Curriculum Units by Fellows of the National Initiative
2005 Volume IV: Astronomy and Space Sciences

Volcanoes in the Solar System

Curriculum Unit 05.04.03, published September 2005
by Mary Jefferson

Introduction

It was a typical hot sultry night in Texas. I sat in the open field with my family, as we excitedly gazed into the dark sky. This was no ordinary night. This was the Fourth of July. We watched in amazement as the fiery lights rumbled, burst, and exploded into a beautiful luminary display. There was so much excitement and energy in the air. I was captivated by the power and magnificence of this man engineered event. I share the same captivation for one of nature's most powerful events, volcanoes.

Volcanoes remind me of those same fireworks from the Fourth of July. They too rumble, burst, and explode. The fiery ejecta accelerate at tremendous speed hurling large chunks of molten rocks, huge quantities of gases and fine grained debris. They are magnificent and have tremendous energy and power. They can be both destructive and constructive. They have altered and preserved history. The eruption of Thera in 1620 BC destroyed the Minoan civilization and may have given rise to the legend of Atlantis. The ancient city of Pompeii was preserved for hundreds of years by the eruption of Mt Vesuvius in 79BC.

My fascination with volcanoes led me to the *Living with Geological Hazards Seminar* at the Houston Teachers Institute. On further study of volcanoes, I began to wonder if volcanoes existed in outer space. To my surprise, I discovered the answer is yes. Unlike volcanoes on this planet that are landforms made from the Earth, planetary volcanoes consist of much different materials. From satellite surveillance, scientists have studied strong volcanic activity on Io, one of Jupiter's moons. This unit will explore origins and characteristics of volcanoes of the Solar System.

This unit includes the following sections: Introduction (Why), Student population (Why), Teaching Strategies (How), Background (What), Lesson Activities (Evaluation), Annotated Bibliography (References), and an Appendix (Answer Key). The Background section will be the most extensive, because it will further divide into sub-topics and will introduce the scientific concepts and principles to be covered during the teaching of the unit. First topic in the background section will address the origin and characteristics of the Solar System. Next, volcanoes on Earth will be studied, followed by those on satellites of Jupiter and Saturn. Students will compare the similarities between the two kinds of volcanoes and discover what drives or provides the energy for each of them. They will identify the roles heat and plate tectonics play in the formation of active volcanoes. They will use the principle of radioactive dating to calculate the age of rocks and to infer the results for volcanic activity. Volcanoes have "erupted" periods and can remember when they last erupted.

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, established by the Texas Education Agency, are serviced or taught, one on one, in homes. They come to the Homebound Program at various degrees of readiness for learning. Some have great academic skills in the sciences and mathematics, while other students lag far below grade level. 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.

This unit is driven by time, district objectives, and the unique nature of the students. This unit will cover three weeks and may be adjusted to meet the need of the individual student. This three-week unit is developed mainly for high school students enrolled in elementary astronomy classes, environmental classes, and Earth science classes. Those studying surface forms and maps in geography will find this unit helpful. This curriculum unit may be adapted for use at lower grade levels. At the end of the semester or at time of withdrawal, I send records of the student's grades earned on the Homebound Program to their home schools.

Objectives

The objectives of the unit are aimed at increasing students' knowledge in science and mathematics. Students need to improve their skills in these areas to insure our place in keeping America safe and secure in the midst of emerging world competition and challenges. Education is the core of a strong nation. Science standards for education must be met in teaching our children, so they will be prepared to fill the jobs in the highly technological job market. Good science teaching removes the mystery of science and lowers the possibility of fake science along with dispelling myths about natural occurring events. This unit will help strengthen the student's science and mathematics concepts. Hopefully, this unit will pique the student's interest in the study of sciences like Geology and Astronomy.

In keeping with the national standards, the students will develop abilities necessary for understanding scientific inquiry. They will identify questions and concepts necessary for scientific investigations. They will formulate and revise scientific explanations using logic and evidence. Students will use maps, charts, and images to explain and to pose questions about the science governing volcanoes.

Students will compare and contrast terrestrial and Jovian planets. They will discuss the physical features of the planets. What features are common? What scientific facts can be drawn from any differences? How may this information help in finding which planets have volcanoes? Are all the identifiable volcanoes still active? If not, why?

Overview

The science classes offered at the high school level are designed mostly toward the life and physical sciences, with little emphasis on the aspects of Geology and Astronomy. Better teacher training is needed to insure growth in learning major scientific concepts and to minimize flaws in scientific thinking amongst our students. Students have many misconceptions about the science and nature of natural happenings. For example, students think the reason for the seasons is due to the proximity of the Earth to the Sun. They think that summer is the time of the year the Earth is closest to the Sun.

This is not true. Instead, the seasons are due to the Earth's axial tilt. 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 and other bodies of the Solar System, such as Io.There are many geologic processes that change the face of the planets and their satellites, but volcanoes, for many people, are the most awesome.

Ancient myths and legends support this preoccupation with volcanoes. Volcanic eruptions destroy and build in the same instant of time. I will show the video titled: *Ancient Civilization for Students*. It contains myths and legends dealing with Atlantis and Thera. In the video, the ancient history of the Minoan and the Mycenaean civilizations, two remarkable cultures off the Aegean Sea some 3500 years ago, are explored. Students will discuss and summarize the video in a brief essay. They will be encouraged to explain 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. I will have the students report on the mythology of Io, Europa, Ganymede, and Callisto, namesakes of the Galilean satellites. These satellites were all linked to the Greek god, Zeus, also called Jupiter by the Romans. All assignments will be kept in the students' notebooks in either the section on Earth Volcanoes or Volcanoes in Space.

The teaching strategies for the unit will vary. Vocabulary will be emphasized. At the beginning of each lesson, vocabulary and formula(s) required for the lesson will be taught and or reviewed. The Houston Independent School District mandates that calculators be used in the mathematics and sciences classes. Whenever possible, the lessons will be planned to develop computer and calculator skills.

Volcanoes on Earth will be studied first. It is essential that the students get a good grasp of what volcanoes are and are not. As stated earlier, volcanoes are landforms formed from vents or opening through which molten rocks reach the surface. The three essential elements of volcanoes are openings, often referred to as fissures, hot molten rocks, and heat. An image or picture will be used to show these elements. Students will be shown a picture of the Earth. This picture will be used to discuss the parts of the Earth and how they may be related to volcanoes.

Using a physical map of the world (Earth), students will identify the zones of active volcanoes and give reasons for their findings using plate tectonics and plate boundaries. On the same physical map, students will identify the volcanoes comprising the 'Ring of Fire' and give explanations for that chain of volcanoes. Finally, students will do case studies on one of the world's (Earth's) most popular volcanoes. The case studies will include factors such as physical features, the geological processes involved, locations, hazards, losses and the economic impact on society. A visual project such as a collage, a picture book, or a PowerPoint will be required of the students as a cumulative evaluation for this section on the Earth.

Volcanoes are found on other planets. Some of them are no longer active. There is activity on Jupiter's moons, especially Io, and there are suspects on Saturn's moons. The evidence for volcanism on Io is a major focus of this unit. Heat is a primary source for volcanism on the Earth and on Io. Is the source of heat that causes volcanism on Earth the same type for volcanism on Io? What is tidal heating and what role does it play in planetary volcanism? Critical thinking and research will be used in answering these and similar questions. Videos and CDs located in the Bibliography will be used to help convey scientific concepts and facts. A field trip to NASA's Johnson Space Flight Center, located here in Houston, will be planned to help students understand these out of the world volcanoes. Since some of my students are often ill and can not always attend local planned activities, I will invite speakers to come to them. Finally, students will write a narrative on volcanoes in the Solar System.

Teaching Strategies

This unit covers science that deals with the nature of Solar System volcanoes and the forces that drive them. Since my students are taught in homes, one-on-one, there is no opportunity for group work. I do e-mail when possible to link ideas and projects to give the students a feel of being connected to other peers. At the beginning of this unit, I will assess student's knowledge about volcanoes and volcanism and the geological processes involved. Vocabulary will be introduced at the onset of the unit and will be developed through-out the three-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: The Solar System, Volcanoes on Earth, and Volcanoes in Space, Activities, Vocabulary, Bibliography and the Appendix.

The section on Volcanoes and Earth will begin with a discussion on Pangaea and its relation to plate tectonics. Plate tectonics is paramount in understanding volcanoes. A brief discussion of Pangaea will help explain the formation of plates involved in the process of tectonics. Plate tectonics is well illustrated in most of the videos and CDs in the Bibliography.I will select several of the videos and CDs for the students to view and discuss. After students have learned the science of plate tectonics, they will use the concept to model plate tectonics that causes the Earth to move, creating earthquakes and volcanoes.

After studying plate tectonics, the three basic volcanic landforms (shield, cinder cone, composite cone) will be introduced. I will show slides of each type of volcano and discuss how they were formed. Students will keep new terms in the *Vocabulary Section* of their notebooks. I will have students compare and contrast examples of these types of volcanoes. Students will complete a matching activity on volcanic sizes, locations, and types, which will serve as a quick assessment of volcanic landforms. I will design a matching card game or use one of the exercises from The Starry Night CD for the assessment. Distribution maps will be used to identify active volcanoes. I will have students locate interactive- activities involving maps of volcanoes on web sites or the CD mentioned previously. Using such maps, students will be able to identify the volcanoes that are a part of the '*Ring of Fire*' and Iceland's '*Born of Fire*' volcanic chains.We will discuss the origin of these groups of volcanoes. The students will build a model of a volcano for the culminating assessment.

BackgroundContent

Solar System

The planetary system formed from a spinning disk of gas and dust, the solar nebula, surrounding the proto-Sun about 4.6 billon years ago. The solid materials, beyond Neptune, never accreted into major planets, but remained as a vast collection of objects known as the Kuiper Belt Objects (KBOs). These icy bodies hold clues to the origin of prebiological organic materials on Earth. These small KBOs are thought to be relatively unchanged since the inception of the Solar System because of the very cold temperatures at the trans-Neptunian distances. These smaller objects are less likely to undergo internal differentiation, leaving them virtually in their interstellar origins. By studying the chemical compositions of KBOs, scientists have learned much about the volatile and organic molecular materials that are found on Earth. The Kuiper Belt is the birth place of short-period comets. Examining samples from them is like examining materials from which planets were formed. Scientists think that the current Earth's atmosphere is not the original one. The change in atmospheres of planets was mostly caused by volcanism on them.

The Solar System is made up of the Sun, our star, the nine planets and all their moons, asteroids, comets, and planetary stuff. The terrestrial planets are Mercury, Venus, Earth, and Mars. The Jovian planets are larger than the Earth and are much farther from the Sun. They are Jupiter, Saturn, Uranus, and Neptune. The Jovian planets are very massive and their escape velocity is also large. They are able to retain much of their hydrogen. Their atmosphere is much like that of the Sun. These large planets' surfaces are not solid, and there are no volcanoes on them. Whereas the smaller inner planets escape velocity is low and the Hydrogen, being very light, gets ejected out of their atmospheres. They have solid surfaces and either active or dead volcanoes. Pluto is a very small planet located beyond the Neptunian distances. Since the age of the space exploration, unmanned satellites have visited every planet except Pluto. Images from these visits have documented Mercury's cratered surfaces, Venus's poisonous cloud cover, and Mar's enormous canyons and extinct volcanoes. Volcanic activities on Io, the rings of Jupiter and Saturn, and Neptune's active atmosphere have all been seen through the eyes of satellites.

Mercury is the nearest planet to the Sun and has a diameter of 4878 kilometers (3031 miles) and is 0.387 astronomical units from the Sun. Its surface is hard and rocky. It is freezing cold at night and burning hot during the day, denoted by its temperature range of 350º C to -170ºC. Mercury has no moons. It's atmosphere is essentially none. Mercury surface is covered with thousands of craters. There are no volcanoes on this planet, either dead or alive. Mercury is a small planet, less than half the size of the Earth and is slightly larger than the Moon. Alternately, it is baked on the side facing the Sun and frozen on the side away from it. Mercury conditions are inhospitable to life.

Venus is our nearest planetary neighbor and is called our sister because of its resemblance in size, and mass. It is near the size of the Earth with a diameter of approximately 12104 kilometers (7521 miles). Venus's surface is hard and rocky, and has many mountains. Venus is only 0.723 astronomical units from the Sun, making it the second nearest planet to the Sun. Venus is the hottest planet in the Solar System. Its temperature is in the range of 800 degrees Fahrenheit. The temperature is hot enough to melt lead. What makes Venus so hot, hotter than Mercury which is closer to the Sun? The thick atmosphere that surrounds Venus, accounts for the high temperatures. The clouds are formed mostly by carbon dioxide probably from volcanic activity. Carbon dioxide is 96.5% of Venus's atmosphere, which is about one million times more than is in the atmosphere of the Earth. The dense atmosphere produces a Greenhouse Effect sealing in the planet's heat, and preventing it from escaping into space (Jastrow,99). The trapped heat raises the temperature tremendously. The Earth's temperature would be hostile to terrestrial life if it was also covered with a thick blanket of carbon dioxide.

In 1969 the spacecrafts Venera 5 and 6 gathered information useful for answering the question, why did two planets formed at the same time out of similar materials and located at comfortable distances from the Sun evolved so differently? The Earth is hospitable to life, while Venus is hot and dry, and most of its water depleted. Venus 4 spacecraft instruments, used for detecting water, showed only small traces of water vapor in the atmosphere of Venus. If this water vapor were condensed to liquid water, it would cover a depth of 1 foot over the surface of Venus. If the ocean were spread out over the Earth, the Earth would be covered in depth of up to 8000 feet of water. (Jastron, 100).

Venus and Earth should have an equal abundance of carbon dioxide, but they do not. The difference in carbon dioxide on these two planets is due to the slightly higher temperature on Venus during the formation of the Solar System. When the Earth was formed, carbon dioxide was absorbed from the atmosphere by rocks. Atmospheric carbon dioxide reacted with rocks to form carbonates, somewhat like oxygen combines with iron in the air to form rust (iron oxide). These reactions do not take place at an accomplished rate if the rocks on the surface are very hot or dry. Since Venus was closer to Sun and hotter, its rocks could not absorb the carbon dioxide. It piled in layers, forming the thick atmosphere. Venus's atmosphere is very dense, some 200 times heavier than that of the Earth. There is strong indirect evidence for recent volcanic activity on this planet, but to date we have not been able to directly detect an active volcano.

Earth is 12756 kilometers (7926 miles) across in diameter and is one astronomical unit from the Sun. Earth's surface is rocky and its atmosphere is approximately 78% Nitrogen, 21% Oxygen, 0.4% carbon dioxide, and 0.6% of other rare gases and water vapor. The Earth's atmosphere has no Hydrogen because the light Hydrogen atoms escaped the atmosphere during the time the Earth was formed. In fact, there is evidence that the young Earth was so hot that all of its original atmosphere was lost, and that the present atmosphere is principally due to volcanic out gassing. Volcanoes eject primarily carbon dioxide, nitrogen, and water vapor. Most of the carbon Dioxide on Earth was absorbed by rocks, and diluted in the oceans.

Earth is the only planet with a differentiated atmosphere suitable for life as we know it. It has one moon that revolves around it once every 28 days. The Earth is very volcanically active. The Earth's face also chronicles many inactive or dead volcanoes, such as, Sacred Mountain Crater at the summit of Mount Fuji, Japan's tallest mountain located on the Island of Honshu, West of Japan. Earth is the only planet that has active confirmed volcanoes. Most of the Earth's volcanoes are dormant, which means they are currently inactive, but more than 600 are active. The active volcanoes sometimes spew smoke, steam, ash, cinders and flows of lava (Synder, Feather, Hesser, 388).

Mars is believed to be composed of rocky materials similar to that of the Earth. Its density is about the same as that of Venus and Earth. Mars' diameter is about 6796 km (4223 miles). Mars is about 1.524 astronomical units from the Sun. The Mars temperature ranges from about 20ºC to -120ºC. Mars is small and its radius is a little over half than that of the Earth. Mars has two moons. Its surface is rocky and covered with craters and old volcanoes. Mars is volcanic inactive.

Jupiter is enormous in size. Its diameter is 142,984 km (88,846 miles) and is located 5.203 astronomical units from the Sun. Its surface is covered with red and yellow clouds. Jupiter's atmosphere is composed of mostly, Hydrogen, and Helium, with significant amounts of Methane and Ammonia. Jupiter's temperature is extremely cold and it has 63 known satellites. Jupiter is not volcanically active, but Io, one of its four Galilean moons, is the most volcanically active object in the Solar System.

Saturn is 9.5 astronomical units from the Sun. In July 2005, The New York Times reported discoveries made by the Cassini-Huygens spacecraft as they entered Saturn's orbit. The Huygens probe transmitted 350 images which revealed that Titan's (Saturn's largest moon) surface is much like that of the Earth, "complete with evidence for methane rain, erosion, stream like drainage channels, and dry lake beds." Titan's temperature is minus 290 degrees Fahrenheit and has a global ocean of liquid methane. Titan is the only satellite in the Solar System with a substantial amount of Nitrogen and methane (about 3 percent). Images from the Cassini-Huygens also showed swirling storms, lighting, and auroras at both poles. Further the Cassini orbiter provided the first view of possible volcanoes, a lake, craters, diverse terrain, and a complex hydrocarbon atmosphere. The strongest evidence for volcanoes on Titan is inferred from an image of a 20 mile icy circular feature interpreted as an icy volcano or cryovolcano. The image has the shape of an Earth volcano known as a caldera, and its surface appears to have "two flow" patterns similar to Earth and Venus, that may have been caused by an erupting volcano. The ejecta consisted mainly of water, ice, and methane. The eruptions of Titan may be caused by tidal heating; a flexing of the Moon's interior as it moves in an elliptical orbit.

Neptune's largest moon, Triton, has shown evidence of volcanism. Voyager II photographed ice geysers spewing from a volcano on Triton's surface. From future space fly bys and exploration, volcanoes on this satellite will become more fully known. Heat for volcanism on Triton is due to tidal heating produced by the changing gravitational forces between Neptune and Triton.

Pluto is a tiny planet located 39.537 astronomical units from the Sun. It is very cold, around -233 degrees Celsius. It is only 2300 kilometers (1430 miles) across. It has one moon and no volcanoes.

Volcanoes in the Solar System

Volcanoes in the Solar System fall into two primary categories: dead volcanoes and active ones. Dead volcanoes are found on Venus, Earth and its Moon, and Mars. Active volcanoes are located on Earth, Jupiter's Io, and possibly on Venus, on Saturn's Titan, and on Neptune's Triton. Terrestrial and outer space volcanoes share some common properties. Volcano-producing bodies must have solid surfaces, molten rocks, and some form of heat. The heat process, that drives volcanic activity on Earth, is different from the type that drives volcanism on Io and other planetary satellites. Radioactive decay is the source of heat for volcanoes on Earth and has been since its formation some 4.6 billion years ago. Radioactivity takes place in the Earth's interior producing enough heat to melt rocks (magma). This magma reaches the Earth's surface through vents or openings forming volcanic lava flows. Tidal heating is the source of heat for volcanism for all the volcanic activity in the satellites of the Jovian planets. Whenever a variable gravitational force exists between planets and their satellites (because of orbital eccentricity), and when the rotation and orbital period of the satellite are not synchronized, as the satellites orbit the planet, they are squeezed and flexed. Their cores may become extremely hot, hot enough to melt rocks creating magma which flows to the surface in the form of volcanoes or gaseous plumes.

Volcanoes on Earth

Planet Earth

Our Earth is the third planet in the Solar System. Scientist has 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. A thin rocky crust (between 3 and 43 miles) overlays the mantle (1800 miles thick). (Rogers, Howell, et al.,180). This is the part upon which man lives. A good example to model this concept is an apple. Zeilinga 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.

Radioactivity

The internal heating machine 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 operating today. **It is fueled by the same type of residual heat and radioactivity that were present when the Earth and the other planets were formed. Scientists use a technique known as radiometric dating to determine the ages of planets, and thus the age of this internal heating machine. Radiometric dating is a technique used to date the ages of planets by analyzing samples of radioactive rocks and minerals. Radiometric dating is very reliable because it depends upon properties of the radioactive decay. All radioactive atoms, after a prescribed period of time, decay to half of the amount that was present at the beginning. This period of time for each atom is called its half-life. As the parent atom decays, the stable daughter atom increases proportionally.For example, the radioactive parent, Uranium 238, and its stable daughter, lead 206, reach a 1:1 ratio in about 4.5 billion years. Radiometric dating is a method used to determine the absolute age of a rock or a geologic event such as earthquakes or volcanoes. (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 isotopes of certain atoms 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, which produces the high temperatures of magma located at the Earth's core and volcanic lava flows.

Poort and Carlson (32) state that radioactive decay proceeds in several ways. Alpha decays occur when the nucleus of an atom emits an alpha particle composed of two protons and two neutrons. This loss changes both the atomic mass number (sum of protons and neutrons) and the atomic number (number of protons). 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. Beta decay occurs when a neutron is converted to a proton through the loss of a high energy electron. The mass remains the same but the atomic number changes as in the decay of Rubidium-87 to Strontium-87. Poort and Carlson list electron capture as a form of radioactive decay. In this type of decay, an electron is incorporated by a proton in the nucleus. A proton is lost and a neutron is gained. Potassium-40 decays to Argon-40 since the atomic number changes and the atomic mass number remains the same.

The rate of radioactive decay is constant and can be determined from laboratory tests and use of decay curves. The decay rate is expressed in terms of a length of time called the half-life. Poort and Carlson (32) define a half-life as the amount of time necessary for half of the original parent atoms to decay to daughter products or atoms. After one half-life, one half of the original material is daughter products and the half is the remaining parent isotope. 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, planets, and events that have occurred during the last 40,000 years. The purpose of this assignment is to have students realize that each radioactive isotope has its own half-life. To date the age of the Earth, U-238, with a half-life of approximately 4.5 billion years, would be used. Potassium has a long half-life of 1.3 billion years. U-235 has a half-life of nearly 713 million years. Carbon-14 has a half-life of 5730 years and is useful in dating events occurring recently in Earth's history.

The relationship between lapsed time and the radioactive decay of an isotope is expressed by the mathematical formula (N= Noe $^{-\Λt}$).

- N = number of atoms
- No= 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: Λ= ln2/thl = 0.693/thl.

- thl =the half-life,
- Λ=decay constant
- t = age of the rock.

To calculate the age of a rock, the following formula is used: t= (lnN/No)/-Λ. (Poort and Carlson, 32)

At this point in the unit, I will include exercises that require students to calculate the ages of rocks mathematically and theoretically (Lesson 1 Activity 2). 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 has 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 half-lives which have elapsed is 2. This number (2) may be found by using a decay curve.

Calculation for the age of the rock may be found by multiplying 2 half-lives x 80 million years. The age of this rock sample is 160 million years. Students may now complete the lesson on Dating Rocks Using the Decay Process?

Pangaea

One of the earliest attempts to explain formations of landforms was introduced by Alfred Wegener in the early 1900's. Wegener introduced his *continental drift hypothesis* called Pangaea. 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).

Plate Tectonics

How landforms are formed and why volcanism exists 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. For example, the North American and Eurasian plates are separating along the Mid-Atlantic ridge about two centimeters a year. (Zeilinga de Boer and Sanders, 109).

Plate tectonics 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). This plate tectonics model also accounts for earthquakes along subduction zones while showing which are shallow, intermediate, or deep-focus. Deep focus earthquakes occur only in association with convergent plate boundaries and subduction zones. (Tarbuck and Lutgens, 507).

The plate tectonics theory describes plate motion and the effects of this motion.The unequal distribution of heat within the Earth is the cause of plate movement. Plates move as coherent units relative to all other plates along boundaries. For example, there are three distinct boundaries depicted by the type of movement they exhibit according to Tarbuck and Lutgens. In divergent boundaries, plates move apart resulting in upwelling of material from the mantle to create new seafloor. In convergent boundaries, plates move together in the subduction of oceanic lithosphere into the mantle. In transform fault 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, a few exceptions being the Red Sea, the site of a young divergent boundary. Here the Arabian Peninsula separated from Africa, embarking on a northeast movement. The Gulf of California, which separates the Baja Peninsula from the rest of Mexico, was created by seafloor spreading. Convergent boundaries zones usually produce strong earthquakes when the spreading axis is located near a young, warm and buoyant lithosphere. The Peru-Chile trench is an example of this type of a subduction zone. Convergent zones can form between two oceans, an ocean and a continent, or two continents. I will use several videos and CDs from the Bibliography to convey the role plate tectonics play in volcanic formation and volcanism.

Volcanic Landforms

Different geological processes produce different kinds of landforms. Eruptions through central vents produce common landforms known as volcanoes. Volcanoes build up the surface and erosion wears them down forming volcanic rocks and exposing batholiths such as those in Yosemite National Park. Volcanic activities take place underground as magma cools forming igneous rocks. Some magma squeezes into horizontal cracks forming sills or into vertical cracks forming dikes. When sills push rock layers upward, rock domes called laccoliths are formed. (Synder, 405).

Note: Most magma never reaches the surface of the Earth, so most of the igneous activity takes place underground.

Some of the more familiar volcanoes are as follows: Shield Volcanoes, Composite Volcanoes, Cinder Cones, and Lava Domes.Craters and calderas are also recognizable volcanoes.

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 also Olympus Mars.

Cinder cones are relatively small, about a km in width and have steep sides up to 30 degrees. They are short lived, usually a single event.

Composite volcanoes are the most recognized types of volcanoes. They are made mainly of layers of alternating pyrocalstic 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. Example, Mount St. Helens, Mount Rainer, and Mount Shasta all part of the Cascade Range.

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, i.e., Mono Craters, California.

Craters and calderas are also volcanic landforms. Calderas are produced when volcanoes collapse into partially drained magma chambers, i.e., Crater Lake, Oregon and Valles Caldera, New Mexico. They are steep-walled depressions and may have younger domes within them. They can be several kilometers wide.

Shapes of Volcanoes

Shapes of volcanoes depend on the type of eruptions (quiet or explosive) and whether the lava flows are basaltic or granitic. Shield volcanoes erupt quietly and spread out basaltic lava in flat layers that form broad volcanoes with gently sloping sides. Examples of shield volcanoes are the Hawaiian Islands and Iceland, located in rift zones. For example, in the Iceland volcanic eruptions, the eruptive force was moderate to low, the silica content was low, and the water content was high. Cinder cone volcanoes are explosive eruptions, throwing lava, in the form of volcanic ash, cinders, gas, and large rocks, high into the air. The magma content is high in silica and water. The lava hardens into layers of tephra. Composite volcanoes are formed between periods of violent eruptions (gas, ash, formation of tephra) and quieter eruptions (spewing lava over tephra). The composite volcano is made up of alternating layers of tephra and lava. They are formed mostly at convergent plate boundaries such as in the formation of Mount Rainer.

Occurrences of Volcanoes

Volcanoes occur at three places directly related to plate tectonics: divergent plate boundaries, convergent plate boundaries, and at hot spots.

Divergent Plates

Iceland, a large island in the North Atlantic Ocean, has volcanic activity because it sits on top of the Mid-Atlantic Ridge which is a divergent plate boundary. Two divergent plates move apart forming deep cracks called rifts. Magma flows through these rifts as lava and is cooled by the seawater. This process continues over long periods of time causing the lava to build up from the sea floor often rising to form volcanic islands such as Iceland and the historical Thera.

Convergent Plate Boundaries

All volcanoes are not islands. Mount Saint Helens is one of several volcanoes that make up the Cascade Mountain Range in the Northwestern United States. These volcanic mountains in the Cascade Mountain Range formed because of convergent plate boundary between the Juan de Fuca Plate and the North American Plate. Magma rises from the subduction zones of convergent plate boundaries, as one plate pushes underneath the other, forming the volcanoes of the Cascades. All volcanoes in the Pacific Ring of Fire are formed at the convergent boundary of where the Pacific Plate collides with other plates. There are numerous earthquakes and volcanoes located around the Pacific Plate of which Mount Saint Helens, Mount Rainer, and Mount Shasta are among them.

Hot Spots

The Hawaiian Islands, like those of Iceland, are volcanic islands. The Hawaiian Islands are formed over hot spots. Hot spots are areas in the mantle that are hotter than other areas. Hot spots melt rocks that rise toward the Earth crust as magma. As the Pacific Plate moved over hot spots, the Hawaiian Islands were formed. Most of this magma rose above sea level forming islands such as Maui, Molokai, and Kauai.

Volcanic Necks

A volcanic neck is formed when a volcano stops erupting. The magma hardens inside the vent forming solid igneous rocks. These rocks are harder than the volcano crater. Over time, erosion wears away the softer crater first, leaving behind the solid core that is called a volcanic neck. Volcanic necks are common in the Southeast United States. Ship Rock is a volcanic neck located in New Mexico.

Volcanoes in Space

Volcanoes in space are found on objects that have solid surfaces, vents or openings to the surface, and some form of heat. These are the same basic requirements for the formation of volcanoes on Earth.

Tidal heating provides the energy for most volcanoes found in the outer regions of the Solar System. Images from the Voyager spacecraft show that Io is volcanically the most active body in the Solar System. From viewing images of the surface of Io, scientists have noted that it is marked by multi-colored layers of material ejected from volcanoes. Freeman and Kaufmann suggest that the energy for this volcanism comes from a gravitational tug-of-war in which Io is caught between Jupiter and the other Galilean satellites. The tug of war in this case means tidal heating, the source of heating for volcanism on Io. The unique coloration of Io is the result of much volcanic activity and the orange color is due to sulfur ejected from eruptions. The white color is probably sulfur snow, according to the authors.

The Io Torus is one of Io's volcanic plumes. It is formed when particles from Jupiter's magnetosphere collide with the plumes and Io's surface. Ions are knocked out of the plumes and off the surface creating a huge doughnut shaped ring of electrons and ions that encircles Jupiter.

Io and Its Volcanoes

It was thought that Io would be like our Moon: geologically dead, with little internal heat to power tectonic movement or volcanic eruptions. Io's surface was expected to be heavily cratered due to lack of volcanic activity. However, the Voyager I spacecraft sent back pictures of Io on March 5, 1979 showing that it has no impact craters at all. Io's surface is marked with irregular shaped pits and is blotched with color, giving it an appearance unlike any other in the Solar System. (Freeman, Kaufmann III , 317). Scientists concluded that Io's surface is the result of intense volcanic activity.

Io's internal heat is caused by Jupiter's tidal forces. Tidal forces are differences in the gravitational pull on different parts of a planet or satellite (Freeman, 318). These forces tend to change on deform the shape of a planet or satellite. Jupiter's tidal forces distort the shape of Io as it orbits around the planet in an elliptical path influenced by Europa and Ganymede gravitational forces. Io's speed varies as it moves around its orbit. Because the orbital and rotational periods are not synchronized, strongly variable tidal stresses are exerted on Io. These varying tidal stresses alternately squeeze and flex Io, similar to the way a ball of clay or bread dough is squeezed and flexed in the palm of a hand. The squeezing and flexing of the clay or dough over a period of time will cause them to heat. Tidal heating adds energy at the rate of about $l0^{14}$ watts, equivalent to 24 tons of TNT exploding energy second. (Freeman and KaufmannIII, 318). Freeman and Kaufmann show that, from Io's interior energy, 2.5 watts of power reaches each square meter of Io's surface. In comparison, the average global heat flow through the Earth's crust is 0.06 watts per square meter. They further stated that only in volcanically active areas on Earth are there heat flows that are somewhat comparable to Io's average.

The Galileo spacecraft sent back detailed images of plumes produced by erupting volcanoes on Io. Some of these plumes reached heights of 70 to 280 km above the surface. These extreme heights can only be reached by materials that are ejected from volcanic vents at speeds between 300 and 1000 m/s (700 to 2200 mi/h). The most violent terrestrial volcanoes, like Vesuvius, Thera, and Mount Saint Helens, have eruption speeds of only around 100 m/s (220 mi/hr). Scientists feel that volcanoes on Io must be different from those on Earth.

Io's volcanism is driven much by sulfur and sulfur dioxide, as shown by, images of Io's volcanic plumes. The plumes are more like geysers. In a geyser on Earth, water seeps down to the rocks heated by the radioactive process, converts to steam and explodes violently through vents. In the case of Io, sulfur dioxide, a solid at the frigid temperatures on Io's surface, becomes molten liquid sulfur dioxide a few kilometers beneath the surface. This liquid sulfur dioxide becomes with a high-pressure gas capable of colossal eruption with velocities up to 1000m/s. (Freeman and Kaufmann III, 319)

Sulfur and sulfur dioxide help explain the noticeable coloration of Io. Ejecta from the volcanic plumes eventually fall back to the surface. The bright yellow is sulfur and is the dominant color of Io's surface. If the sulfur is heated and cooled suddenly, the sulfur would take on a range of colors from orange to red to black, as in the case of a volcanic eruption through a vent. The sulfur would be heated, ejected through a vent and would be cooled rapidly. These colors are found around volcanic vents.

Sulfur dioxide on Io leaves a white deposit after a volcanic eruption. When hot sulfur dioxide gas is released through a volcanic vent into the cold frigid atmosphere, the sulfur dioxide crystallizes into white snowflakes and falls to the surface of Io as "Snow" rain. (Freeman and Kaufmann III, 319). On Earth, sulfur dioxide is ejected through vents and fall back to the surface of the Earth in the form of acrid gas.

Types of Volcanoes on Io

Io's surface shows a mosaic of volcano forms from extensive plumes which cover 5 per cent of Io's surface as black spots, to vested chains of volcano calderas (pits) with black lava flows, to fissures through which lava erupt in vertical sheets or curtains of fire. Freeman and Kaufmann state, that Io has two distinct styles of volcanic activity: unique geyser like plumes, and Earth-like lava flows.

There are thermal areas like those in Yellowstone National Park, fumeroles, and calderas. The names of some of the plumes and volcanoes come from Greek and Roman Gods and Goddesses such as Prometheus and Zamama. Other large volcanoes on Io are Acala, Pillan, Pele, Svarog and Marduk.

The plumes of Io are mostly sulfur and sulfur compounds, but the lava flows are made from different compounds. The temperatures in lava flows on Io ranges from 1700 to 2000k (2600? to 3150?F), as determined by Galileo spacecraft infrared measurements. At these temperatures, sulfur evaporates instantly. Earth volcanoes have lower temperatures (1300 to 1450) which indicate that the chemical composition of lavas on Io is not the same as those on Earth. The high temperatures of Io's lava flows indicate that they are probably ultramafic lavas rich in magnesium and iron. The presence of molten ultramafic lava on Io shows that the interior of Io is much hotter than the present day Earth. In lava beds that formed billions of years ago when the Earth was much hotter than it is today, solidified ultramafic lavas are found. (Freeman and Kaufmann III, 320.) Researchers have developed a model that explains volcanoes and mountains formations on Io. According to this model, Io has a 100-km (60mile) thick crust that floats on a global ocean of liquid magma some 800km (500 mile) deep. This magma ocean accounts for the volcanic activity found everywhere on Io's surface, whereas on Earth, volcanoes are concentrated in spots or regions. In this model, mountains are blocks of Io's crust that have tilted before sinking into the magma ocean. These mountains reach heights up to10 km (30,000 ft).

Io's substantial volcanic activity consists of over 300 active volcanoes, each ejecting some 10,000 tons of material per second into its atmosphere. This material would cover its entire surface, up to a meter thick, in about a century. Thus, Io's surface is constantly being renewed and its impact craters are eroded. Io's volcanoes exhibit longevity. In 1979, Voyager I and Voyager II viewed volcanic plumes, some four months apart. These same volcanic plumes continued to erupt at nearly the same intensity as the first viewing. In 1996, the Galileo spacecraft showed that half of the volcanoes, viewed by the earlier spacecrafts, were still very active and other new ones had formed.

Io is one of Jupiter's inner (Galilean) satellites and its orbital period is in a 1:2:4 ratio with those of Europa and Ganymede. In 1992 the Hubble Space Telescope showed features of Io as small as 150 km across when Io was 4.45 AU form the Earth. Io is roughly the same size and density as our Moon. It is thought that the Galilean satellites probably formed in a similar fashion to our Solar System but on a smaller scale, and are composed roughly of rocky materials. The Galileo observations suggest that Io has a dense core composed of iron and iron sulfide, with a radius of about 900 km, surrounded by a mantle of partially molten rock, topped by Io's visible crust. (Freeman and Kaufmann, 321)

Comparing Volcanoes: Earth and Io

Earth eruptions are very violent, noisy, or somewhat quiet. Io's massive eruptions are much more violent, hotter, and longer lived than those on Earth. Earth's volcanoes are fueled by radioactive decay whereas Io's volcanoes are fueled by tidal heating. Earth volcanic activities are violently- explosive, mild, or moderate. Io's eruptions are always violent, due to high sulfur content.

Earth volcanoes have specific shapes depending on the geologic processes involved. They are broad-gently sloping or small-steep sloping or anywhere in between. Shield, cinder and composite cones are the most popular terrestrial ones. Io's volcanoes are in shapes similar to those on Earth: plumes, shields, calderas and hot spots. They are huge and eject tons of materials into Jupiter's magnetosphere.

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: Radioactive Decay

Radioactive decay is the spontaneous disintegration of isotopes of certain atoms, such as Uranium, Potassium, and Thorium, into new isotopes and the process continues until a stable isotope is reached. Some by-products of the decay process are Alpha particles, Beta particles, Gamma rays, and heat. Radioactive decay is expressed in half-lives, the time it takes for half of the parent atoms to disintegrate into daughter atoms. As the parent decays, the stable daughter atoms increase proportionally, always maintaining the total ratio of one. The rate of decay can be shown by use of a decay curve. Most decay takes place within the first three half-lives.

Activity 1 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

A reference source of radioactive isotopes, paper, pen, graph paper, graphing calculator.

Procedures: In Activity 1,the students will make a list of five radioactive isotopes and place them on the chart.They will graph a decay curve of the isotopes from the chart. The student will make a statement about the shape graph of the half life of any isotope. Each student will complete the chart for this activity. In Activity 2 students will complete the exercises on dating rocks using the decay process.

Radioactive Isotopes

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

Activity 2: Dating Rocks Using the Decay Process.

1. Parent isotope X has a half-life of 100 millions. A rock sample has a ratio of 3/4 isotope X and 1/4 daughter isotope Y. What is the age of *that rock*? (Show work)
2. Parent isotope A has a half-life of 200 million years. A rock sample has 1/8 parent A and 7/8 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 800 millions years old. What is the half life of *that rock*?

(Show work).

Lesson 2: A Scissor Cut: Snipping away at the Decay Process

Objective

To show how the decay process works. To identify the constant of atoms in the decay process. To graph exponential curves.

Materials

Pencil, paper, 1″ X 8″ paper strips, color crayons, scissors, graphing calculator or a computer with a graphing program.

Procedure

- 1. Take one strip of paper and fold it in half.
- 2. Unfold the strip. The left side represents the parent atoms and the right side
- represents the daughter atoms.
- 3. Color the daughter atoms (the right side) only.
- 4. Cut the fold so you have two separate pieces, a parent and a daughter.
- 5. Label the daughter ½ and set it aside. This is the first generation (Do not further cut
- the daughter strip)
- 6. Repeat steps 1-4 using the remaining parent atom. (Do not use a new strip.)
- 7. This time label the daughter strip ¼, and set it aside. This is the second generation.
- 8. Continue to repeat steps 1-4 using only the remaining parent atoms until you have six
- generations. (Six cuttings). Place all the daughter atoms in a row.

Complete the following exercises:

- 1. After the 3 rd cutting (half-life), how much of the parent strip is left? How much
- daughter atoms are now present?
- 2. After the 4 th cutting (half-life), what do you observe about the original length (total
- amount of parent atoms). How much of the parent atoms are left? What fraction of
- daughter atoms is now created?
- 3. If the progression continues, what can you predict about the subsequent white strips?
- Color strips?
- 4. Did you ever run out of the white (parent) strips? Explain your answer.
- 5. What type of functions should be used to show this relationship between parent and
- daughter atoms as the parent atoms decays and the daughter atoms grow? Graph the
- curves.
- 6. Draw a graph showing both functions as they occur. Use different colors to denote
- decay and growth. Color the asymptote green. What is the quantity of daughter
- atoms? after the 3 rd half-life? 4 th half-life? 5 th half-life? Show your work. Give the

- answer in fractional form. How much of the parent atoms remain after each
- problem above?
- 7. What is the sum-total of both parent and daughter in each case above?
- 8. This number is known by what mathematical term?

Lesson 3 Making and Mapping a Volcano

Modeling Volcanoes on Earth and Io.

Volcanism is one of the major geologic processes on Earth and on Io. Volcanoes on Io look very much like those on Earth. The process is different when comparing the source of heat and chemical composition. The heat source for volcanism on Earth is radioactive decay, while the heat source on Io is tidal heating. Shield, calderas hot spots, and plume volcanoes are common to both Earth and Io. The focus of this activity is on the progressions of lava flows produced by multiple eruptions over time representing a shield volcano. The lava flows are modeled by using vinegar, baking soda, and color play dough. As eruptions occur, new lava flows (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 used in the classrooms throughout the educational community. They must model one volcano from Earth and one from Io.The following procedure is a modified version of volcano modeling taken from NASA Education model. (NASA: Education Model, 1994). The students may choose some other model if preferred. The students may use on-line services to learn how to construct volcanoes.

Objective

To model Solar System volcanoes. To interpret the nature of Solar System volcanoes.

Vocabulary

Lava, shield volcanoes, composite volcanoes, cinder cones, calderas, plumes, hot spots, Io, stratigraphy, eruption, magma, lava flows.

Materials

1 paper cup 4 oz, baking soda ¼ cup, 1 spoon, vinegar ½ cup, play dough (red, yellow, black, white, blue, and green), 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 is the original land surface.
2. Mark the directions North, South, East, and West on the edges of the cardboard.
3. Place one heaping spoonful of baking soda in the short cup. Adjust the amount of baking soda and vinegar (in step 5) to create more volume and height for Io volcanoes.
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 lava 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.
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 and on Io?
8. What does the yellow color represent on Io? What type of eruption causes a yellow color?
9. What type of eruption produces a white color around the crater on Io?
10. What color indicates a plume eruption on Io?
11. What geologic processes produce red or black colors on Io's landscape?
12. Why are craters smoothed so rapidly on Io.

Lesson 4: Galilean Satellites

Objective

To observe the Galilean satellites of Jupiter with the use of the Starry Night Backyard program. To describe the different surface features of the Galilean satellite. To find the apparent position of the Galilean satellites for any date and time using the Starry Night Backyard CD-ROM.

Vocabulary

Galilean satellites, occultation, bright terrain, dark terrain, prograde orbit, retrograde orbit, field of view, orbital periods, synchronous rotation.

Materials

Starry Night Backyard CD ROM

Procedure

Using CD ROM: Starry Night Backyard, chapter 15, the students will answer the following questions:

1. At what field of view do any of the Galilean satellites become visible?

2. Identify the satellites you can see at that field of vision.

3. Draw a picture of one of the satellites and describe it, including as many details as possible.

Extension

Have students continue to work through the interactive CD and complete one additional exercise.

Annotated Bibliography

Works Cited

Chaisson, Eric, and Steve McMillan. *Astronomy Today: The Solar System.* Upper Saddle River: Pearson Prentice Hall, 2005.

This is a very good resource for the study of Astronomy. It includes a full range of topics from the foundations of the history of Astronomy to the study of the Galaxies and Cosmology. The Solar System chapters include beautiful images. A CD-Rom comes with the book.

Freedman, Roger A., and William J. Kaufmann III, *Universe 7 th Edition*. New York:

W.H. Freeman and Company, 2005.

This comprehensive thirty-chapter textbook covers concepts, facts, and data about the entire Universe, from it's origin to the present. There are beautiful animated and interactive CDs that accompany the book. The Starry Night Backyard CD is an ideal electronic resource that permits one to explore the local Universe. This book is a one stop resource for studying the Universe.

Jastrow, Robert. *Red Giants and White Dwarfs: Man's Descent From the Stars*. New York: Harpers and Row, 1971.

Robert Jastrow, created a scientific story of creation that documents the beginning of the Universe to the appearance of life. This book is recommended for high school and adult readers because it requires higher cognitive level.

Jefferson, Mary. *The Legends, Myths, and Science of Volcanoes*: *Living With Geological*

Hazards. Houston: Houston Teachers Institute, 2005.

This gives an extensive review of volcanoes on Earth. (Note: The information

on radioactive decay, pangaea, plate tectonics, and landforms in Volcanoes in the Solar System unit, were taken from this reference.)

Levy, Matthys, and Mario Salvadori. *Why the Earth Quakes: The Story of Earthquakes and Volcanoes.* New York: Norton Co.

This simple written text contains over one hundred illustrations detailing the manner of earthquakes and volcanoes from the Earth's beginning to recent developments in the use of seismic technology.

Poort, Jon M., Roseann J. Carlson. *Historical Geology: Instructions and Applications.*

Upper Saddle River: Prentice Hall, 1998.

This comprehension manual is an excellent resource for the high school and above users. The manual has seven chapters that cover the fundamental concepts of historical geology and its use to interpret and model real world situations.

Tarbuck, Eduard J., and Frederick K. Lutgens. *Earth an Introduction to Physical Geology*. Upper Saddle River, New Jersey: Prentice Hall, 1999.

This book contains the GEODEII-ROM which brings difficult-to-visualize geologic processes to life making it easier to understand the geological concepts inclusive of earthquakes and volcanoes.

Zeilinga de Boer, Jelle, and Donald Theodore Sauders. *Volcanoes in Human History: The Far-Reaching Effects of Major Eruptions*. Princeton: Princeton UP, 2002.

This book tells the story of nine epic volcanic events and the role they played in human history. It is a resource filled with pictures, facts, and stories of the profound impact volcanic eruptions have had upon the human race.

Student Resources

Jastrow, Robert. *Red Giants and White Dwarfs: Man's Descent From the Stars*. New

York: Harpers and Row, 1971.

Robert Jastrow, created a scientific story of creation that documents the beginning of the Universe to the appearance of life. This book is recommended for high school and adult readers because it requires higher cognitive level.

Solar System: A Golden Book. New York: Golden Book Publishing Co., Inc., 1999.

This fact-filled book is easy reading and is useful for all grade levels, This book allows one to travel through the Solar System with stops at the Sun, the planets and their moons, and the rest of the planetary bodies.

Videography

Born of Fire. Producers Dennis B. Kane, Thomas Skinner. National Geographic, 1983.

This is a review of five case studies of volcanic eruptions from different geographical regions and geological origins.

Earth Revealed. Producer Southern California Consortium. The Annenberg/CPB

Collection, 1992.

Explores how scientific theories are developed and how the Earth's continuing evolution is impacted by plate dynamics.

The Eruptions of Mt. St. Helens. Director Otter Sieber. Holiday Video Library, Year?.

Offers the only photographic footage of the instant a volcano blasted itself apart devastating over 150 square miles of forest, killing over 50 people and millions of wildlife.

The Eruption of Mount St. Helens. Director George V. Casey. Sling Shot Entertainment, 1990.

This Academy Award Nominee Best Short Documentary Chronicles the cataclysmic events of the Mount St. Helens Eruption of 1980 whose height was decreased by 1300 feet after hurling 8.8 billion cubic yards of ice, rock, and dirt into the surroundings.

Inside Hawaiian Volcanoes. Director Maurice P. Krafft. Smithsonian Institute, 1989.

Shows how Hawaiian volcanoes actually work by going underground to look at volcanic plumbing systems assisted by use of cutaway vies and transparent models of volcanoes.

Message from the Mountain: As Seen at the Mount St. Helens Johnston Ridge Observatory. Northern Light Productions. Northern Light Productions, 1997.

This award winning video captures the fury of the May 18,1980 Mount St. Helens eruption resulting in the largest landslide in recorded history.

Ring of Fire. Director George Casey. Finley-Holiday Film Corp., Year?.

Discusses the great circle of volcanoes and seismic activity that rings the Pacific Ocean and the half a billion of people who live in shadow of there immense volcanic powers.

Web Sites

Brantley, Steven. *Volcanoes of the United States*. 1997. USGS. 12 Mar. 2005. http://pubs.usgs.gov/gip/volcus/page03.html>

"NASA Education Home Page." Accessed on July 12, 2005 at http://education.nasa.gov.

This internet site serves as a gateway to information on NASA education programs and services for educators and students. This directory provides specific details and points of contact for all of NASA's education efforts, Field Center offices, and points of presence within each state.

"NASA Spacelink." Accessed on July 12, 2005 at http://spacelink.nasa.gov

Spacelink is an electronic resource specifically developed for the education community. Spacelink is a virtual library in which local files and hundreds of NASA World Wide Web links are arranged in a manner familiar to educators. Using the Spacelink search engine, educators can search this virtual library to find information regardless of its location within NASA.

"NASA Central Operation of Resources for Educators (CORE)." Accessed on July 12, 2005. at http://core.nasa.gov

Central Operations of Resources for Educators is a worldwide distribution center for NASA's educational multimedia materials.

"This Dynamic Earth: the Story of Plate Tectonics." Accessed on July 12, 2005 at http://pubs.usgs.gov/publications/text/dynamic.html>

Topinka, Lyn. "Cascade Volcano Observatory (CVO)." Accessed on July 8, 2005 at http://vulcan.wr.usgs.gov/home.html>

"Volcano World." June 28, 2005. Accessed on July 12, 2005 at http://volcano.und.nodak.edu>

Volcano Resources for Educators. Accessed on July 10, 2005 at http://volcanoes.usgs.gov.educators.html>

Appendix

Answer Key

A Scissor Cut: Skipping Away at the Decay Process

1. 1/8, 7/8

2. Shorter or less parent atoms, 1/16, 15/16

3. Decreases exponentially. Increases proportionally

4. No, a half will always remain.

5. Parent Exponential Decay, Daughter ñexponential growth

6. ?, 15/16, 31/32

?, 1/16, 1/32

7. 1

8. Constant