

Before You Go

Volcán Arenal

There must be a storm coming. In the distance, you can hear the low, gurgling rumble signaling its impending approach. But there are a few things wrong with this situation. First of all, the thunder does not seem to be getting closer or farther. It doesn't seem to be coming from the sky either, but rather from deep beneath your feet. Not to mention the fact that there are no clouds in the sky and you are standing at the base of the most active volcano in the Western Hemisphere. Following, a hollow, crackling roar you look to the peak of the perfectly conical behemoth in time to see a dense, gray cloud of smoke and ash rising steadily into the atmosphere. Residents of the peaceful villages at the foot of the vociferous giant go on about their lives, without taking much notice of the column of debris reaching towards the sky. That is because today is just like any day; Volcán Arenal roars and spews and the tiny people in the valley below are spared.

The Arenal Volcano rarely reaches dangerous explosivity because it is almost constantly releasing built-up pressure in the form of lava, rock fragments and gas outbursts. Due to the relatively plastic composition of its magma, the gas buildup in Arenal is able to escape to the surface in the form of minor, but frequent eruptions. Occasionally, the hardened material traps gases within the volcano until it finally surrenders to the tremendous pressure. Weather permitting, you and the student group will be privileged to witness the reformation of the earth in action. For the most part, as explosive as Arenal is, it is safe to observe... from a distance.

Water is the source of life and its maintenance and cleanliness impact upon the health of the living creatures that depend upon it. Near the volcano, Ríos Arenal and Fortuna carve out rocky gorges in the northern mountains and merge with natural springs heated by the magma boiling beneath Arenal to form oases of life. At the foot of the volcano lies Costa Rica's largest inland body of water, Laguna de Arenal, created when engineers dammed the Río Arenal in 1973. With a surface area of 48 square miles (124 sq km), this elongated lake fills a depression between two mountain ranges. When it was formed, the lake inundated the original town of Arenal, leading its inhabitants to form a new settlement on the north shore of the lake, appropriately named Nuevo Arenal. High winds originating in the Caribbean lowlands whip across the lake at speeds in excess of 60 mpg (96 kph), creating ideal conditions for windsurfing. The powerful flow of the river and the winds drive turbines in the dam and on hillsides, providing power for nearby residents. The location of the lake at the foot of one of the most picturesque volcanoes in the world make this the perfect setting for painting, drawing and photography as well. Not far down the road is the captivating Catarata La Fortuna (La Fortuna Waterfall), where Río Fortuna suddenly plummets more than 300 feet over a rock cliff amidst pristine cloud forest. The waterways around Costa Rica are home to scores of fish species that feed other fish, birds and crocodilians. Caiman and crocodiles inhabit the streams and lakes of Costa Rica and maintain the natural equilibrium of these aquatic ecosystems by controlling the populations of fish, frogs and turtles.

This area of Costa Rica is not only known for its fascinating geology. Towering over a valley between the Cordilleras de Guanacaste and Tilarán, Arenal encompasses 12 life zones, varied natural habitats that provide homes for a diverse array of wildlife. To preserve this natural treasure, the Costa Rican government created Parque Nacional Volcán Arenal in 1995, a 26,690-acre (10,800 ha) reserve surrounding its centerpiece, the 5,389-foot (1,643 m) volcano. This park, along with protected areas around Volcanoes Tenorio, Miravalles and the Monteverde Cloud Forest Reserve make up the Area de Conservación Arenal, a rugged section of the Cordillera de Tilarán containing about half of the land vertebrates in Costa Rica.

Information on Volcanoes

Plate Tectonics

The earth is made of layers, at the center of which is the core. According to the theory of plate tectonics, the outer layer, or the crust, is not a solid, contiguous layer, but rather an assemblage of plates, called lithospheric plates, of varying thicknesses that slowly float along the underlying viscous mantle layer. The thick crustal plates form the world's continents while the thinner ones lie beneath the oceans. Some 225 million years ago, all

the earth's continents were fused together in a giant super-continent called Pangea. For reasons unknown, it began to break up and the continents gradually drifted across the face of the earth. One theory explaining this movement is that convection generated in the mantle surges upward. When it reaches the rigid crust, these currents are forced sideways, carrying the crustal plates along with them. There are four different types of reactions between plates localized at their boundaries, the first two of which can result in volcanism and all of which can result in earthquakes: divergent boundaries, where new crust is formed; convergent or subduction boundaries, where crust is consumed; collisional boundaries, where two land masses collide; and transform boundaries, where two plates slide against each other. The process of fracture and collision of continental plates dramatically changes the face of the earth by creating new seas, islands and mountain ranges and geographically isolating and uniting living creatures.

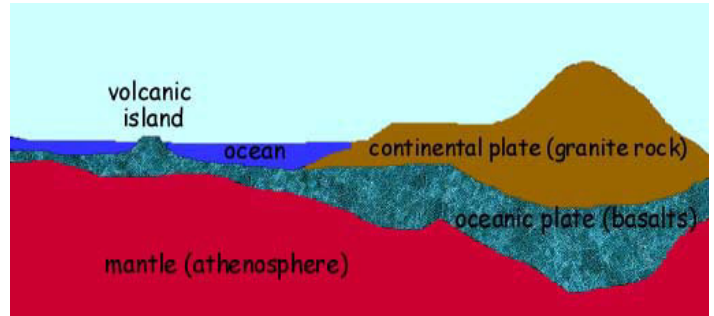
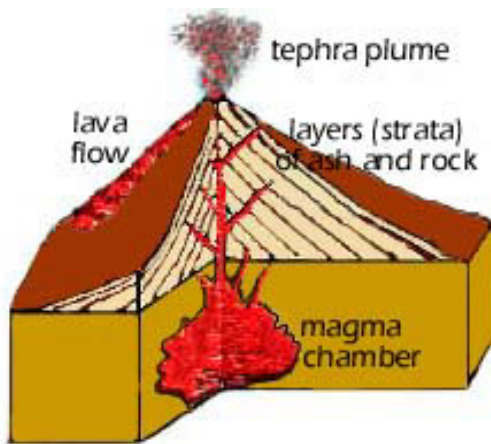


Diagram of the lithosphere



Cross-section of a volcano

What is a Volcano?

Volcanoes are the result of magma - molten rock found beneath the earth's crust - under pressure that surges through a weak spot in the crust towards the surface. Volcanism occurs in three main regions of the world: at divergent boundaries, intraplate hot spots and subduction zones. The first type occurs where thin oceanic plates diverge from one another and magma emerges to form new crust. These are known as divergent plate boundaries. Hot spots (intraplate volcanism) are areas such as Hawaii, Iceland and Galápagos, where a particularly hot pocket of magma melts through the overlying crust and erupts through a volcanic spout. This condition generally occurs within thin oceanic plates and results in a chain of

mid-ocean islands because the hot spot remains in one place while the mobile oceanic crustal plate glides over it. Isla de Coco, an island off the Pacific Coast of Costa Rica is actually part of the Galápagos Island chain. Divergent boundary and hot spot volcanoes are generally not violent and destructive due to the constant release of energy, but lava flow may destroy vegetation and buildings and render a plot of land useless for building or farming for decades to come.



Information on Volcanoes

Another type of volcano results from where a lighter oceanic plate is drawn (or subducted) under a thicker continental plate, ie. two plates are moving towards each other. These are known as subduction zone volcanoes, also sometimes called andesitic volcanoes, named after the great

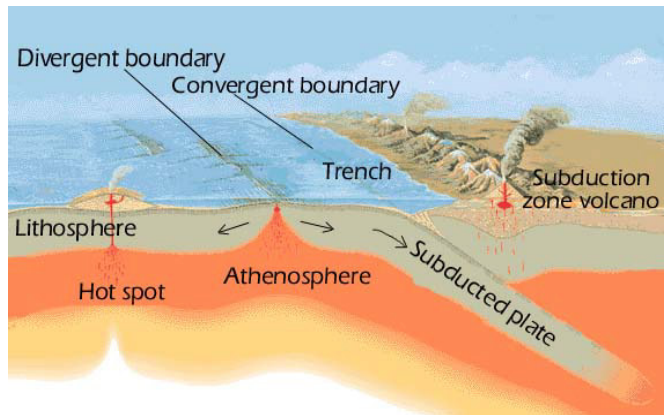


Diagram showing plate activity

string of active and dormant volcanoes along the continental and oceanic plate boundaries that form the Andes mountains of South America. Friction between the plates and exposure to super-heated magma in the mantle causes the subducted earth to be melted down into plastic magma. Groundwater seeps into magma chambers through aquifers (underground water reservoirs) and oceanic trenches (deep seams along a submerged subduction zone). At high temperature and pressure, water is converted into steam, a molecular form that occupies much greater volume than liquid. However, sometimes all the vents that might

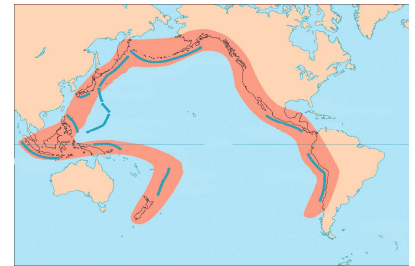
allow the steam to escape into the atmosphere are blocked by thick, viscous magma. The steam is then trapped in the underground magma chamber, continually building up pressure as more steam enters the chamber and its temperature increases. Eventually, this pressure mounts until the rocky terrain above can no longer contain the pressurized water vapor and the extreme pressure is released in one or more powerful explosions. The force of these eruptions can blow large chunks of rock from the volcano and reduce it to dust. The explosion of a volcano can result in the propulsion of volcanic debris called tephra, steam and liquid lava into the air and down the volcanoes flanks.

Volcanologists also classify volcanoes according to their degree of activity. "Active volcanoes" are ones that have erupted during recorded history and/or are currently experiencing releases of gas, debris or lava. "Dormant volcanoes" are ones that have not erupted in the last 10,000 years. It is important to note, however, that both types of volcanoes have the potential to erupt in the future. "Extinct volcanoes" are ones that have not erupted in the last 10,000 years and scientists believe that they will never erupt again. This is an ambiguous and subjective system of classification and even volcanoes that were believed to have been extinct have erupted. Besides location on plates or plate boundaries and activity level, volcanoes are also grouped according to their shape and composition of ejected material. The makeup of lava is generally categorized according to its density in silica. Lava low in silica is very runny, easily allowing gas to escape through the vent without an excess build up of pressure. The most explosive, and therefore the most dangerous, volcanoes are those containing silica-rich lava, a highly viscous material that keeps vapor trapped, so that the pressure of expanding gas builds up over time until the rock can no longer withstand the pressure and the gas and lava is released with colossal force. Scoria cones have straight, steep sides with a large summit crater, the result of silica-poor lava. Shield volcanoes, like Hawaii, have gentle sloping sides with fluid, basaltic lava. The term stratovolcano is used to refer to a volcanoes with a variety of lava types, but volcanoes of this type - like Volcán Arenal - share the form of a steeply graded slope near the crater that gradually fades with that of the surrounding terrain.



Volcanoes of Costa Rica

Of the world's 600 active volcanoes, more than two-thirds are andesitic types found along the Ring of Fire, a geologically dynamic circle of subduction zones that runs along the entire Pacific coast of the Americas, Asia, the South Pacific Islands and New Zealand. Among these, seven stand in Costa Rica (from north to south): Rincón de la Vieja, Miravalles, Tenorio, Arenal, Poás, Irazú and Turrialba, not to mention more than 60 dormant volcanoes. Thus, this relatively tiny land is one of the most geologically active places on earth. Costa Rica's volcanoes are the result of collisions between the Cocos plate, which is constantly moving northeast and being subducted under the Caribbean Plate at a speed of about four inches (10 cm) per year. This process began underwater about 5 million years ago and caused the land that now comprises Central America to uplift and pierce the ocean's surface about 3 million years ago. In some cases, rainwater seeps into the porous ground above a volcano's magma chamber where it is heated to over 5,000°F (2,760°C). Boiling water rises again to the surface where it may rejoin groundwater and streams and form springs or mingle with earth to form boiling mud pools. The steam released from the boiling water is given off through fumaroles of gaseous water, such as those found at Tabacón and Volcanes Miravalles and Rincón de la Vieja, and potentially dangerous sulfur dioxide and carbon dioxide. Sulfur dioxide can form sulfuric acid when combined with water molecules in the air. Sulfur dioxide in the atmosphere is capable of reflecting solar radiation and lowering the temperature of the earth, depleting the ozone layer and falling in the form of acid rain. Odorless carbon dioxide can be lethal to animals that breathe excessive amounts and vegetation found soil where the compound is concentrated.



Map showing the Ring of Fire

History of Arenal



Previously thought to be just a mountain, Arenal has since displayed some spectacular eruptions

Although the volcano has the symmetrical conical form stereotypical of many volcanoes, local villagers were not aware of the geological potential of Cerro Arenal (Arenal Mountain) until 1968. Volcán Arenal began to form some 7,000 years ago when the neighboring Chato volcano found a new release vent. Chato became extinct about 3,500 years ago, but Arenal has remained active ever since. There had been no measurable activity since the arrival of the Spaniards around 1500 AD. It was therefore not known to be a volcano until July 29, 1968 when a major eruption tore the western flank of the volcano apart, demolishing the nearby towns of Pueblo Nuevo and Tabacón, killing 78 people, about 45,000 head of cattle and devastating 5.8 square miles (15 sq km) of terrain. In the following days, successive eruptions created three new craters along the western slope. In June 1975, a series of four eruptions launched ash into the air that landed as far away as Tilarán - about 16 miles (26 km) west - and sent searing avalanches careening northwest along the Río Tabacón valley. A total of 23 explosions on May 5 1998 tore away the

northwest crater wall and opened a fissure in the volcano flank 1640 feet (500 m) in length. These eruptions produced avalanches of ash, rock and lava, leading authorities to declare a "red alert" and evacuate some 450 people from the immediate vicinity of the volcano. Since its modern activity began, Arenal has continued minor eruptions almost every day, usually only producing a small column of ash and smoke and trickles of flowing lava. However, its history of major eruptions lends credit to its reputation as one of the most volatile volcanoes on earth.

Arenal is considered a strombolian volcano because of its frequent, moderate eruptions with a major pyroclastic eruption every few hundred years. The massive volcano erupts nearly every day, ranging in magnitude from small ejections of sulfuric gas seeping from cracks in the mountainside to tremendously violent displays where glowing rock is hurled into the air. Sometimes built up pressure inside the volcano causes its slopes to heave and expand, breaking loose large cinder boulders and sending them tumbling down its slopes. At night, red hot lava can often be seen trickling down Arenal's slopes, even through partial cloud cover. It is also at night, when the din of engines has died down, that the low growl of underground activity can sometimes be heard from ten miles (15 km) away. It's no wonder that indigenous people considered the mighty Arenal Volcano to be a god; it has the power to take life and to buckle the earth. Today, this powerful giant is one of the most spectacular attractions for tourism to Costa Rica. Despite the regular frequency of eruptions however, visitors are not guaranteed of seeing lava or ash spewing from the crater because



Hazards of Volcanoes

The explosivity or degree of explosion of a volcano is based on three primary factors: viscosity, temperature and amount of dissolved gases in the magma. Viscosity is the resistance of a substance to flow, or the opposite of fluidity. Molasses, for example, has a higher viscosity than milk. The viscosity of magma is influenced by its chemical composition and temperature. It should be intuitive that temperature is inversely proportional to viscosity. In other words, a substance at a higher temperature flows easier. Most magma is composed of only ten elements, the bulk of which is silica (Si) and oxygen (O). Magma rich in silica will crystallize more readily due to the electrically charged nature of the molecule, giving the substance a higher viscosity.

The dissolved gases provide the fire power of a volcanic eruption. The pressure exerted by gas bubbles that escape from the magma solution is dependent on temperature and pressure exerted by the confining rock. As the temperature of the steam inside the chamber increases, the gas bubbles enter an excited energy state. As the magma rises, it cools and hardens, so the gas has no room to expand and its pressure simply increases. When the vapor pressure of the gas bubbles exceeds the confining pressure of the surrounding rock, an explosion results. This is where the viscosity of the magma becomes important. In a magma with low viscosity, like basalt, the fluid substance allows trapped gases to easily escape to the surface so that vapor pressure never reaches excessive levels. In highly viscous magma, however, like silica-rich rhyolite, the stiff substance will not allow bubbles to reach the surface, so the gas pressure continually builds. The magma of Arenal falls somewhere in the middle of the range of silica content, so that it erupts often, but has the capability of building up to high energy explosions.

Sometimes a volcano erupts through a side vent, a particularly dangerous situation that can result in debris being launched horizontally at great speeds. Such destructive avalanches, called pyroclastic flows, often contain boulders and red-hot ash at temperatures in excess of 1,300°F (704°C) that race down mountainsides at speeds of up to 60 miles per hour (97 kph). Pyroclastic flows cause more death and destruction than any other consequence of volcanism. Powerful eruptions may cause the volcano to heave, sending loosened rocks and soil barreling down the slopes. Particularly on volcanoes in a climate with high precipitation, eruptions potentially result in fast-flowing lahars, landslides mixed with water from streams or melted snow and ice. Landslides destroy living creatures that are not able to get out of the way and can even reroute waterways. Besides blocking sunlight, airborne ash can threaten airplanes by limiting visibility and contaminating the air inside.

While subduction zone eruptions may be violent and destructive, capable of leveling trees for miles around and burning animals alive, they are a natural process that ultimately helps the environment by distributing mineral-rich ash over the surrounding terrain, thus creating more fertile soil. Costa Rica's combination of volcanic soil, high rainfall and proximity to the equator creates ideal growing conditions for forests and crops alike. Opportunistic animals also take advantage of such "disasters". Predatory birds, for instance, may wait in flight for lizards, snakes and rodents fleeing a lava flow. The natural earth cyclically injures and heals itself.

