PLATE TECTONICS - LEARNING THE SCIENCE TO UNDERSTAND THE HAZARD

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ABSTRACT

The scientific evidence for Plate Tectonics can help students understand earthquake hazards. Overcoming fear and anxiety of any hazard starts in the elementary grades. Activities and lesson plans that emphasize critical thinking skills and content about a particular type of hazard gives students confidence to deal with problems if the student should experience that hazard. An elementary science program, Integrating Science, Math, and Technology (I. Science MATE) has students develop the skills within a year long science program. Learning about earthquake hazards requires a coherent, grade leveled, and scientifically rigorous look at volcanoes, earthquakes, and plate tectonics (Plate Tectonic Cycle). The hands-on materials were designed to highlight the evidence that geologists and seismologists use to "prove" plate tectonics as a working model. These lines of evidence include data from the structure of the surface of the earth, geophysical data from earthquakes, and paleontological clues. This scientific rationale has guided the development of activities so students learn sequential concepts that provide insight on prevention of hazards.

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INTRODUCTION

Fear and anxiety is common when a subject is not understood. It is easy to explain unknown phenomena by blaming a "higher" spirit then to research the real cause. Terrifying temblors, swaying of land, the rumbling sound during an earthquake, can cause any person to be in complete awe of the earth's powers. The steaming, hot magma, oozing down the sides of an erupting volcano, reveals another mystical power created by our earth. This fear led ancient people to create myths to explain these events. Modern people usually just live with the danger, without really knowing what is happening to the earth. Not understanding leads to apathy, which is the main reason why people do not want to think or prepare for a disaster before it happens.

Scientifically, it was very difficult for geologists prior to the mid-1900's to explain what was happening to the earth. Geophysical equipment was developed that would help obtain new data that scientists used to unlock the mystery of the moving earth. There were clues, but it was not until the 1960's that geologists began putting the pieces of the puzzle together and felt confident that the plate tectonic theory was a new working model. Active research in seismology, tectonophysics, geophysics, and engineering may someday provide information that will help predict and possibly control the earth's movement. Because new data may change the current philosophy, one who teaches about plate tectonics must make students understand that this is an evolving, dynamic subject. Solutions for today's hazard might also change as we learn more and more about how our earth releases stress.

An integrated elementary science curriculum helps to teach earthquakes and volcanoes effectively. Scientists and educators associated with the Math/Science Nucleus have developed and piloted a year long science curriculum for elementary grades, Integrating Science, Math, and Technology (I. Science MATE). It is not an added program that demands certain materials to be used, as much as it is an integration of science materials for use by all teachers at a school. Science in this program is taught as a way of thinking, using content materials from the different science disciplines to illustrate concepts. The I. Science MATE curriculum is designed to allow a school to build a basic science program that is tailored to that specific school. The philosophy of the curriculum is that Applied Sciences can be explained by the five interlocking cycles of Universe, Plate Tectonics, Rock, Water, and Life (figure 1). The evolution of the universe gave birth to our solar system. The heating up of the Earth's internal engine created movement within the earth's interior, expressed as volcanoes and earthquakes on the surface (Plate Tectonics). Erupting volcanoes expelled steam creating the first step toward the water cycle. Different environments on earth caused the creation of different types of rocks. The water created conditions for the miracle of life to develop.

The Plate Tectonics Cycle, a 4 week portion of the I. Science MATE program, is divided into Volcanoes, Earthquakes, Plate Tectonics, and Hazards. A secondary curriculum is also being piloted, however the curriculum evolves around plate tectonics as a unifying theme in teaching how rocks were created.

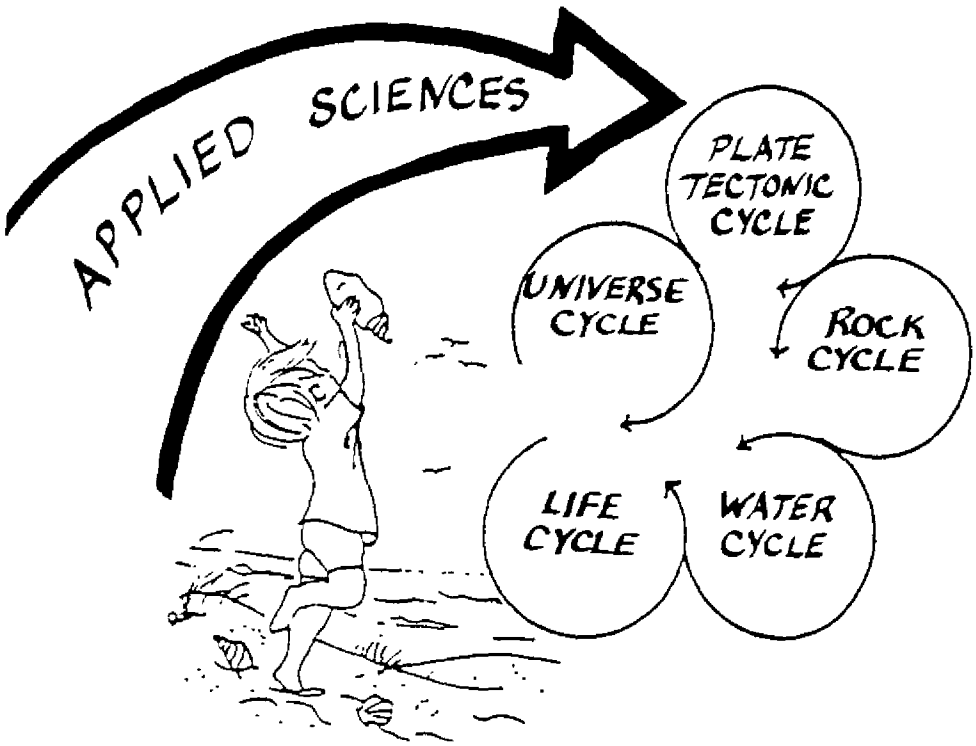


Figure 1. The main components of the I. Science MATE program.

SCIENTIFIC RATIONALE

In the Kindergarten through sixth grade, I. Science MATE Program (Blueford, 1989), earthquakes is a theme of the unit on the PLATE TECTONIC CYCLE (figure 2) (Blueford,

PLATE TECTONIC CYCLE

OBJECTIVES AT A GLANCE - 4 WEEK PROGRM

K	1	2	3	4	5	6	THEME
Volcanoes produce rocks	Volcanoes have definite shapes	Products of volcanoes	Creating rocks from lava	3 basic types of volcanoes	Volcanoes produce different rocks	Location of volcanoes	VOLCANOES 1 week
Shaking during an earthquake	Earthquakes release energy	Earthquake faults	Energy waves cause damage	Measuring earthquakes	Wave movements and seismograms	Dividing the earth by waves	EARTHQUAKES 1 week
Continents and oceans	Continents have moved	Evidence from continents	Pressure in the earth	Diverging, converging, transform	Crustal movement	Definition of plate boundaries	PLATE TECTONICS 1 week
Earthquakes and volcanoes cause damage	Volcanic eruptions	Where do you go for help?	Historical damage (volcanoes)	Damage during earthquakes	Mudslides and volcanoes	Earthquake "proof" structures	HAZARDS 1 week

Figure 2. An overview of the Plate Tectonic Cycle.

1988). The Plate Tectonic Cycle refers to the movement of large portions of the earth's lithosphere in what is termed plates. The boundaries of these plates are generally defined by the occurrence of volcanoes and earthquakes. The driving forces that move these plates are a combination of events that occur within the earth and external stresses on the earth caused by a rotating sphere. The immediate fueling of the movement occurs within the asthenosphere which includes the crust of the earth and the upper portion of the mantle. There are 2 divisions that geologists use to divide the earth - one that deals with the entire earth (core, mantle, and crust) and one that deals with the outer portion (asthenosphere, lithosphere, hydrosphere, and atmosphere) (figure 3). The hydrosphere refers to the water on the earth. The atmosphere is the gaseous envelope that surrounds the earth. The lithosphere is a term that includes the crust and portions of the upper mantle and defines the thickness of the "plates." The asthenosphere is a more viscous portion of the upper mantle on which the plates move. Exactly how the various layers of the earth interact is still being investigated.

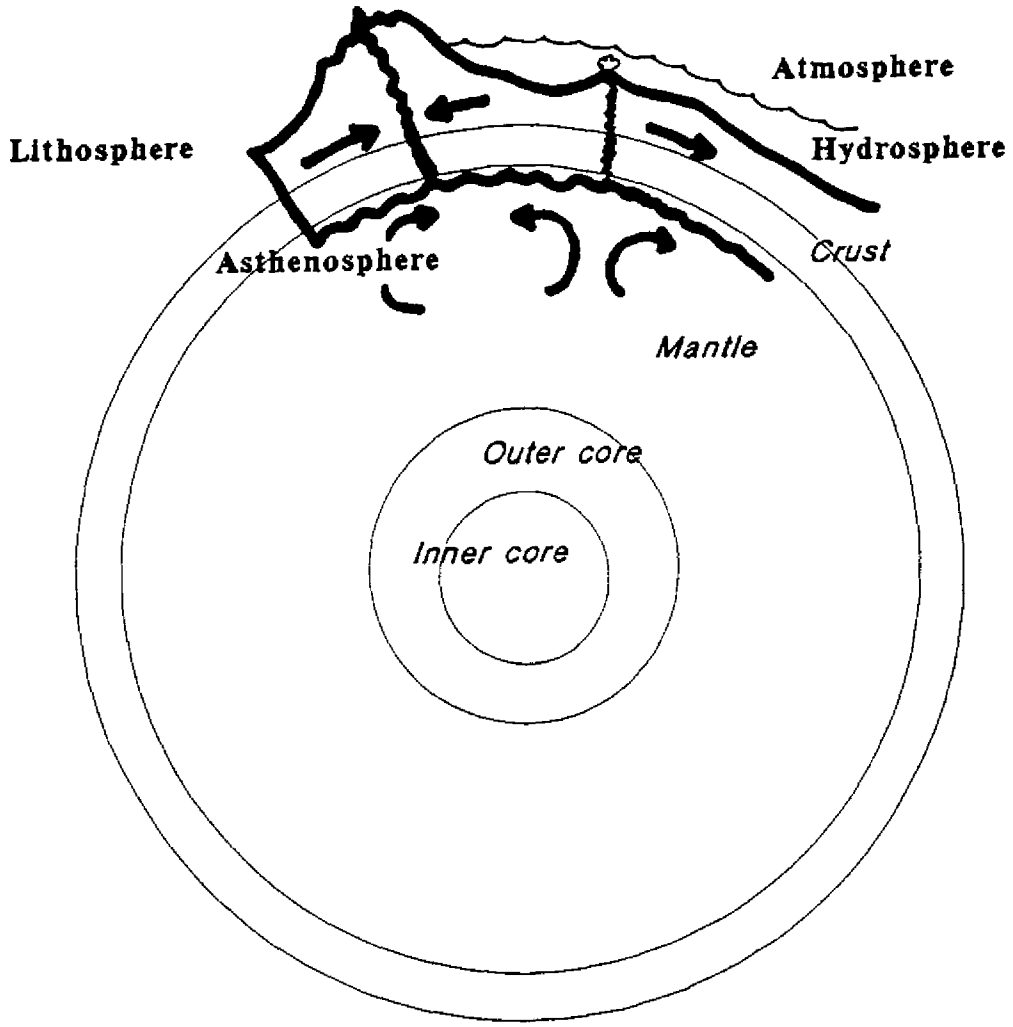
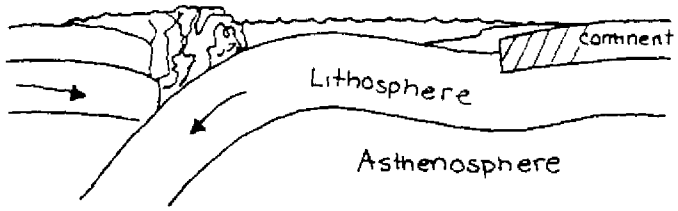


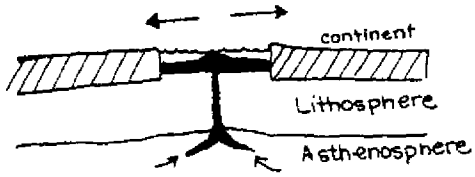
Figure 3. Cross section of the earth with the 2 types of divisions.

The boundaries of the plates are defined by earthquakes and volcanoes. These boundaries seem to move in 3 general ways. Apart (rift zone, spreading center, divergence); together (subduction, obduction, converging); or past each other (transform fault, slip slide) (figure 4). It is from the active boundaries of the plates that geologists and seismologists derive most of their information about plate tectonics, because volcanoes and earthquakes provide quantitative data.

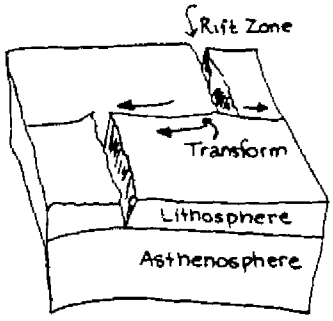
Elementary students don't need to know all the evidence for plate tectonics, which includes paleontological, structural, and geophysical evidence. In elementary grades, structural and geophysical evidence is emphasized because the concepts are more definitive. Since we stress the use of real data, paleontological parameters require more background than most elementary students have. Historically, paleontological data were the first pieces of evidence that made geologists "think" about moving continents but it wasn't until geophysical data confirmed it that many geologists viewed plate tectonics as a good working model. At the secondary level, all three lines of evidence are taught. You can present the data in a historical context for secondary students, so students realize how difficult it was to convince even the scientific community of plate tectonics. Remember it wasn't until the 1960's that "plate tectonics" was included in many of the college level geologic textbooks, and not until the 1970's did it start appearing in the pre-college text.



A. Converging



B. Diverging



C. Transform

Figure 4. Three basic types of plate boundaries.
A. Converging; B. Diverging; and C. Transform.

PALEONTOLOGICAL DATA

Paleontologists had long recognized that the east coast of South America and the west coast of Africa have many fossils in common, especially land organisms. Coal-bearing beds and associated paleofaunas also seem to connect. Biologists had also noted that some North Atlantic organism's land distribution like garden snails, earthworms, mussels, and mud minnows also "linked" across the ocean. The data only started to accumulate when explorers to the "New World" started bringing naturalists on their ships. The more they looked, the more they realized that there were similarities. By the late 1800's, geologists started to notice these "links." The similarities were explained by the "land bridge" theory. Simply, this referred to the connection of the continents by extensive land, which was thought to be now underwater. However, many of the geologists felt this theory had serious problems. Imagine a little road connecting South America with Africa...how bizarre! Geologists started to visualize a moving continent or "continental drift" to account for this similarity. The continents must have been together once, but had moved apart. Paleontological evidence was convincing for those paleontologists and biologists who knew that fossils are very reliable evidence. Many geologists without this understanding of biological life, were still not convinced. They wanted more evidence.

STRUCTURAL DATA

As the world was being charted and mapped, the structural fit of many of the continents became obvious. As mountain ranges, active volcanoes, island arcs, and faults were mapped, a pattern started to emerge. Geologists noticed that certain areas on the earth have a higher concentration of these structures. Later, geologists realized that many of the structures outlined what is called the "plate boundaries."

The best method to introduce this material to your students is for them to plot volcanoes on a world map. Advanced students can take a state like California, Oregon, and Washington or countries like Chile, and try to find added information, like hot springs, parallel mountains, and valleys to find more evidence. Students can also look at detailed maps of Italy, the Middle East, East Africa, India, and China to find more structural evidence.

When discussing the structural data, volcanoes can be explained as mountains which are built by the accumulation of their own eruptive products - lava, bombs, and ash flows. There is a vent that connects the reservoirs of molten rock (magma) below the surface of the earth to the surface. Driven by buoyancy and pressure, the molten rock, which is lighter than the surrounding solid rock, forces its way upward and breaks through weak zones in the earth's crust. These zones of volcanoes define certain plate boundaries. However, not all volcanoes are on plate boundaries. For instance, the Hawaiian volcanoes do not define a plate boundary. There are a few theories about why this is so...but not one fits all the data.

GEOPHYSICAL DATA

Geophysical data is the evidence that confirmed plate tectonics as the probable cause of crustal movement to all those doubting geologists. There were many lines of evidence including magnetic anomalies, heat flow, seismic, and gravity. It is only through these investigations that a geologist can "see" inside the earth. Evidence from earthquakes record how energy passes through different substances, which is the cornerstone of present-day investigations. However, geophysical evidence is the most difficult to explain, because it involves high-level physics to really understand the principles. A teacher in the pre-college area, has to introduce the material in a simple, but logical manner as suggested below.

Earthquakes are generally thought to be caused by the fracturing of rock masses along faults and to be associated with sudden displacements along pre-existing faults. The point on the fault at which the displacement occurs is called the FOCUS OF THE EARTHQUAKE and the point on the surface of the earth above the focus is the EPICENTER. Your students must understand that earthquakes are part of the earth's lithosphere that has been stressed. This stress is stored until the actual break (the earthquake) releases the energy. This energy travels in the form of waves, which is what seismologists can record and study.

The waves generated by an earthquake can be recorded and measured on a seismogram. The interpretation of the waves and how they go through a different substances as they go through the earth, helps seismologists distinguish the different layers of the earth. Since we cannot drill very far into the crust, the evidence from different waves becomes important in interpreting the earth's structures.

There are many types of waves generated from earthquakes. The major types are P (push/pull; compression; primary) and S (shear; secondary). The simple facts are (1) P waves are faster than S waves; (2) S waves cannot travel through liquid; (3) P waves can travel through liquid and solid. These basic facts (plus many more) have helped seismologists to interpret the inner structure of the earth.

ACTIVITIES

The Plate Tectonic Cycle has a total of 72 activities centered around 4 hands-on labs per grade level with pre- and post material that reinforces the concepts of the lab. The time required to complete the materials is a minimum of 150 minutes per week. The entire school follows the same themes in order to coordinate materials more effectively. Individual activities are modified to a particular area to reflect the local geology. For instance, Los Angeles students use a fault map of Southern California and not one from the San Francisco Bay area. The main components of each of the units are explained in more detail below.

VOLCANOES

Children are fascinated with the spectacular volcanic eruptions that occur throughout the world. In geology, volcanoes are very important to help interpret what is going on inside the earth. Volcanoes have played an important part of the developing earth. As the new earth developed, volcanoes helped to create steam, which later became the major source of water on this planet. In the lower primary grades, recognizing the various shapes that volcanoes can take and that volcanoes produce igneous rocks should be emphasized. In the upper primary grades, learning where volcanoes are and plotting them on a map will help them to understand how volcanoes unravel clues about earth movements. Activities include discovering volcanic rocks; making shapes of volcanoes; and evaluating the different types of volcanoes around the world.

EARTHQUAKES

Understanding earthquakes teaches students about the inside of the earth and what causes movement on the outside of the earth. Students first have to understand what tensions occur in the earth. When the crust breaks, the energy is released in the form of waves. The transmission of these waves can cause minor to major damage to structures on the surface of the earth, depending on the intensity of the earthquake. Students will see where earthquakes occur on the earth; try to figure out why earthquakes happen; and relate earthquake occurrence with plate tectonics. Activities include making shake tables to visually see movement; making waves go through different substances; and using sticky glue balls to develop a relationship between stress and strain.

PLATE TECTONICS

Plate Tectonics is just a fancy name for explaining how and why the outer crust of the earth has moved through time. The continents that are recognized today have not always had their present shape nor been in their present location. They have shifted and moved since the inception of the continents. The Plate Tectonic units relate how earthquakes and volcanoes provide data to understand plate tectonics. Activities include making geographic puzzles, locating plate boundaries, and testing other theories of earth's movement.

HAZARDS

Natural disasters have occurred throughout time. Catastrophies caused by volcanoes and earthquakes can not only be spectacular, but devastating. This unit describes what hazards can be produced by volcanoes and earthquakes. Students will begin to learn that these hazards are natural. But if a student experiences such an event, they should be prepared to act sensibly. Students should also be acquainted with past damages to see that "mother nature" is a force that you cannot tame. Humans must understand volcanoes and earthquakes, in order to avoid the danger. Activities include simulating earthquakes on shake tables, learning to engineer structures to withstand earthquakes, and discovering damage caused by landsliding.

CONCLUSIONS

The Plate Tectonics Cycle is a unique subject to teach students, because it is important in understanding the Rock Cycle, Water Cycle, and Life Cycle. How can this be? If it wasn't for the moving of the crust, we wouldn't have a mechanism that would produe the three different types of rocks. Pressures caused by this movement creates metamorphic rocks. Volcanic eruptions along plate boundaries creates igneous rocks. The volcanoes over eons of time produced the chemical merger of hydrogen and oxygen inside the earth. Then, outgassing of volcanoes in the form of steam occurred, which gave us the vast amounts of water we presently have. Water not only sustains life, but the erosive powers of water on and through rocks and its ability to act as a solute, creates the majority of sedimentary rocks. The internal engine creates the magnetic field that surrounds our earth, which is needed for our existence on this planet.

So most people are in fear of the powers of earthquakes and volcanoes, but without them, humans would not be on this planet. Understanding the mechanisms of plate tectonics can alleviate that fear. The Plate Tectonics Cycle of the I. Science MATE program stresses the importance of the dangers and damage that are associated with volcanoes and earthquakes. Extensive damage is usually associated with poorly engineered centers of urbanization which in many cases could be avoided. The units in the elementary grades are a natural extension of the science content that precedes the units on hazards because it makes children understand the importance of it all.

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