

# A Volcanic Eruption as the Earth's Devastating Force

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## ABSTRACT

*Volcanic eruptions are generally preceded by increased seismic activity. We demonstrate that earthquakes related to volcanic eruptions are no different than other earthquakes. The results show that earthquakes under volcanoes also form Omega-sequences. Future T-synchronizations associated with various seismic states define future earthquakes and possible eruptions. At the same time, we show that the large earthquakes under volcanoes are also synchronized with the global seismic activity of the entire Earth. Therefore increased seismic activity of volcanoes is not only a product of a local geological situation (e.g., pressure caused by the lava chambers), but is also related to the global seismic state of the Earth. We conclude that volcanoes are an important constitutive part of the globally synchronized tectonic activity of the entire planet. These results bring some hope that future work in this direction could allow for a better forecasting/prediction of future volcanic eruptions.*

*Volcanic eruptions and global warming are inextricably related since the formation of the Earth. This is because volcanoes have been spewing enormous amount of ash, water vapor, and GHG into the atmosphere. These expulsions of gases along with hot lava that burns the vegetation around can noticeably change the climate, often in devastating ways in the geological history.*

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## 1. Introduction

Volcanoes are a key part of the Earth system. Most of Earth's atmosphere, water, and crust were delivered by volcanoes, and volcanoes continue to recycle earth materials. Volcanic eruptions are common. More than a dozen are usually erupting at any time somewhere on Earth, and close to 100 erupt in any year.

Volcano landforms and eruptive behavior are diverse, reflecting the large number and complexity of interacting processes that govern the generation, storage, ascent, and eruption of magmas. Eruptions are influenced by the tectonic setting, the properties of Earth's crust, and the history of the volcano. Yet, despite the great variability in the ways volcanoes erupt, eruptions are all governed by a common set of physical and chemical processes. Understanding how volcanoes form, how they erupt, and their consequences requires an understanding of the processes that cause rocks to melt and change composition, how magma is stored in the crust and then rises to the surface, and the interaction of magma with its surroundings.

Our understanding of how volcanoes work and their consequences is also shared with the millions of people who visit U.S. volcano national parks each year. Volcanoes have enormous destructive power. Eruptions can change weather patterns, disrupt climate, and cause widespread human suffering and, in the past, mass extinctions. Globally, volcanic eruptions caused about 80,000 deaths during the 20th century. Even modest eruptions, such as the 2010 eruption in Iceland, have multibillion-dollar global impacts through disruption of air traffic. The 2014 steam explosion at Mount Ontake, Japan, killed 57 people without any magma reaching the surface. Many volcanoes in the United States have the potential for much larger eruptions, such as the 1912 eruption of Katmai, Alaska, the largest volcanic eruption of the 20th century. The 2008 eruption of the unmonitored Kasatochi volcano, Alaska,

distributed volcanic gases over most of the continental United States within a week.

Finally, volcanoes are important economically. Volcanic heat provides low-carbon geothermal energy. U.S. generation of geothermal energy accounts for nearly one-quarter of the global capacity. In addition, volcanoes act as magmatic and hydrothermal distilleries that create ore deposits, including gold and copper ores. Moderate to large volcanic eruptions are infrequent yet high-consequence events. The impact of the largest possible eruption, similar to the super-eruptions at Yellowstone, Wyoming; Long Valley, California; or Valles Caldera, New Mexico, would exceed that of any other terrestrial natural event. Volcanoes pose the greatest natural hazard over time scales of several decades and longer, and at longer time scales they have the potential for global catastrophe.

Volcanoes are Earth's geologic architects. They've created more than 80 percent of our planet's surface, laying the foundation that has allowed life to thrive. Their explosive force crafts mountains as well as craters. Lava Rivers spread into bleak landscapes. But as time ticks by, the elements break down these volcanic rocks, liberating nutrients from their stony prisons and creating remarkably fertile soils that have allowed civilizations to flourish.

The impact of volcanoes on ecosystems ranges from catastrophic local effects to diffuse global effects. Volcanic eruptions can result in complete destruction of ecosystems close to the volcano. Volcanic ash falls vary in their effects from total burial of ecosystems to negligible, depending on their depth. Volcanic gases can have a variety of toxic effects. Extremely large volcanic eruptions can have global effects due to releases of large quantities of carbon dioxide and high-altitude aerosols.

There are several different types of volcanoes with differing types of hazards and resulting ecological effects. Most of the variations between volcanoes are related to the silica content of their lava, which in turn governs its viscosity.

Generally, the more viscous the lava, the less readily gases can escape from it and the more violent the eruptions.

Volcanoes can change the weather. They can cause rain, thunder and lightning. Volcanoes can also have long-term effects on the climate, making the world cooler.

## 2. Effects of volcanoes

There are two things to think about. The first is how the weather near an erupting volcano is being affected. The second is how large eruptions will affect the weather/climate around the world. I think more people are worried about the second issue than the first.

The main effect on weather right near a volcano is that there is often a lot of rain, lightning, and thunder during an eruption. This is because all the ash particles that are thrown up into the atmosphere are good at attracting/collecting water droplets. We don't quite know exactly how the lightning is caused but it probably involves the particles moving through the air and separating positively and negatively charged particles.

As for the world-wide affects of volcanic eruptions, this only happens when there are large explosive eruptions that throw material all the way into the stratosphere. If it only gets into the troposphere it gets flushed out by rain.

The effects on the climate haven't been completely figured out. A lot depends on the size of the particles (again mostly droplets of sulfuric acid). If they are big then they let sunlight in but don't let heat radiated from the Earth's surface out, and the net result is a warmer Earth (the famous Greenhouse effect). If the particles are smaller than about 2 microns then they block some of the incoming energy from the Sun and the Earth cools off a little. That seems to have been the effect of the Pinatubo eruption where about a 1/2 degree of cooling was noticed around the world. Of course that doesn't just mean that things are cooler, but there are a wide variety of effects on the wind circulation and where storms occur.

## 3. How volcanoes influence climate

Volcanic eruptions are responsible for releasing molten rock, or lava, from deep within the Earth, forming new rock on the Earth's surface. But eruptions also impact the atmosphere.

The gases and dust particles thrown into the atmosphere during volcanic eruptions have influences on climate. Most of the particles spewed from volcanoes cool the planet by shading incoming solar radiation. The cooling effect can last for months to years depending on the characteristics of the eruption. Volcanoes have also caused global warming over millions of years during times in Earth's history when extreme amounts of volcanism occurred, releasing greenhouse gases into the atmosphere.

Even though volcanoes are in specific places on Earth, their effects can be more widely distributed as gases, dust, and ash get into the atmosphere. Because of atmospheric circulation patterns, eruptions in the tropics can have an effect on the climate in both hemispheres while eruptions at mid or high latitudes only have impact the hemisphere they are within.

Below is an overview of materials that make their way from volcanic eruptions into the atmosphere: particles of dust and ash, sulfur dioxide, and greenhouse gases like water vapor and carbon dioxide.

## Particles of dust and ash

Volcanic ash or dust released into the atmosphere during an eruption shade sunlight and cause temporary cooling. Larger particles of ash have little effect because they fall out of the air quickly. Small ash particles form a dark cloud in the troposphere that shades and cools the area directly below. Most of these particles fall out of the atmosphere within rain a few hours or days after an eruption. But the smallest particles of dust get into the stratosphere and are able to travel vast distances, often worldwide. These tiny particles are so light that they can stay in the stratosphere for months, blocking sunlight and causing cooling over large areas of the Earth.

## Sulfur

Often, erupting volcanoes emit sulfur dioxide into the atmosphere. Sulfur dioxide is much more effective than ash particles at cooling the climate. The sulfur dioxide moves into the stratosphere and combines with water to form sulfuric acid aerosols. The sulfuric acid makes a haze of tiny droplets in the stratosphere that reflects incoming solar radiation, causing cooling of the Earth's surface. The aerosols can stay in the stratosphere for up to three years, moved around by winds and causing significant cooling worldwide. Eventually, the droplets grow large enough to fall to Earth.

## Greenhouse gases

Volcanoes also release large amounts of greenhouse gases such as water vapor and carbon dioxide. The Amounts put into the atmosphere from a large eruption doesn't change the global amounts of these gases very much. However, there have been times during Earth history when intense volcanism has significantly increased the amount of carbon dioxide in the atmosphere and caused global warming.

## 4. Plants & Animals Around Volcanoes

We typically think of a volcanic eruption as a catastrophic and highly destructive event. While it's true that a volcano can cause great devastation, it can also be ecologically beneficial by shaping habitat and fertilizing soil. Even after a major eruption, a great variety of plants and animals can quickly recognize the affected landscape and rebuild the ecosystem.

## Volcanic Eruptions

The immediate impacts of a volcanic eruption can be devastating for plants and animals, including humans. An erupting volcano can release gases, ash and magma, a mixture of molten rock, crystals and gases. Magma, called "lava" once it reaches Earth's surface, typically ranges in temperature from 600 to 1200 degrees Celsius, or 1112 to 2192 degrees Fahrenheit. Flowing lava and eruption-associated mudflows and debris avalanches can kill plants and animals outright, and also profoundly impact organisms by transforming habitat and resources. Volcanic ash, which may cause respiratory issues in animals, can also kill insects due to its sharp-edged consistency; this, in turn, affects the food supply of insectivorous birds and bats, at least in the short term.

## Volcanic Soils

Although a volcanic eruption is very destructive, it also has benefits to the ecosystem around the volcano. Magma can

contain silica, iron, magnesium, calcium, potassium and sodium, and thus the soil derived from weathering volcanic rocks and ash is often exceptionally rich in nutrients. Such soil fertility bolsters vegetation growth, aiding in the recovery of an ecosystem after an explosion. It also explains the great productivity of agricultural lands in the vicinity of many of the world's volcanoes.

### **The Returning Ecosystem**

The plants that grow around a volcano are instrumental to re-establishing the ecosystem. There are many ways plants return to the ecosystem: The seeds of plants may be protected in the soil during an eruption, for instance, or seeds may be deposited in an area later by wind or birds. Shrubs, ferns and other small plants like mosses are often the first to begin growing. Their growth helps break down rock into soil for other plants. Rain is also a factor in recovery, with areas that have high precipitation often recovering faster than dry areas.

### **Plants and Animals**

Specific plant and animal species inhabiting a volcano will vary depending upon the greater geographic context. For instance, the volcanic Hawaiian archipelago is isolated by thousands of miles of open Ocean, mainly limiting the indigenous fauna to animals that could fly, swim or raft from distant landmasses, such as insects, bats, birds and turtles. Many of these organisms – which, by virtue of their extreme seclusion from mainland relatives, evolved into highly unique forms – are now threatened by exotic invasive species such as cats introduced by human beings. Less isolated volcanoes typically have more varied ecosystems. Mount St. Helens in the Cascade Range, for example, supports everything from frogs and voles to elk, black-tailed deer, black bears and mountain lions.

### **Thermophiles**

Some forms of life, known as thermophiles, have adapted to survive in extremely hot environments and can actually live in volcanic conditions. Thermophiles are generally microorganisms. For example, the hot pools at Yellowstone National Park, heated by volcanic geothermal activity and often above the boiling point of water, are home to thriving communities of thermophilic microorganisms. Specially adapted enzymes, known as extremozymes, protect these organisms from the extreme temperatures.

## **5. Major health threats from a volcanic eruption**

Volcanoes spew hot, dangerous gases, ash, lava, and rock that are powerfully destructive. People have died from volcanic blasts. The most common cause of death from a volcano is suffocation. Volcanic eruptions can result in additional threats to health, such as floods, mudslides, power outages, drinking water contamination, and wildfires. Health concerns after a volcanic eruption include infectious disease, respiratory illness, burns, injuries from falls, and vehicle accidents related to the slippery, hazy conditions caused by ash. When warnings are heeded, the chances of adverse health effects from a volcanic eruption are very low.

Exposure to ash can be harmful. Infants, elderly people, and people with respiratory conditions such as asthma, emphysema, and other chronic lung diseases may have

problems if they breathe in volcanic ash. Ash is gritty, abrasive, sometimes corrosive, and always unpleasant. Small ash particles can abrade (scratch) the front of the eye. Ash particles may contain crystalline silica, a material that causes a respiratory disease called silicosis.

Most gases from a volcano quickly blow away. However, heavy gases such as carbon dioxide and hydrogen sulfide can collect in low-lying areas. The most common volcanic gas is water vapor, followed by carbon dioxide and sulfur dioxide. Sulfur dioxide can cause breathing problems in both healthy people and people with asthma and other respiratory problems. Other volcanic gases include hydrogen chloride, carbon monoxide, and hydrogen fluoride. Amounts of these gases vary widely from one volcanic eruption to the next.

Although gases usually blow away rapidly, it is possible that people who are close to the volcano or who are in the low-lying areas downwind may be exposed to levels that may affect health. At low levels, gases can irritate the eyes, nose, and throat. At higher levels, gases can cause rapid breathing, headache, dizziness, swelling and spasm of the throat, and suffocation.

## **6. Causes**

Magma forms deep in the Earth's crust and in the upper parts of the mantle. In these areas, the temperature and pressure are very high. Changes in pressure and temperature can cause magma to form. Part of the upper mantle is made of very hot, solid rock. The rock is so hot that it can flow, like soft chewing gum, even though it is solid. If rock of this temperature were found at the Earth's surface, it would be molten, or melted. The rock in the mantle does not melt because it is under high pressure. This pressure is produced by the weight of the rock above the mantle. In the figure below, the curved line shows the melting point of a rock. The melting point is the temperature at which the rock melts for a certain pressure.

Magma contains dissolved gases, which provide the driving force that causes most volcanic eruptions. As magma rises towards the surface and pressure decreases, gases are released from the liquid portion of the magma (melt) and continue to travel upward and are eventually released into the atmosphere. Large eruptions can release enormous amounts of gas in a short time. By far the most abundant volcanic gas is water vapor, which is harmless. However, significant amounts of carbon dioxide, sulfur dioxide, hydrogen sulfide and hydrogen halides can also be emitted from volcanoes. Depending on their concentrations, these gases are all potentially hazardous to people, animals, agriculture, and property.

- **Carbon dioxide (CO<sub>2</sub>) trapped in low-lying areas can be lethal to people and animals-** Carbon dioxide constitutes approximately 0.04% of the air in the Earth's atmosphere. In an average year, volcanoes release between about 180 and 440 million tonnes of carbon dioxide. When this colorless, odorless gas is emitted from volcanoes, it typically becomes diluted to low concentrations very quickly and is not life threatening. However, because cold carbon dioxide gas is heavier than air it can flow into in low-lying areas where it can reach much higher concentrations in certain, very stable atmospheric conditions. This can pose serious risks to people and

animals. Breathing air with more than 3% CO<sub>2</sub> can quickly lead to headaches, dizziness, increased heart rate and difficulty breathing. At mixing ratios exceeding about 15%, carbon dioxide quickly causes unconsciousness and death. In volcanic or other areas where CO<sub>2</sub> emissions occur, it is important to avoid small depressions and low areas that might be CO<sub>2</sub> traps. The boundary between healthy air and lethal gas can be extremely sharp; even a single step upslope may be adequate to escape death.

- **Sulfur dioxide (SO<sub>2</sub>) is irritating to eyes, skin and respiratory system-** Sulfur dioxide is a colorless gas with a pungent odor that irritates skin and the tissues and mucous membranes of the eyes, nose, and throat. SO<sub>2</sub> emissions can cause acid rain and air pollution downwind of a volcano—at Kilauea volcano in Hawaii, high concentrations of sulfur dioxide produce volcanic smog (VOG) causing persistent health problems for downwind populations. During very large eruptions, SO<sub>2</sub> can be injected to altitudes of greater than 10km into the stratosphere. Here, SO<sub>2</sub> is converted to sulfate aerosols which reflect sunlight and therefore have a cooling effect on the Earth's climate. They also have a role in ozone depletion, as many of the reactions that destroy ozone occur on the surface of such aerosols.
- **Hydrogen sulfide (H<sub>2</sub>S) is very toxic in high concentrations-** Hydrogen sulfide is a colorless, flammable gas with a strong, offensive odor. It is sometimes referred to as sewer gas. Interestingly, the human nose is more sensitive to H<sub>2</sub>S than any gas monitoring instrument we have today: air mixtures with as little as 0.000001% H<sub>2</sub>S are associated with a rotten egg smell. Unfortunately, however, our sense of smell is not a reliable alarm - at mixing ratios above about 0.01%, H<sub>2</sub>S becomes odorless and very toxic, causing irritation of the upper respiratory tract and,

during long exposure, pulmonary edema. Exposure to 500 ppm can cause a human to fall unconscious in 5 minutes and die in an hour or less.

- **Hydrogen halides (HF, HCl, HBr) are strong, toxic acids-** When magma ascends close to the surface, volcanoes can emit the halogens fluorine, chlorine and bromine in the form of hydrogen halides (HF, HCl and HBr). These species are all strong acids and have high solubility; therefore they rapidly dissolve in water droplets within volcanic plumes or the atmosphere where they can potentially cause acid rain. In an ash-producing eruption, ash particles are also often coated with hydrogen halides. Once deposited, these coated ash particles can poison drinking water supplies, agricultural crops, and grazing land.

## 7. Conclusion

Volcanoes are best defined as cracks in the Earth's surface where magma has flowed and turned into lava. Volcanoes can be active, dormant or extinct. While active volcanoes erupt regularly, dormant volcanoes erupted in the past, but do not now; and extinct volcanoes have never erupted and scientists do not expect that they will.

Scientists also classify volcanoes further as to their form. These forms include fissure volcanoes, composites, cinder cones, shield volcanoes and lava domes. Fissure volcanoes form when tectonic plates spread apart, while composites form when two plates meet, and one is beneath the other. Composite volcanoes have a crater and several layers of lava and hardened ash and debris. They can erupt because of gas build-ups. Cinder cones often form on other volcanoes as cooled lava and usually only erupt once. Lava domes can be quite explosive, while shield volcanoes are not. In lava domes, lava can plug the vent causing a build-up, which can lead to an eruption. Shield volcanoes are mainly comprised of many different layers of hardened lava.

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