OCEAN EXPLORATION LESSON PLAN

Bang! You’re Alive!

Theme
Ocean Exploration

Links to Overview Essays and Resources Needed for Student Research
http://oceanservice.noaa.gov/topics/coasts/assessment/
http://www.csc.noaa.gov/products/tsunamis/
http://www.oceanservice.noaa.gov/topics/oceans/oceanex/

Subject Area
Earth Science

Grade Level
9-12

Focus Question
How does understanding the theory of plate tectonics and the history of life on Earth directly benefit humans?

Learning Objectives
- Students will be able to describe and explain the theory of plate tectonics.
- Students will be able to describe and explain the “Big Bang” theory for the origin of the universe.
- Students will be able to identify the approximate age of the Earth and the point in Earth’s history at which living organisms first appeared, according to current geological evidence.
- Students will be able to explain at least two ways in which understanding the theory of plate tectonics and the history of life on Earth are of direct benefit to humans.

Materials Needed
- copies of “History of the Earth Worksheet,” one copy for each student group

- (optional) Computers with internet access; if students do not have access to the internet, download copies of materials cited under "Learning Procedure" and provide copies of these materials to each student or student group

Audio/Visual Materials Needed

None

Teaching Time

One or two 45-minute class periods, plus time for student research

Seating Arrangement

Groups of 2 – 4 students

Maximum Number of Students

32

Key Words

Earthquake
Tsunami
Volcano
Plate tectonics
Big bang

Background Information

Some of the most spectacular discoveries made by recent explorations of the Earth's deep oceans have been near the boundaries of the "plates" that make up the outer rigid shell of the Earth's crust (lithosphere). According to the theory of plate tectonics, these plates float on the molten rock of the Earth's mantle. At some of the boundaries, molten rock rises to the surface of the lithosphere to form new crust and the plates move apart (divergent boundaries). Where plates press against each other, one plate sinks beneath the other and crust is destroyed (convergent boundaries). A third type of boundary is found where plates slide past each other (transform boundaries).

Plate tectonics is one of the great unifying theories in geology, because it explains nearly all rocks and geologic features. Plate tectonics also causes many events of direct importance to humans, including earthquakes, volcanoes, and tsunamis.

These events create hazards that are particularly significant to ports and harbors, whose location often makes them vulnerable to a wide range of natural disasters. For example, ports and harbors built on fill material or surrounded by steep slopes are at risk of damage from earthquakes, tsunamis, and landslides. In addition, secondary hazards, such as fires, floods, and hazardous spills, can also occur during these events. Ports and harbors play significant roles in the economic and cultural development of coastal communities. Because they are at the hub of major transportation systems, ports and harbors also play a major role in response and recovery after natural disasters. For both reasons, it is essential that plans are developed for preventing damage to ports facilities before natural disasters occur, and for speeding recovery after they happen.

The National Ocean Service provides information on natural hazards to help coastal communities develop and implement these plans. The scientific basis for this information is the plate tectonic theory. But despite its usefulness, this theory was repeatedly rejected by scientists until new technologies produced measurements that strongly supported the basic concepts. The purpose of this lesson is to introduce students to development of the plate tectonic theory and current ideas about the origin of the Earth.

Hundreds of years ago, scientists noticed that the eastern margin of the South American continent appeared to closely match the western margin of the African continent. Sir Francis Bacon and Galileo Galilei both made this observation in the 17th century. Benjamin Franklin proposed that Earth's continents floated on a fluid inner core. In 1858 an Italian geographer, Antonio Snider, drew maps of the continents as he thought they would have appeared before they drifted apart. An Austrian geologist (Edward Suess) developed the idea further in the late 19th and early 20th centuries that included the supercontinents Gondwanaland (comprised of all the southern continents and India) and Laurasia (which included all the northern continents). Two geologists, Frank Taylor and Howard Baker, demonstrated that the mineral content and rock formations of the Caledonian mountains in northern Europe were the same as those found in the Appalachians of North

America. In 1912, Alfred Wegener, a German meteorologist, used evidence from paleontology, climatology, geography, and geology in a detailed analysis of the idea that continents drift across the Earth's surface (the "continental drift theory"). But all the evidence put together could not explain how a solid continent could move across the stone floor of the ocean. As a result, Wegener's hypothesis was rejected by other scientists and his professional reputation was badly damaged.

Still, scientists continued to debate the theory, because there also was no satisfactory explanation for many other observations. Similarity of fossils in Africa and South America were particularly troubling, as was the discovery of ancient coal forests in the Arctic and glacial deposits in the tropics. Geophysicists discovered that sediments at the bottom of the ocean were not nearly as thick as they should have been if these sediments had been accumulating for millions of years. Ships began carrying echo sounders, and discovered mountain ranges in the middle of Earth's oceans. Magnetic detection devices developed to find submarines revealed that magnetic rocks on either side of the mid-ocean ridges were oriented toward the north pole or south pole in alternating bands. In 1960, two geologists (Harry H. Hess and Richard Dietz) suggested that molten rock might be rising along the mid-ocean ridges and that the sea floor was sinking in the submarine trenches found along the edges of continents. Two other geologists (Frederick Vine and Drummond Matthews) saw a connection between the sea-floor spreading hypothesis and the patterns of magnetism in rocks near the mid-ocean ridges. They suggested that the molten rock rising along the mid-ocean ridges became new crust, and that iron particles in the liquid rock aligned themselves with the Earth's magnetic field and became fixed in this alignment as the rock cooled. Geologists knew that the Earth's magnetic field periodically reverses (the magnetic north pole becomes the magnetic south pole and vice versa), which would explain the bands of rock with alternating magnetic orientation.

All of these observations were brought together in 1967 by two British geophysicists and an American geophysicist who independently proposed the theory of plate tectonics. Because this theory explained many separate observations, including the mechanism and location of earthquakes, Wegener's ideas were finally accepted. Unfortunately, he had died nearly forty years before.

Plate tectonic processes are driven by Earth's internal heat, which is a remnant of the Earth's formation about 4,500 million (4.5 billion) years ago. Many astrophysical observations support the theory for the formation of universe known as the Big Bang hypothesis. According to this theory, all matter and energy in the universe were once condensed into a very small and hot mass. At least 15,000 million years ago, a huge explosion (the "Big Bang") took place, sending matter (primarily hydrogen and helium) and energy flying out in all directions. As the universe expanded, matter condensed into clouds and began to rotate. Where there was sufficient mass, gravitational attraction caused the clouds to collapse, compressing matter to the point that nuclear reactions began and thus creating stars. Nuclear reactions in these stars converted hydrogen and helium into heavier elements, such as carbon, nitrogen, and oxygen. These elements were blasted back into space by exploding stars (supernovas), and formed clouds containing simple molecules such as water, carbon monoxide, and hydrocarbons. Our sun was formed in a rotating disk of gas and dust-like matter. These particles collided, first forming small grains and then larger bodies called planetesimals (which had diameters on the order of several hundred kilometers). The planetesimals eventually aggregated into larger bodies that became planets and satellites.

Formation of Earth from planetesimals took place over a period of 100 – 200 million years. As the mass of aggregating planetesimals increased, so did their gravitational fields, so that heavy materials accumulated near the center of the mass. The increasing gravitational field also attracted meteoroids (which are called "meteors" as they pass through Earth's atmosphere; if any of the meteroid survives the trip through the atmosphere the remnant is called a "meteorite"). Many astrophysicists now believe that when Earth was about half-formed, the impact from a very large meteoroid dislodged material from the outer part of the Earth-mass and flung it into space to become the moon. This theory explains why the moon does not have a large metallic core like the Earth. Repeated impacts from meteoroids transferred huge amounts of heat that kept the Earth in a molten state as it was being formed. Decay of radioactive materials in the Earth's core also contributed heat, and continue to do so today. As the Earth's surface cooled about 4,200 million years ago, water vapor condensed into torrential rains that formed Earth's oceans. During the next 700 million years, complex molecules were formed that provided the basis for living organisms. The oldest known micro-organisms are about 3,500 million years old, so it is likely that those key molecules were formed much earlier; but we don't know exactly how or when that happened.

Learning Procedure

1.
You may want to visit NOAA's Ocean Explorer Web site, which includes reports, lesson plans, animations, and photo and video logs from expeditions to several tectonic plate junctions (see "Resources" for specific recommendations and Web addresses).

2.
Ask students to describe the processes of plate tectonics. Individual knowledge may vary, but at a minimum students should understand the concepts of tectonic plates, continental drift, and divergent/convergent boundaries. Tell student groups that their assignment is to research current theories about plate tectonics and the origin of the Earth, using the "History of the Earth Worksheet" as a guide, and to design a timeline of key events in Earth's history listed on the worksheet. Timelines should be to a scale that illustrates the relative magnitude of the times involved (for example, if a scale of 1 ft = 1 million years were used, the entire timeline would have to be 4,500 • 1 ft = 4,500 ft = 0.85 mi long to represent 4,500 million years of Earth history).

You may want to direct students to Web sites listed under "Resources," or allow students to discover these (or other information sources) on their own.

3.
Review students' responses to questions on the worksheet, and each group's design for a timeline. Correct responses to the questions are:

1. What is the “Big Bang” theory?
   [That all matter and energy in the universe were once condensed into a very small mass, and that approximately 15,000 million years ago, a huge explosion sent matter flying out in all directions]

2. What elements were most abundant in the universe shortly after the Big Bang?
   [Hydrogen and helium]

3. In the late 1920s, American astronomer Edwin Hubble made an important discovery that supports the Big Bang theory. What was this discovery?
   [That distant stars and galaxies are receding from Earth in every direction, and the velocities of recession increase in proportion with distance, suggesting that the universe is expanding]

4. According to current theory, after the Big Bang matter collected into clouds. How did stars form in some of these clouds?
   [Where there was enough mass, gravitational attraction caused the cloud to collapse. If the material in the cloud was sufficiently compressed, nuclear reactions began forming a star.]

5. What are “planetesimals,” and how are they relevant to the origin of the Earth?
   [Planetesimals are aggregations of gas and dust which may be several hundred kilometers in diameter. Earth (and other planets) are believed to have been formed by aggregations of planetesimals.]

6. According to current theory, about how long ago was the Earth formed?
   [About 4,500 million years ago]

7. How old are the oldest known rocks on Earth?
   [Zircon crystals found in Western Australia have an estimated age of 4,300 million years.]

8. As the Earth was being formed, materials in the developing planet were kept in a molten state by intense heat. What was the source of this heat?
   [Heat was produced by compression of matter due to gravitational attraction of the growing planet, by the impact of meteoroids, and by decay of radioactive materials.]

9. Unlike the Earth, the moon has only a tiny metallic core. What theory for the moon's formation provides an explanation for this observation?
[That the moon was formed when a large meteoroid struck the Earth when the planet was about half-formed, dislodging a mass of material from the outer layer and flinging it into space to become the moon.]

10. What were the first known living organisms on Earth and when did they appear?
[There is evidence that primitive bacteria-like organisms lived on Earth 3,850 million years ago.]

11. Why haven't scientists been able to measure the age of the Earth by measuring the age of the Earth's oldest rocks?
[Because rocks that were formed when the Earth's crust first cooled have almost certainly been recycled by plate tectonics and erosion processes; the same problem applies to determining when living organisms first appeared, because the remains of these organisms have probably been recycled as well.]

12. Where are Earth's oldest rocks found?
[Rocks more than 3,500 million years old are found on all of Earth's continents. The oldest rocks found on Earth so far are the Acasta Gneisses in northwestern Canada near Great Slave Lake (4,030 million years old) and the Isua Supracrustal rocks in West Greenland (3,700 to 3,800 million years old), but well-studied rocks nearly as old are also found in the Minnesota River Valley and northern Michigan, Swaziland, and Western Australia.]

13. What is the lithosphere?
[the outer rigid shell of the Earth's crust]

14. What is the theory of plate tectonics?
[According to this theory, the lithosphere is composed of separate "plates" that float on the molten rock of the Earth's mantle, moving apart in areas where molten rock rises from the Earth's mantle to form new crust, and colliding where plates are pushed together by new crust formation.]

15. What are divergent boundaries, convergent boundaries, and transform boundaries?
[Divergent boundaries occur where plates move apart. Convergent

boundaries occur where plates press against each other, and one plate sinks beneath the other. Transform boundaries occur where plates slide past each other.]

16. What are Laurasia and Gondwanaland?
[Supercontinents that were proposed and named by Austrian geologist Edward Suess. Gondwanaland included all the southern continents and India, while Laurasia included all the northern continents.]

17. Who was Alfred Wegener, and what theory did he propose?
[Wegener was a German meteorologist who published a detailed analysis of the continental drift theory in 1912.]

18. Why did scientists reject Wegener's theory?
[Because Wegener could not explain how a solid continent could move across the stone floor of the ocean.]

19. What are five observations or lines of evidence that support Wegener's theory? Which of these was key to gaining widespread acceptance for the theory?
[The oldest relevant observation was the similarity of the shape of the east coast of South American and west coast of Africa. Other similarities include fossils found on the two coasts, as well as the mineral content and rock formations of the Caledonian mountains in northern Europe and the Appalachian mountains of North America. Discovery of mid-ocean ridges provided a solution to the major objection to Wegener's theory. This discovery and evidence of magnetic banding on either side of the ridges were key to acceptance of Wegner's theory.]

20. Plate tectonics provides the basis for predicting what geologic events that are of direct importance to human safety?
[earthquakes, volcanoes, and tsunamis]

Timelines should place the specified events at approximately the following points. Times may vary somewhat, depending upon sources of information.

- Formation of Earth begins as dust, planetesimals, and meteoroids start to condense
[4,500 Million Years Before Present (MYBP)]

- The moon is formed
[about 4,300 MYBP]
- Torrential rains form oceans
[4,200 MYBP]
- First living organisms appear
[3,850 MYBP]
- First photosynthetic organisms appear
[3,600 MYBP]
- Cyanobacteria proliferate and begin to add oxygen to Earth's atmosphere
[2,500 MYBP]
- Protoctists appear
[1,700 MYBP]
- Eukaryotic algae appear
[1,200 MYBP]
- First multicellular animals appear
[600 MYBP]
- Cambrian "explosion" of animal diversity
[570 MYBP]
- Ordovician extinction of more than 50% of all marine animal species
[400 MYBP]
- Devonian extinction of more than 50% of all marine animal species
[365 MYBP]
- Permo-Triassic extinction of more than 95% of all species
[245 MYBP]
- First mammals appear
[225 MYBP]
- Dinosaurs dominate
[190 – 65 MYBP]
- Asteroid impact induces Cretaceous-Tertiary extinction
[65 MYBP]
- Humanoids appear
[10 – 5 MYBP, depending upon how human-like you want a "humanoid" to be]

Students should realize that humans have existed for less than 0.2% of the total history of life on Earth. If students represented the history of all life on Earth as one hour, modern humans would exist for approximately one second. In fact, all multicellular organisms are relatively recent arrivals; for most of the history of life on Earth, life consisted of single-celled microbes. Students should also realize that mass extinctions have happened repeatedly throughout this history, some caused by climate change, some by asteroid impacts, and some for unknown reasons. Some scientists believe that such extinctions may happen again, perhaps at least partially caused by human activities.

Encourage students to discuss how plate tectonic theory and the history of life on Earth may be of direct benefit to humans. Improved understanding of earthquakes, volcanoes, and tsunamis are obvious benefits. In addition, the recurrence of mass extinctions coupled with the fact that humans are very recent arrivals in geologic time could lead to serious reflection on possible scenarios for the future of the human species.

Point out that, as far as we know, humans are the first species to be conscious of geologic history and to have the ability to consider their place in Earth's living systems. Ask whether these abilities offer any advantage to humans compared to other species, and if there are advantages, how could we put them to good use?

The Bridge Connection

http://www.vims.edu/bridge/ – In the navigation menu on the left side of the page, click on "Ocean Science Topics," then "Marine Geology" for links to resources about plate tectonics.

The Me Connection

Have students write a brief essay on the potential consequences of a mass extinction event on the human species.

Extensions

Divide the class into two groups. One group should be assigned to prepare a presentation of the major elements of Alfred Wegener's theory of continental drift. The other group should prepare a presentation of objections to this theory. Stage a formal debate between the groups.

Resources

NOAA's Ocean Explorer Web site includes reports, lesson plans, animations, photo and video logs from expeditions to several tectonic plate junctions.

Lesson Plans:

"Volcanoes, Plates, and Chains" (*http://oceanexplorer.noaa.gov/explorations/02alaska/background/edu/media/volcanoes5_6.pdf*)

"The Biggest Plates on Earth" (*http://oceanexplorer.noaa.gov/explorations/02fire/background/education/media/ring_big_plates_5_6.pdf*)

"Islands, Reefs, and a Hotspot" (*http://oceanexplorer.noaa.gov/explorations/02hawaii/background/education/media/nwhi_hot.pdf*)

"Hawaiian Bowl!" (*http://oceanexplorer.noaa.gov/explorations/02hawaii/background/education/media/nwhi_bowl.pdf*)

"Roots of the Hawaiian Hotspot" (*http://oceanexplorer.noaa.gov/explorations/02hawaii/background/education/media/nwhi_roots.pdf*)

Photo and Video Logs:

Submarine Ring of Fire 2002 (*http://oceanexplorer.noaa.gov/explorations/02fire/logs/photolog/photolog.html*)

Galapagos Rift (*http://oceanexplorer.noaa.gov/explorations/02galapagos/logs/photolog/photolog.html*)

Submarine Ring of Fire 2003 (*http://oceanexplorer.noaa.gov/explorations/03fire/logs/photolog/photolog.html*)

Submarine Ring of Fire 2004 (*http://oceanexplorer.noaa.gov/explorations/04fire/logs/photolog/photolog.html*)

Animations

http://oceanexplorer.noaa.gov/explorations/04fire/background/marianaarc/marianaarc.html

http://oceanexplorer.noaa.gov/explorations/03fire/logs/subduction.html; *http://oceanexplorer.noaa.gov/explorations/03fire/logs/ridge.html* *http://www.globalcommunity.org/wtt/walk_photos/print_pages/index.htm* – A Walk Through Time

http://www.psrd.hawaii.edu/Dec98/OriginEarthMoon.html – "Origin of the Earth and Moon " by G. Jeffrey Taylor, Hawai'i Institute of Geophysics and Planetology

http://cmex-www.arc.nasa.gov/VikingCD/Puzzle/Evolife.htm – Web page presented by NASA's Planetary Biology Program, illustrating natural phenomena that collectively have created life as we know it

National Science Education Standards

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science
- Structure and properties of matter
- Chemical reactions
- Motions and forces
- Interactions of energy and matter

Content Standard D: Earth and Space Science
- Energy in the earth system
- Geochemical cycles
- Origin and evolution of the earth system
- Origin and evolution of the universe

Content Standard E: Science and Technology
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Content Standard G: History and Nature of Science
- Nature of scientific knowledge
- Historical perspectives

Links to AAAS "Oceans Map" (aka benchmarks)

5D/H2 – Like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough equilibrium. In the long run, however, ecosystems always change when climate changes or when one or more new species appear as a result of migration or local evolution.

5D/H3 – Human beings are part of the earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems.

OCEAN EXPLORATION REVIEW

History of the Earth Worksheet

1. What is the "Big Bang" theory?

2. What elements were most abundant in the universe shortly after the Big Bang?

3. In the late 1920s, American astronomer Edwin Hubble made an important discovery that supports the Big Bang theory. What was this discovery?

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11. Why haven't scientists been able to measure the age of the Earth by measuring the age of the Earth's oldest rocks?

12. Where are Earth's oldest rocks found?

13. What is the lithosphere?

14. What is the theory of plate tectonics?

15. What are divergent boundaries, convergent boundaries, and transform boundaries?

16. What are Laurasia and Gondwanaland?

17. Who was Alfred Wegener, and what theory did he propose?

18. Why did scientists reject Wegener's theory?

19. What are five observations or lines of evidence that support Wegener's theory? Which of these was key to gaining widespread acceptance for the theory?

20. Plate tectonics provides the basis for predicting what geologic events that are of direct importance to human safety?

Major Events in Earth's History to be Included in Timelines:

- Formation of Earth begins as dust, planetesimals, and meteoroids start to condense
- The moon is formed
- Torrential rains form oceans
- First living organisms appear
- First photosynthetic organisms appear
- Cyanobacteria proliferate and begin to add oxygen to Earth's atmosphere
- Protoctists appear
- Eukaryotic algae appear
- First multicellular animals appear
- Cambrian "explosion" of animal diversity
- Ordovician extinction of more than 50% of all marine animal species
- Devonian extinction of more than 50% of all marine animal species
- Permo-Triassic extinction of more than 95% of all species
- First mammals appear
- Dinosaurs dominate
- Asteroid impact induces Cretaceous-Tertiary extinction
- Humanoids appear