

The Legends, Myths, and Science of Volcanoes

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INTRODUCTION

I like things that are awe-inspiring. Things that rumble, burst, and explode. I attribute this fact to the child in me. Therefore, I have chosen to write my unit on volcanoes. I like things that surface from deep invasive places where man cannot go. There is a bit of mystery about this natural phenomenon as if driven by some mystical force. Ancient cultures had beliefs that many natural processes and disasters were due to some human frailty or action that angered the gods. Volcanoes form from vents through which molten rock escapes to the earth's surface. The main theme of this unit will embrace the science behind volcanoes and will attempt to dispel myths about the causes of volcanic eruptions.

Students, being inhabitants of this great planet, benefit by knowing what impact volcanoes have upon society. Volcanic eruptions change the face of the earth and thus alter society in the process. Volcanic processes are both constructive and destructive. Many of our mountains, islands, and plains have been built by volcanic eruptions. Volcanoes can impact agriculture and even affect air travel. The solid earth surface undergoes changes as a result of volcano eruptions that cover the earth with lava flows, layers of thick ash, pyroclastic materials, and other volcanic fall-outs. Existing soils and vegetations are buried and atmospheric gases play havoc on animal and plant life as well as lower forms of life. Eventually, very rich soils are generated through chemical and physical processes. New vegetation will begin to grow, and animals will migrate back to the area. Man too will return to live again in the shadow of a sleeping giant. His inborn nature for risk-taking drives him to the geologic hazards that may one day claim his life.

Student Population

Not all children are taught in classrooms. I have spent much of my professional life working with homebound teenagers. Youngsters with medical conditions outlined by the Texas Education Agency are serviced or taught, one on one, in homes. This unit is aimed at that population. This population ranges from children with physical or mental challenges to children with great intellectual abilities. The Appraisal Review Dismissal (ARD) Committee of Community Services High School places these students on Homebound for a period of at least four weeks depending upon the medical request. Because of this time frame, my students are usually taught on short term-basis and enter and withdraw from my curriculum throughout the year. Students come to the Homebound Program at various degrees of readiness for learning. This unit is driven by time, district objectives, and the unique nature of the students. It is designed to cover six weeks and may be adjusted to meet the need of the individual student. This six-week unit is developed mainly for high school students enrolled in environmental and earth science classes and for those studying landforms and maps in geography. This curriculum unit may be adapted for use at lower grade levels.

Teaching Strategies

Students have little knowledge about the science of natural occurrences in the world in which they live and function. They experience big storms, coastal flooding, and seasonal hurricanes.

They observe the blackened skies and heed the warnings of impending tornadoes. For those students living in earthquake zones, they are able to identify with those menacing tremors and to understand the danger they impose. The knowledge of volcanoes is even more limited, especially amongst the students living along the Gulf Coast. The science classes that are offered on the high school level are designed more toward the life and physical sciences and do not tend to build objectives relating to the geological aspects. Better teacher training is needed to insure growth in learning major concepts in the earth and space sciences. Flaws in scientific thinking amongst our students must be corrected. Students have many misconceptions about the science and nature of natural geologic happenings. For example, students may define a volcano as a vent through which lava escapes to the earth surface. That sounds like a fairly acceptable definition. But, volcanoes are landforms formed from vents through which molten rocks reached the surface of the earth. There are many geologic processes that change the face of the Earth, but volcanoes, for many people, are the most awesome. Ancient myths and legends support this pre-occupation with volcanoes. Volcanic eruptions destroy and build in the same instant of time.

I will show the video titled: *Ancient Civilization for Children*. It contains myths and legends dealing with Atlantis and Thera. The ancient history of the Minoan and the Mycenaean civilizations, two remarkable cultures off the Aegean Sea some 3500 years ago, are explored. The students will discuss the video along with the teacher. Do they see any truth or value in these myths and legends? Students will then summarize the discussion in a brief essay. They will be encouraged to include maps of the region showing where these two cultures once existed. Students will read further accounts of myths and legends that relate to volcanic eruptions such as Kilauea and those in the Iceland volcanic zones. All assignments on this topic will be kept in the students' notebooks in the section titled Myths and Legends.

This unit covers science that deals with the nature of volcanoes and the hazards and risks of living in the shadows of their eruptions. At the beginning of the unit, I will assess what students know about volcanoes and volcanism and how well they are able to support their convictions. Vocabulary will be introduced at the onset of the unit and will be developed throughout the six-week period. When possible, pictures, sketches and drawings of the words will be illustrated to convey their meanings and usages. A vocabulary bibliography will be maintained in the science notebook. The science notebook will be divided into sections corresponding to the topics of the unit: Origin of the Earth, Myths and Legends, Effects of Volcanoes, Types of Volcanoes, Case Studies, Activities, Vocabulary, Bibliography and the Appendix.

After many years of teaching, I am still learning science, good science, the way science should be taught and learned. After taking this science seminar, I am committed to teach scientific concepts more rigorous and accurately. I will have students research and gather scientific facts and data on the interrelationships amongst earthquakes, volcanoes and tsunamis. The research will be integrated throughout the curriculum unit as the topics are presented. Volcanoes, earthquakes, and tsunamis are closely related. Students will also view videos and the CD listed in the Bibliography. The videos are excellent visuals and tools for introducing science concepts that are often difficult to understand. My students will use the part dealing with volcanoes from Dr. William Dupré's CD, designed for the fellows of the 2005 Living with Geological Hazards Seminar at University of Houston Teachers Institute. The Plate Tectonics Theory is well illustrated in most of the videos and CD. Students will complete activities on plate tectonics after studying this topic. Student activities will involve several types of projects. One of the activities is to model plate tectonics to show earth movement that lead to earthquakes and volcanoes.

After studying the three main volcanic landforms (shield, cinder cone, composite cone), students will compare and contrast examples of these types of volcanoes. A matching activity on volcanic sizes, locations, and types will be developed and administered to the students.

Distribution maps of active volcanoes will be used to show where people are living with the greatest risk. I will have students locate interactive- activities involving maps of volcanoes on web sites. Using such maps, students will be able to identify the volcanoes that are a part of the 'Ring of Fire' volcanoes and those that are part of the Iceland's 'Born of Fire' chain. We will discuss the origin of these groups of volcanoes. The students will show a correlation between earthquake zones and volcano zones. The culminating assessment will be the building of an active volcano model that will erupt (Lesson 3, Activity 1).

In the section on "Hazards and Lesson Learned," students will look at several videos found in the Bibliography and Dr. Dupré's CD to assess the hazards and lessons learned when volcanoes erupt. I will model a case study for them using information from the visuals. Since Mt. Vesuvius is one of the most talked about volcanoes, I will target it for our first case study. Mount St. Helens eruption of 1980 was daunting. I think students will enjoy studying this recent eruption. In addition, it is part of the Cascade Range here in our own country. Afterwards, students will conduct their own research on two volcanic eruptions from different geographical areas, geologic origins, and geological time periods to answer such question as: What is the geological control? Was this an active volcano? What triggered the eruption? What hazards were involved? What damage was done? What did the people learn from the eruption? What types of volcanoes are more lives lost? Why? The students will culminate this section by preparing and presenting a PowerPoint presentation.

BACKGROUND

Myths and Legends

Scientist's knowledge of the understanding of volcanoes had its birth in myths and faulty beliefs. Zeilinga de Boer and Sanders explain that "well into the European middle ages, many people thought of volcanoes with their fiery summits and unearthly roarings, as entrances to the underworld, the hellish world of suffering sinners" (de Boer and Sanders 2). *The Divine Comedy* by Dante Alighieri is an allegory that shows a similar parallel between hell, the dwelling place of the devil, with its high leaping flames and the burning inferno of a volcano belching from the core of the earth (de Boer and Sanders 2).

The association of evil, punishment and suffering can be seen in the explanations offered by early Hawaiian settlers in their explanations of Kilauea. They believed that Pélé, the goddess of fire, was the cause of the violent volcanic eruptions. Many myths came from the belief that Pélé was irritable and could appear as either a beautiful maiden or an ugly old woman. When angered, she would stump her feet (earthquake) or hurl fiery boulders (volcanic bombs) at the offenders, or she would send streams of molten lava that spewed from tops of mountains destroying everything in their paths. The only hope the people had lay within the powers of Pélé's sister Nawaka Okahai, the goddess of the sea, who could put out the fires started by Pélé and who could erode the land created by Pélé's cooled hardened lava (de Boer and Sanders 22).

In Christina Blait's *Atlantis-The Legend of a Lost City*, the myth of what happened to Atlantis is depicted in this version below:

Floating on the emerald sea is a small rocky island belonging to the mighty sea-god Poseidon. Few visit its shores until Poseidon marries a beautiful islander called Cleito and transforms the island into a rich and fertile paradise, where all things flourish and a magnificent city arises. Poseidon names his perfect island Atlantis, after his first borne son, Atlas. Atlantis prospers, and the people live in peace, but as the years pass, Poseidon's descendants start to act less like gods and more like men. Raising his trident, he stirred the seas into a wave that lashed the heavens. In a single day and night, Atlantis was swallowed up by the sea. The people of Atlantis did not die. They continued to exist

beneath the waves, but they never spoke or quarreled or fought again. To this day, Atlantis has never been found. (Blait's, unnumbered pages)

Blait's account of Atlantis is based on Plato's *Timaeus and Critias*. Also included in this story is a note by historian Geoffrey Ashe on the location of Atlantis. He offers several legends that attempt to answer the question: where was Atlantis and what happened to its people? Ashe's account follows:

People have suggested many different places where Atlantis might once have been. The oldest Greek legends describe Atlantis as being out to the west, in the middle of the ocean-the ocean that is still named the Atlantic, after Cleito's son. The people of Atlantis are said to have spread to other countries, founding settlements in Europe and Africa, and even in a land we now call America.

Some think Atlantis existed more or less as Plato described it, and that its people left traces behind them. Egypt has pyramids, Mexico has pyramids, so perhaps the Atlantean settler built them in both places and their submerged homeland was midway between the two countries.

Others suggest that Atlantis was closer to America. The native inhabitants of the West Indies told early explorers that their islands were once part of a single landmass but that a disaster long ago shattered it. The fifth-century Greek philosopher Proclus, who wanted to convince his readers that Atlantis was real, writes, very mysteriously, as if he knew of the West Indies and their story.

Some people suggest that Atlantis was a part of Britain. Legend tells of a sunken land between Cornwall and the Isles of Scilly.

The theory taken most seriously is that the story is actually about the island of Crete, which was highly civilized and ruled over several smaller islands. One of them, Thera, was partially destroyed in about 1450 B.C.E. by a tremendous eruption, which also destroyed part of Crete, and its civilization never recovered. With so much uncertainty, some argue that the story of Atlantis is not history at all but a myth warning us against conflict and power seeking. Yet the legend is so vivid that many will always believe Atlantis existed somewhere. (Blait, pages unnumbered)

There are many interesting myths and legends that tell the stories of volcanoes and their effects upon the human race. This unit has included a few of them. Students will learn the difference between a myth and a legend. Myths always include some mystical beings with supernatural powers or abilities such as gods or goddesses. Students will reflect on English stories involving myths and draw similarities between them and the ones in this unit. I will guide the students through the lessons outlined in the Teaching Strategies Section of this unit that is related to this topic.

Origin and Age of Planet Earth

Our Earth, our world, is the third planet in the Solar System. Scientists have found that the earth is divided into a solid inner core (700 miles thick) and an outer liquid core (1360 miles thick) at its center. The core is overlain by another layer of less dense material called the mantle (1800 miles thick). A thin crust (measuring between 3 and 43 miles) overlays the mantle (Rogers and others 180). This is the part upon which man lives. A good example to model this concept is an apple. De Boer and Sanders say that if an apple is sliced into two, the cross section reveals a small, circular "core" (where the seeds are), a thick "mantle" (the edible flesh), and a "crust" (the very thin skin). Those parts of the apple are relatively proportional to the main parts of the earth. I will have students illustrate the parts of the earth by using a peach or an egg as the physical

model, which shows a more accurate correlation. Students will locate and place a copy of a labeled diagram of the earth's structure in their cumulative science notebook.

Two major heat machines, one externally driven and the other internally driven, control Earth's processes. The sun drives the external heat machine. It drives the movement of the atmosphere and the hydrosphere, and in doing so, sculpts the surface of the earth. The heat derived from the sun largely determines the weather and climate of our planet. Hurricanes, tornadoes, and floods, as well as the circulation of the ocean and erosion of the land, all are affected by the sun's energy. The other heating machine is found deep inside the interior of the earth. This internal heating machine gives rise to energy that produces volcanoes, earthquakes, and tsunamis. Man lives on Earth, the sphere where the two energy-producing systems collide.

The internal heat machine, which is the focus of this unit, is found deep inside the interior of the earth. This internal furnace was formed at the heart of the planet some 4.6 billion years ago and is still operable today. The internal energy comes from a combination of the residual heat when the Earth was first formed, and radioactive decay that continues to the present. Scientists use a technique known as radiometric dating to date the age of planets by analyzing samples of radioactive rocks and minerals. Radiometric dating works because the rates of radioactive decay of many elements are known constants. The rate of radioactive decay is best described using the concept of radioactive **half-life**. The half-life of an element is the time it takes for one-half of the unstable ("parent") atoms decay to stable ("daughter") atoms. For example, the unstable Uranium 238 element has a half-life of approximately 4.5 billion years. Thus, the number of stable daughter atoms increases proportionally as the parent isotope atoms decay. By measuring the ratio of parent to daughter elements, and knowing the half-life of the elements in question, we can determine the absolute age of the rocks in which these unstable isotopes were formed. Radiometric dating is the main method by which we can determine the absolute age of rocks and the events recorded in those rocks (e.g. evolution of life, volcanic eruptions, etc.) (Poort and Carlson 32).

Radiometric dating is based on nuclear decay of naturally occurring radioactive isotopes, such as Uranium, Potassium, Rubidium and Thorium, and is applicable to all methods of age determination involving radioactive decay (Poort and Carlson 32). Radioactive decay is the spontaneous disintegration of the atoms of certain isotopes into new isotopes until a stable isotope is reached. Certain types of particles are always emitted when an isotopic atom disintegrates. Alpha Particles, Beta Particles, and Gamma Rays are generated during radioactive decay. Heat is always a by-product of radioactive decay, thus continually adding fuel to the Earth's internal heat machine.

The three main ways in which radioactive decay occurs: alpha decay, beta decay, and electron capture (Poort and Carlson 32). Alpha decay occurs when the nucleus of an atom emits an alpha particle, which is composed of two protons and two neutrons. This loss reduces the atomic mass of the atom (the sum of protons and neutrons) by four and the atomic number (the number of protons) by two. A new element is formed when the atomic number is changed. For example, in the Uranium decay series, the parent isotope Uranium-238 decays to the daughter isotope Thorium-234. The reduction of the atomic mass by four indicates process of alpha decay. Beta decay occurs when a neutron is converted to a proton and an electron. The high-energy electron leaves the nucleus as a beta particle. The mass remains the same but the atomic number is increased by one, thereby changing the element. Such is the case in the decay of Rubidium-87 to Strontium-87. In electron capture, an electron from outside the atom merges with a proton in the nucleus to form a neutron. In this case, a proton is replaced by a neutron, keeping the atomic mass the same but decreasing the atomic number by one. Potassium-40 decays to Argon-40 via electron capture, as the atomic number is reduced by one, however the atomic mass remains the same.

The rate of radioactive decay is constant and can be determined from laboratory tests and the use of decay curves. The decay rate is expressed in terms of a length of time called the “half-life.” Poort and Carlson define a half-life as the amount of time necessary for half of the original parent atoms to decay to daughter atoms. After one half-life, one half of the original material has converted to daughter products and the other half remains as the original parent isotope (32). After the second half-life, one fourth of the original parent isotope remains. At this time in the teaching of the curriculum unit, I will have the students design a decay curve showing the half-life progression for radioactive isotopes such as U-235, U-238, Potassium-40, and Carbon-14 (Lesson 1, Activity 1). Students will discuss which isotopes are more useful for dating certain ages of rocks and events that have occurred during the last 40,000 years. The purpose of this assignment is to have students realize that radioactive isotopes with different half-lives must be used to date different time intervals. For example, to date the age of the Earth, one must use an isotope with a long half-life (e.g. U-238, with a half-life of ~ 4.5 billion years, or Potassium with a half-life of 1.3 billion years). On the other extreme, Carbon-14 has a half-life of 5730 years, thus is useful in dating events occurring recently in earth’s history (e.g. in the past 70,000 years or so).

The relationship between lapsed time and the radioactive decay of an isotope is expressed by the mathematical formula:

$$N = N_0 e^{-\lambda t}$$

N = number of atoms

N₀ = original number of atoms of the isotope

e = mathematical constant 2.718

λ = decay constant

The relationship of the half-life of an isotope and the decay constant is expressed by the following expression:

$$\lambda = \ln 2 / t_{1/2} = 0.693 / t_{1/2}$$

t_{1/2} = the half-life

λ = decay constant

t = age of the rock.

To calculate the age of a rock, the following formula is used:

$$t = (\ln N_0 / N) / \lambda \quad (\text{Equations from Poort and Carlson 32})$$

At this point in the unit, I will include exercises that require students to calculate the ages of rocks (Lesson 1 Activity 3). Students may be given tagged rock samples containing descriptive data useful for calculating the ages of the rock samples. For example, I will give the student a “faux rock” sample containing both a parent-isotope X and its daughter-isotope Y. The parent X will be assumed to have a half-life of 80 million years. The students have a copy of the rock analysis from the Universal Geochronology Laboratory showing the following results: one-fourth of the total is parent X and three-fourth of the sample is daughter Y. The students will find the age of the rock whose half-life is 80 million years. The number of elapsed half-lives may be found by using a decay curve or the accompanying exponential chart (Lesson 1 Activity 2). We are given that ¼ of the original atoms remain. The chart in Activity 2 indicates that a ¼ of the original isotope atoms corresponds to an exponent of 2. Therefore, two half-lives have elapsed since the rock was formed (actually since the unstable isotope was incorporated into a mineral within the rock). The age of the rock may be found by multiplying 2 half-lives x 80 million years. Thus the age of this rock sample is 160 million years. Students may now complete the lesson on How Old Is That Rock?

Volcanic Landforms

Different geological processes produce different kinds of landforms. Eruptions through central vents produce common landforms known as volcanoes. Some of the more familiar volcanic landforms include: Shield Volcanoes, Composite Volcanoes, Cinder Cones, Lava Domes, and Calderas (figures 1-5).



Figure 1: Mauna Loa Shield Volcano (USGS photo by D. Little, date unknown)

Shield volcanoes are usually huge. Some are as large as 190 km wide. They are formed mainly of basaltic lavas. They have long duration of activity, ten thousands of years. They have gentle sloping sides of 2 to 10 degrees and usually erupt non-violently. Shield volcanoes are typical of volcanoes found in Hawaii, (e.g., Mauna Kea and Mauna Loa).



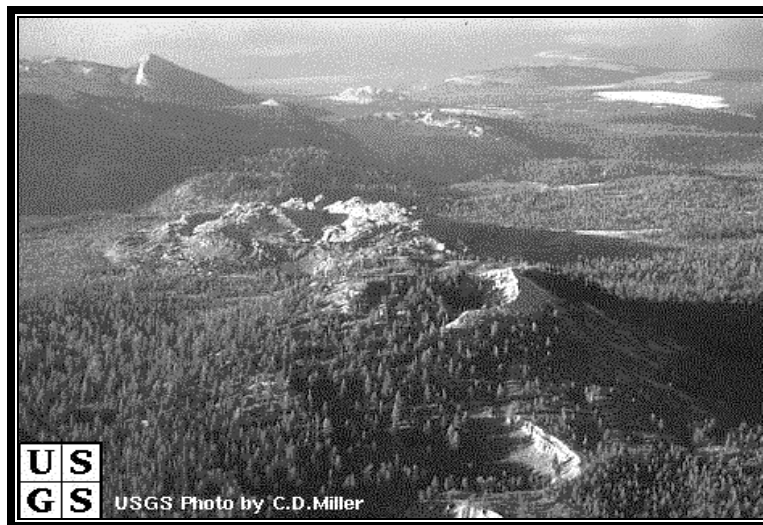
Figure 2: Cinder Cone on flank of Mauna Kea Shield Volcano (USGS: photo by J.P. Lockwood, 1975)

Cinder Cones are relatively small, about a km in width and have steep sides up to 30 degrees. They are short-lived - usually formed in a single event. Examples can be found in Capulin Crater and Sunset Crater National Monuments.



Figure 3: Composite Volcanoes, Lake Atitlan, Guatemala (photo by W. R. Dupré, 1969)

Composite Volcanoes are the most recognized type of volcano. They are made mainly of layers of alternating pyroclastic deposits and andesitic lava flows. They slope intermediate in steepness and are quite large 10 to 15 km wide. Composite volcanoes are highly explosive and have intermittent eruptions over a long time span, thousands of years. Examples in the Cascade Range: Mount St. Helens, Mount Rainer, and Mount Shasta.



*Figure 4: Lava domes – Inyo Crater Chain, CA
(USGS/Cascades Volcano Observatory: photo by C.D. Miller, 1984)*

Lava domes are associated with violent eruptions. They are small, steep-sided and are hundreds of meters wide. They are formed from viscous felsic lavas. Examples in California include Mono Craters and Inyo Crater Chain.



Figure 5: Aniakchak Caldera, Alaska (National Park Service photo by M. Williams, 1977)

Calderas are produced when volcanoes collapse into partially drained magma chambers, e.g. Crater Lake in Oregon, Aniakchak Caldera in Alaska, and Valles Caldera in New Mexico. They are steep-walled depressions and may have younger domes within them. They can be several kilometers wide.

Other volcanic landforms such as craters, volcanic pipes, and necks will be discussed during class lectures.

The Effects of Volcanoes

Tarbuck and Lutgens state that when a volcano erupts, lava from the earth's interior may flow out at the surface and form large landforms. The lava may block nearby valleys affecting the regions drainage system by creating a lake or causing streams to change course. The atmosphere may also be impacted by the large quantities of volcanic ash and gases emitted during an eruption that are blown high into the atmosphere and carried miles away. The amount of solar energy that can reach the earth's surface may be reduced causing a drop in the temperature throughout the globe.

Climatic variability can sometimes be related to the explosive volcanic eruptions that eject huge quantities of gases and fine-grained debris into the atmosphere. These air-borne suspensions rise high into the stratosphere spreading around the globe, often lingering for months. The sulfuric and droplets found in the volcanic emissions filter some of the sun's radiations, which in turn lowers the temperatures world wide.

The 1815 eruption of Mount Tambora in Indonesia produced a cooling effect that was felt around the world. The unusual cold spring and summer of 1816 became known as the "year without a summer" in parts of the northern hemisphere including England (de Boer and Sanders 153). I will have students research the volcano-climate connection by looking at the temperature changes during the eruptions of volcanoes such as United States' Mount St. Helens (1980), the Philippines' Mount Pinatubo (1991), and Indonesia's Krakatau (1883).

The surface of planet earth interacts constantly with the hydrosphere, the atmosphere and the biosphere. The solid earth and these three spheres form an interrelated system known as the Earth System. In the study of volcanoes, a change in one part of the system can have far reaching effect in any part or in the entire system.

The solid earth surface undergoes changes as a result of volcano eruptions. The eruptions leave the Earth's surface covered by lava flows, layers of thick ash, and other pyroclastic

material. Existing soils and vegetations (and sometimes, whole cities) are buried. New vegetation will begin to grow, however, and the volcanic rocks and soils will eventually alter to very rich soil through the processes of chemical and physical weathering.

The biosphere will also experience significant changes. Some organisms and their habitats would be destroyed by the lava and ash. Volcanoes can affect climate by dropping temperatures and blocking radiation from the sun for sustained periods of time. These climate changes can affect sensitive life forms. Millions of trees and animals were destroyed in the May 1980 eruption of Mount St. Helens alone. Now the area is replenished with new soil, new vegetation and other life have returned to the area. The creations of lakes also provide opportunities for new life.

Continental Drift to Sea-floor Spreading

One of the earliest attempts to explain formations of large-scale landforms was introduced by Alfred Wegener in the early 1900's, when he introduced his *Theory of Continental Drift*. He proposed that a super continent called Pangaea began breaking into smaller continents about 200 million years ago. These smaller continent fragments then drifted to their present positions. Certain kinds of evidence were used to prove this chain of reasoning. Among them were the "fit of South America and Africa, fossil evidence, rock types and structures, and ancient climates" (Tarbuck and Lutgens 507). However, the continental drift hypothesis failed to provide an acceptable mechanism for the movement of continents.

Harry Hess in 1962 formulated the idea of seafloor spreading, which states that new seafloor is being generated at the mid-oceanic ridges and old, dense seafloor is being consumed at the deep ocean trenches. Hess's sea-floor spreading idea was widely accepted "with the discovery of alternating stripes of high-and-low-intensity magnetism that parallel the ridge crests" (Tarbuck and Lutgens 507).

By the 1960's, Hess's Sea Floor Spreading and Wegner's Continental Drift had merged and evolved to form the *Theory of Plate Tectonics*, which remains the "Ruling Paradigm" of the Earth Sciences to the present.

Students will be encouraged to research Pangaea over the 200 million years period addressed by Wegener. They will be asked to download pictures from the Internet to enhance their findings. In addition, they will show what the world may look like 50 million years from now using their research findings on the break-up of Pangaea.

Plate Tectonics

The formation of large-scale landforms, including the distribution of volcanoes, can best be explained by the use of plate tectonics. Plate tectonics theorize that segments of the earth's lithosphere called tectonic plates, move about, giving rise to earthquakes and volcanic activity, usually at the boundaries between adjacent plates. For example, the North American and Eurasian plates (figure 6) are separating along the Mid-Atlantic ridge about two centimeters a year (de Boer and Sanders109).

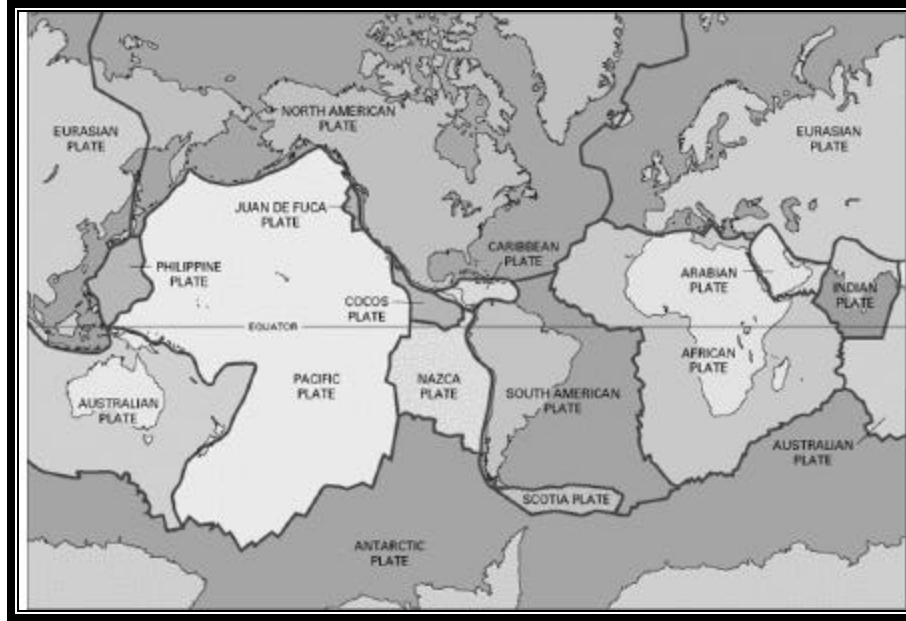


Figure 6: Major lithospheric plates of the world (USGS:< <http://pubs.usgs.gov/publications/text/slabs.html>>)

The Plate Tectonics Theory was firmly established by 1968. Three seismologists published papers showing how successful the plate tectonics theory explains the distribution of earthquakes (Tarbuck and Lutgens 497). The theory also explained the distribution of most volcanoes!

The plate tectonics theory describes plate motion and the effects of this motion. Heat from the interior of the earth sets large-scale convection currents in motion within the mantle (part of the earth's internal heat machine). These convecting currents within the mantle drive the lithosphere plates. Plates move as coherent units relative to all other plates along boundaries. There are three distinct types of plate boundaries based on the relative motion between plates. (Tarbuck and Lutgens) At **divergent** plate boundaries, plates move apart resulting in upwelling of material from the mantle to create new seafloor. At **convergent** plate boundaries, plates move together in the subduction of oceanic lithosphere into the mantle. At **transform** plate boundaries, plates grind past each other without the production or destruction of lithosphere (Tarbuck and Lutgens 483).

Most divergent boundaries are located along the crests of oceanic ridges, such as the Mid-Atlantic Ridge. Some, however, occur where continental crust is being split apart, such as the Red Sea, where the Arabian Peninsula separated from Africa, and the Gulf of California, where the Baja Peninsula is pulling apart from the rest of Mexico. Volcanoes formed along divergent plate margins (e.g. Iceland, Mt Kilimanjaro, Africa) are typically shield volcanoes. Convergent zones can form between two oceanic plates (e.g. the mid-Atlantic Ridge), between an oceanic and a continental plate (e.g. along the western margin of South America), or between two continental plates (e.g. the Himalayan mountains). Convergent boundaries zones are capable of producing the strongest earthquakes in the world. They are also the sites of the most destructive volcanic eruptions in the world, associated with the growth of composite volcanoes. Interestingly, no volcanic activity occurs along transform plate boundaries!

I plan to show several videos from the Bibliography that will convey the concepts of volcanic formation and volcanism. I will use Dr. William Dupré's CD on volcanoes and other geological features to help explain plate tectonics and how they relate to the formation of earthquakes, volcanoes, and tsunami's during the lectures. After students have worked through this section on plate tectonics, Lesson 4 (Plate Tectonics) will be assigned.

Case Studies: Hazards and Lesson Learned

I will have my students research several of the major volcanoes using Internet services to identify the hazards and lessons learned. They will present a power point presentation on the two volcanoes of their choice. I like to give student choices when possible because they tend to take more ownership of that kind of an assignment.

More than 3000 eruptions have been recorded during the last three hundred years. Most volcanoes have low VEI (Volcanic Explosivity Index) similar in principle to the Richter scale for measuring earthquake magnitudes. Each VEI category is ten times greater in explosivity or explosive power than the next lower category (de Boer and Sanders 15). Most eruptions like those in Hawaii have VEI's of 0 to 1 and ooze lava with little or no violent activities, however those with VEI's of 2 to 5 have explosive eruptions. The most powerful eruptions are ranked with VEI's of 6 or above like those of Bronze Age Thera in the eastern Mediterranean and Indonesia's Tambora (VEI of 7) and Toba (VEI of 8). The VEI is based on the volume of explosion products and the heights of the eruption cloud. Fortunate for man, low-VEI eruptions occur more frequently than high-VEI eruptions. Volcanoes have memories and can remember when they last erupted. Volcanoes with VEI's between 0 and 3 erupt somewhere on Earth every few years, whereas volcanic events greater than 6 occur at intervals of up to thousands of years (de Boer and Sanders 15-17).

There are numerous hazards associated with volcanic eruptions. Lives lost, property damaged, crops destroyed, rivers and lakes blocked or rechanneled are some of the most common ones. These case studies will look at the hazards and lessons learned in some of the most deadliest and costly volcanoes.

1815	Indonesia	~92,000 killed
1822	Indonesia	5,500 killed
1826	Indonesia	3,000 killed
1883	Indonesia	36,417 killed
1902	Martinique	29,025 killed
1902	Guatemala	6,000 killed
1919	Indonesia	5,110 killed
1951	New Guinea	2,942 killed
1982	Mexico	1,700 killed
1985	Columbia	23,000 killed

Table 1: Lives lost due to historical volcanic eruptions (compiled by W.R. Dupré)

The eruption of Thera (VEI 6) of Greece in 1620 BCE, created a huge caldera that filled with seawater resulting in tsunamis that surged across the region in all directions resulting in the demise of Thera (Atlantis), Minoan Crete, and global cooling. The lesson learned: There was no historical record of one of the greatest geological disaster to befall humankind. However, it can be inferred that the lesson learned is: do not build villages on an active volcano. The risks are too great, in spite of the lack of human remains found in the archeological surveys of Thera (de Boer and Sanders 49).

The eruptions of Mount Vesuvius in 79 C.E. in southern Italy literally buried Pompeii and Herculaneum. The eruptions killed thousands of people, devastated the surrounding countryside, and destroyed six other towns. Vesuvius is the most widely known volcano on earth, as well as the best studied. Vesuvius left a cultural and historical legacy that has resonated through western civilization for almost 2000 years. Lesson learned: The Vesuvius eruption gave birth to the science of volcanology and advanced the science of archaeology (de Boer and Sanders 74).

Iceland is among the world's most active volcanic areas, located some 370 kilometers east of Greenland astride the Mid-Atlantic Ridge. There have been more than 150 eruptions both from volcanic mountains and fissures. Iceland eruptions tend to be relatively explosive because their magma is more viscous (less fluid-like). There have been twenty-seven eruptions with VEIs of 4 to 5 since the country was settled. Iceland's population and culture have been greatly affected by their large eruptions (de Boer and Sanders 107).

The Laki fissure zone eruption of 1783-1784 is typical of volcanism in Iceland. The Laki eruption began on June 8, 1783, and lasted for eight months. Large quantities of gases, some poisonous, were released into the atmosphere reaching heights of 12,000 to 13,000 meters. These gases were wind blown by atmospheric turbulence created by heat differential between hot volcanic gases and ice from Vatnajökull. The amount of sunlight was reduced, causing a severe winter in Iceland during the years of 1783 and 1784. Harbors remained frozen for a longer period of time, preventing fishermen from going out sea. The cold temperatures affected the seawater temperatures, limiting the cod population. Forage for cattle was greatly reduced. The gases, which contained sulfur dioxide, carbon dioxide, hydrogen chloride, and fluorine, created a calamity in Iceland. The sulfur dioxide combined with atmospheric vapor to form about 150 million tons of sulfuric-acid aerosols that increased the acidity of the land, stunting the grasses used for livestock feed. Fluorine poisoned the water streams and a blue haze of noxious gases filled the lowlands where livestock grazed. Half of Iceland's cattle and three-fourth of the sheep and horses died. More than a fourth of Iceland's 50,000 inhabitants died (de Boer and Sanders 120-129). Lesson learned: Documented recognition that volcanic activity can be hazardous at many scales, from the local to worldwide.

Another well-known eruption occurred on the island of Tambora. The eruption of Indonesia's Tambora in 1815 (VEI-7) produced weather conditions resulting in the year without a summer. Crops failed and more than a 100,000 people died of famine or typhus epidemic (de Boer and Sanders 151).

Our very own Mt. Saint Helens (VEI-5) in the state of Washington erupted May 18, 1980, blasting the top 400 meters of the mountain. Mt. Saint Helens is one of the fifteen volcanoes in the Cascade Range where the Juan de Fuca plate is subsiding beneath North America. Volcanic ash, steam, pyroclastic flows, and mudflows devastated the area. Many animals, plants, and vegetation were killed. Millions of trees felled like matchsticks. Fortunately, only sixty-one people lost their lives (de Boer and Sanders 229). Lessons learned: Communication and cooperation between local civil authorities and volcanologists, monitoring the volcano, saved lives. Volcanologists recommended access restriction of the area, and local officials kept the people out of the area. Rescue and evaluation plans proved invaluable, and in the end, many lives were saved.

Volcano	Location	Year	Intensity	VEI
Toba	Indonesia	c. 74,000 B.P.	Humongous	8
Tambora	Indonesia	1815	Colossal	7
Vesuvius	Italy	79	Huge	6
Thera	Greece	c. 1620 B.C.E.	Huge	6
Krakatau	Indonesia	1883	Huge	6
Mount St. Helens	United States	1980	Very Large	5
Kilauea	Hawaii	c. 1970	Large	4
Laki/Grimsvötn	Iceland	1783	Large	4
Pelée	Martinique	1902	Large	4
Surtsey	Iceland	1963	Moderate	3
Eldfell	Iceland	1973	Moderate	3
Tristan da Cunha	Tristan da Cunha	1961	Moderate	2

Table 2: The major eruptions discussed in order of decreasing VEI

B.C.E. means “before the common era”; B.P. means “before the present.” The terms used to describe intensity are those employed by volcanologists. VEI stands for volcanic explosivity index. Modified after de Boer and Sanders (17).

LESSON PLANS

This section includes lesson plans for the curriculum. Additional activities are integrated throughout the teaching unit and may not be found in this section. In the first lesson, students will have been introduced to graphing exponential functions using graphing calculators in their mathematics classes. I will review those skills again. The half-life of radioactive substances is a concept tested on the TAKS (Texas Assessment of Knowledge and Skills). The term will be defined as exponents are reviewed. All assignments are kept in the individual notebooks as discussed in the strategies.

Lesson 1: Radiometric Dating

Activity 1: Half-Lives: Fingerprints of Radioactive Isotopes

Objectives

- To identify half-lives of certain radioactive isotopes
- To draw and use Decay Curves
- To use half-lives in dating rocks

Vocabulary

Radiometric dating, radioactive decay, half-life, alpha particles, beta particles, gamma rays, exponential function, isotope, atomic mass, atomic number.

Materials

Paper, pen, graph paper, graphing calculator, and a reference source of radioactive isotopes.

Procedures

The students will make a list of five radioactive isotopes. They will trace the decay process of the parent isotope to the stable daughter isotope. I will guide the students through this part of the degeneration of the parent isotope. Each student will complete the chart for this activity and design a decay curve for the isotopes.

Activity 1A: Radioactive Isotopes

Name of Radioactive Isotope	Half-Life (years)
1)	
2)	
3)	
4)	
5)	

Activity 1B: Decay Curve

Plot a decay curve for one of the isotopes through four half-lives. Plot (in fractions) the remaining of the Parent Isotope along the y-axis and the time (half-lives) elapsed along the x-axis. Label the graph appropriately and place it in your science notebook. What would the graphs for the remaining samples look like if plotted? Justify your answer.

Activity 2: One-half to the Power of “n”

Procedure: Two to the power of n shows growth of a function exponentially. For example, $2^5 = 2 \cdot 2 \cdot 2 \cdot 2 \cdot 2 = 32$. Likewise, the inverse of $2^n = (1/2)^n$ or $(1/2)^n$ shows decay exponentially. Whereas, $(1/2)^5 = 1/2 \cdot 1/2 \cdot 1/2 \cdot 1/2 \cdot 1/2 = 1/32$. The exponent in this case represents the number of half-lives in the decay process of the original parent isotope. A student can readily infer that the number of half-lives elapsed for this sample is 5 and that only $1/32$ of the original amount remains to decay. Each student should complete the chart titled *One-half to the power of “y”* through the seventh generation. Afterwards, students will calculate the “faux” rock sample problems found in Lesson 1: Activity 3.

Elapsed Time Power of “y”	Half-life Exponent (1/2) ^y	Fractional Amount of Parent isotope remaining	Quantity Remaining Carbon 14 = 5730
0	(1/2) ⁰	1	5730 years
1	(1/2) ¹	1/2	2865 years
2			

Question: Will the sample of Carbon 14 ever be completely decayed? Explain your answer. (Consider an exponential function as part of your explanation).

Activity 3: How Old Is That Rock?

1. Parent isotope X has a half-life of 100 millions. A rock sample has 1/8 isotope X and 7/8 daughter isotope Y. What is the age of *that rock*? (Show work)
2. Parent isotope A has a half-life of 700 million years. A rock sample has 1/16 parent A and 15/16 daughter isotope B. What is the age of *that rock*? (Show work)
3. A rock contains 50% parent isotope X and 50% daughter isotope Y. The age of this rock has been determined to be 400 millions years old. What is the half-life of *that rock*? (Show work).

- Using one of your decay curves from Lesson 1- Activity 1, determine the percent of daughter, isotope Y, that is present in a rock that is 178 million years old. (Hint, the exponent for the elapsed half-life of the parent, isotope X, at this time is 2. Show work.)

Lesson 2: Topographical Maps and Aerial Photographs -What Do They Tell Us About Volcanoes?

Student will build a landscape by creating topographic maps of areas where volcanoes are located. This active art activity will permit student to draw topographic maps that will draw the elevation, relief and shape of surface features as seen from above. On topographical maps, a contour line connects points of equal elevation. The change in elevation from contour line to contour line is called the contour interval. The contour interval for a given map is always the same. Most international topographic maps give contour intervals in meters. Some of the United States maps are still given in feet. For example, using a United States map with a contour interval of 100 feet, one will find that a change of five contour lines on the map corresponds to a direct change of 500 feet in elevation. Slopes can be easily compared using contour maps. Using information from topographic maps can provide information about the landscape that photographs cannot convey. Street, vegetation, and landforms can be depicted on contour maps. These maps are useful in explaining photographs taken of areas affected by volcanoes that have erupted.

Objectives

- To learn vocabulary associated with Volcanoes.
- To identify features of volcanic landforms represented by various colors on the map.
- To observe patterns and mapping of the region
- To analyze and synthesize data.
- To read topographic maps with color-coded images.

Vocabulary

Topographic map, crater, lava, volcano, magma, ash, fault, slope, contour lines, basins, calderas.

Materials

Topographic map with color-coded images, color-aerial photographs of volcanoes, highlighter, pen and paper

Procedure

Using color-coded images, the student will look for features that are identifiable by the various colors on the map. The Student will identify the path of lava flows. He or she will try to identify what part of the country the volcanic area is located using topographic over laid maps. The teacher will serve as a facilitator to guide the student through the activity since he or she is serviced in a class of one. This activity works well with a group of three or four students. Students will answer the questions in this activity and place the result in their Science Notebook.

Activity 1: Aerial Photographs

1. This is a photograph of what type of natural land formation? What colors are shown on the aerial photograph?

2. What does each color represent?
 Red _____
 Orange _____
 Green _____
 Black _____
 Brown _____
 Pinkish _____
 Blues _____
3. Do any colors represent water? Clouds?
4. Which directions did the lava flow? How do you know?
5. What patterns do you observe?

Activity 2: Topographic Map(s) Overlays

1. What features do you notice in the higher terrain? Lower terrain? How do you know?
2. Which terrain is older? How do you know?

Lesson 3: Making and Mapping a Volcano

Activity 1: Modeling a Shield Volcano

Volcanism is one of the major geologic processes on Earth. Some volcanoes are basaltic shields like those in the Hawaiian Islands where as others are cinder canes, and hot spots. The focus of this activity is on the progressions of lava flows produced by multiple eruptions over time. The lava flows are modeled by using vinegar, baking soda, and color play dough. As eruptions occur, new lava flow (vinegar and baking soda) will be indicated with different colors of play dough. The younger flows overlay the older ones. The student will track where the flows travel, make a play dough model, and interpret the stratigraphy. This is a popular model uses in the classrooms throughout the educational community. The students may choose some other model if preferred. (NASA: Education Model, 1994). I have used modified versions of this model in previous lessons.

Objective

- To construct a model volcano
- To interpret the history of the volcano

Materials

1 paper cup 4 oz, baking soda ¼ cup, 1 spoon, vinegar ½ cup, play dough (4 different colors), large square pan, cardboard for pan, pen, markers, paper

Procedure

1. Take one paper cup that has been cut to a height of 2.5 cm and secure it onto the cardboard. This short cup is your eruption source and the cardboard in the original land surface.
2. Mark North, South, East, and West on the edges of the cardboard.
3. Place one heaping spoonful of baking soda in a short cup.
4. Set aside 4 balls of play dough, each in a different color.
5. Slowly pour a small amount of vinegar into your source cup and watch the eruption of simulated lava.
6. When the lave stops, quickly draw around the flow edge with a pencil or marker.
7. Wipe up the fluid with paper towels.
8. Use a thin layer of play dough to cover the entire area where lava flowed. Exact placement is not necessary. Match flow color and play dough if available.

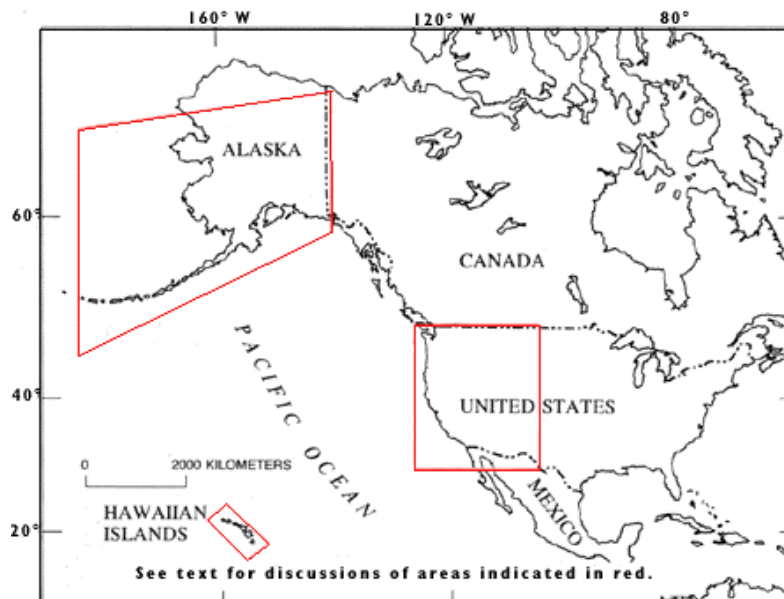
9. On a separate sheet of paper record information about the flow. Indicate color, shape, direction of flow, and thickness. Indicate where this flow is in the sequence; first, second, etc.
10. Repeat steps 7-11 for each color of play dough available. Four to six flows show a good example of a shield volcano. (NASA)

Questions:

1. Look down on your volcano and describe what you see. Make a quick sketch.
2. Where is the oldest flow?
3. Where is the youngest flow?
4. Did the flows always follow the same path? (be specific)
5. What do you think influences the path direction of lava flows?
6. If you had not watched the eruption, how would you know that there are many different layers of lava?
7. Which of the reasons listed in answer 6 could be used to identify real lava layers on Earth?

Lesson 4: Plate Tectonics and Earth Movement

How do tectonic plates move and why are you unable to feel the movement? Where are the plates located? Do plate movements cause the earth to quake and mountains to explode? Before beginning Activity 1, review tectonic movements in the regions outlined in red on the map below. Discuss briefly the plates in the area and the direction of movements. Recall the geologic process involved, and then review the vocabulary by using slides correlating to tectonics from the CD. These and similar questions can be appreciated when inquiring minds seek scientific solutions to them. Plate tectonics will be used in this activity to help students find answers to these type questions.



Map: From *Volcanoes of the United States* by Steven Brantley (<http://pubs.usgs.gov/gip/volcus/page03.html>)

Activity 1: Plate Tectonics and Earth Movement

Objectives

- Explain how landforms were formed.
- Read physical maps.
- Make map legends.
- Locate boundaries.
- Determine where earthquakes occur.
- Show the association of earthquakes and volcanoes.

Vocabulary

Core, magma, crust, mantle, tectonic plates, convergent boundary, divergent boundary, transform boundary.

Materials

Physical map of the world, map pencils, computer, paper, pen, Internet service, CD

Procedure

Using a physical map of the world, label the continents and the tectonic plates listed below. Use a reference source (i.e. geology or geography textbook), the CD, or the Internet to assist in this portion. Use arrows to show the movement of the plates. Then mark, using colored pencils, the type of boundaries that is formed between two plates. Explain at least two kinds of boundaries and the landforms associated with them.

Put completed work in the Activity Section of your science notebook.

Tectonic Plates of the World

Antarctic Plate
African Plate
Arabian Plate
Caribbean Plate
Cocas Plate
Eurasian Plate

Fiji Plate Indo-Australian Plate
Pacific Plate
Philippine Plate
North American Plate
Nazca Plate
South American Plate

Activity 2: Plate Boundaries

Using different wooden blocks, model and explain tectonic plate movements:

1. Divergent Boundaries
2. Convergent Boundaries
3. Transform Boundaries

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