- "Geologic Events Strips," a set for each group. Best to print each set on different colored paper (for ease of collection), card stock, laminated
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/Geologic%20Processes%20that%20Can%20Be%20Inferred%20from%20a%20Rock%20Sample.doc
- Black/white and color coded paragraphs in Claims-Evidence-Reasoning format for quartzite
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/BW%20and%20Color%20Coded%20CER%20Ppg-Quartzite.doc
- Rock cycle diagram
  Atlas URL:
  http://oaklandk12.rubiconatlas.org/links/Science_6/Science_Gr_6_Plate_Tectonics_I/Simple%20Rock%20Cycle2.gif

Teacher Preparation

1. Carefully review the classroom procedures as well as the "Every Pebble Tells a Story" website at: http://web.ics.purdue.edu/~braile/edumod/pebble/pebble.htm
2. To the extent it is helpful, teacher can review ancillary materials provided by Braile: http://web.ics.purdue.edu/~braile/edumod/pebble/pebbleAM.pdf
3. Prepare the Geologic Events Strips. Each team will receive one set. It will be easiest to manage if each set is on different colored paper (for ease of collection), put on card stock, and laminated. Pull a subset of eight or ten statements from each batch. These will be handed to students first so they aren't overwhelmed. It doesn't matter which ones, except that the conversation will be more productive if a number of groups has a statement about glacial history or uplift (events that are common to all rocks).
4. Organize rock identification kits that include: diluted HCl or vinegar, a steel nail, a penny, a streak plate, and a magnifying glass.
5. Prepare the black/white and color-coded paragraphs in C-E-R format for quartzite. There are three paragraphs in black and white on page one. The same three are color coded on page two, which serves as an answer key. Each team of three will receive the two sets. Color print and cut the pages into the separate paragraphs.
6. Gather cobbles from school or home landscaping. Landscaping companies will sell a bucket of cobbles inexpensively as well. Try to find clean, easy-to-identify rocks. There are some amazing special rocks worth hunting for. These include the following:

Granite
Granites form deep underground as magma cools and crystallizes into the minerals feldspar, quartz, biotite, and amphibole. The minerals are large enough to identify. The light-colored minerals clearly outnumber the dark-colored minerals. It's common for granite to contain two types of feldspar. One of them is pink (orthoclase), and the other is white (plagioclase). Any granite cobble is evidence of a convergent plate boundary and a mountain-build event. A great deal of granite is exposed in Canada, suggesting Canada was the location of a huge mountain range.

Diorite or Gabbro
These types of rocks have many of the characteristics of granite, except the dark-colored minerals are in equal proportion (in the case of diorite) to light-colored minerals, or are a majority (in the case of gabbro). Quartz and pink feldspar are absent. Darker igneous rocks are evidence of melts that spent less time in continental crust, and may be affiliated with ocean crust or earth's mantle.

Volcanic Rock
Cobbles of volcanic rock may be light to dark in color. They are evidence of magma reaching the surface to become lava where it cooled and hardened at the surface. Most, if not all, crystals are too fine to see even with a hand lens. Some crystals may be larger, indicating that cooling began before eruption. There also may be gas bubbles, empty or filled, evidence of dissolved gas coming out of solution as the magma rose towards the surface. A great deal of Precambrian basaltic lava is exposed in Michigan's Upper Peninsula and Canada. The basaltic lava is evidence of continental rifting and the birth of an ocean basin. Other evidence underground suggests it extends down toward the Detroit area. In the other direction, the volcanic rock

appears to extend as far south as Texas. A recent study correlated rock with nearly identical chemistry in Antarctica, suggesting the rift was thousands of miles long.

Gneiss (nice)
Like granite, gneiss is formed in the roots of huge mountain ranges. Had temperatures been elevated even higher, the rock could have eventually melted to become a magma. Gneisses are common and distinctive. They look like granite with light and dark-colored minerals, but they are concentrated in bands or stripes. The history of a gneiss would include rock formation of another type, such as the deposit of a sand or mud, or even the cooling of a magma.

Quartzite or Marble
The protolith (original rock) of a quartzite or marble is obvious: sandstone or limestone respectively, where a gneisses' protolith may be impossible to determine. Quartzite or marble are metamorphosed so much harder than their original rock type. Quartzite is common because they are especially strong. It is common to find a white variety and purple variety.

Limestone
Because the Michigan Basin includes thick deposits of reef-related limestone, glaciers did not necessarily transport them very far. Many sedimentary rocks have broken apart through erosion and are poorly represented in gravel pits and on Michigan beaches. Limestone precipitated out of sea water, and unlike most of the Canadian rocks, were formed when complex marine life flourished on Earth. The presence of fossils indicates warm, shallow marine environments.

Tillite (a conglomerate)
A very common and very remarkable cobble has traveled from exposures in Canada, where ancient glacial till is exposed. Till is the mud-dominated sediment left behind in glacial moraines. While dominated by mud, it includes larger clasts of sediment. It's common to see identifiable granite clasts rounded off and containing pink feldspars. The rock is black, dense, and hardened by metamorphism, so it can be called metaconglomerate. It is thought to be approximately one billion years old and indicates that Earth experienced an ice age early in its history.

Classroom Procedure

1. Provide teams of three students with a cobble.
2. Ask them to identify their rock and discuss the rock's origin.
3. Walk the room and help students who are struggling with identification. They need to know the type of rock they are studying.
4. After 3-5 minutes of small group discussion, elicit comments in a whole-group discussion. Suggestions: *"What can you infer about the geologic history of your sample?"* followed by, *"Please site the evidence you are basing that inference on."*
5. Hand out the subset of strips with this instruction: Choose at least three strips that you think are part of the rocks history, and three others that are most likely not part of the history. Students can also have a category of those strips they don't know.

6. Again, initiate a whole-group discussion, prompting students to compare their observations, reasoning, and conclusions. Allow students to offer their viewpoints but ask this key question: *"Did we notice any aspects of the rocks histories that are common?"* (All Michigan cobbles have similar final stages in their histories: erosion and transport by glaciers, as well as rounding by rivers or beaches.)
7. Distribute more strips in batches small enough for students to handle, until they have them all.
8. Prompt students to lay out their strips in a sequence that they think represents the rock's history. Ask students how strips should be spaced if they were to scale.
9. Check students' reasoning and challenge their assumptions when you notice they could be out of sequence.
10. When prompting the writing phase, use the process below:
    a. Briefly explain the **Claims-Evidence-Reasoning** structure of scientific writing.

    b. To groups of three, pass out the three sample paragraphs for the story of a quartzite (each student gets one of the versions).

    c. Tell students to individually underline the Claim in one color, the Evidence in another color, and the Reasoning in a third color.

    d. When students are finished, ask them to show and explain their solution. Because they have different paragraphs, they should naturally begin to compare and evaluate the writing.

    e. Provide the colored answer key to each group to compare with their solution.

    f. After this process, students will be better prepared to write their own paragraph for their rock. Their history should include the content from the statements on the strips.

    g. As students begin to write their narratives of earth history for their rock sample, help them with the word choice that will promote a scientific way of thinking. Here are some examples:

        - The Centrality of Evidence: "Based on ____ (some feature of the rock), it is reasonable to conclude_____________."
        - Tentativeness: "It is possible that…" or "The observation suggests that…"
        - Frameworks of Knowledge: "Knowing that igneous rocks are..."
        - Questioning: "It would be interesting to know..."
        - Honesty: "We aren't aware of where this rock may have originated, but…"

Science Scope on Atlas Rubicon Curriculum Manager:
http://oaklandk12.rubiconatlas.org/public/

Oakland Schools: http://www.oakland.k12.mi.us/