Volcanoes!

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UNIVERSIDAD DE COLIMA

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Contents

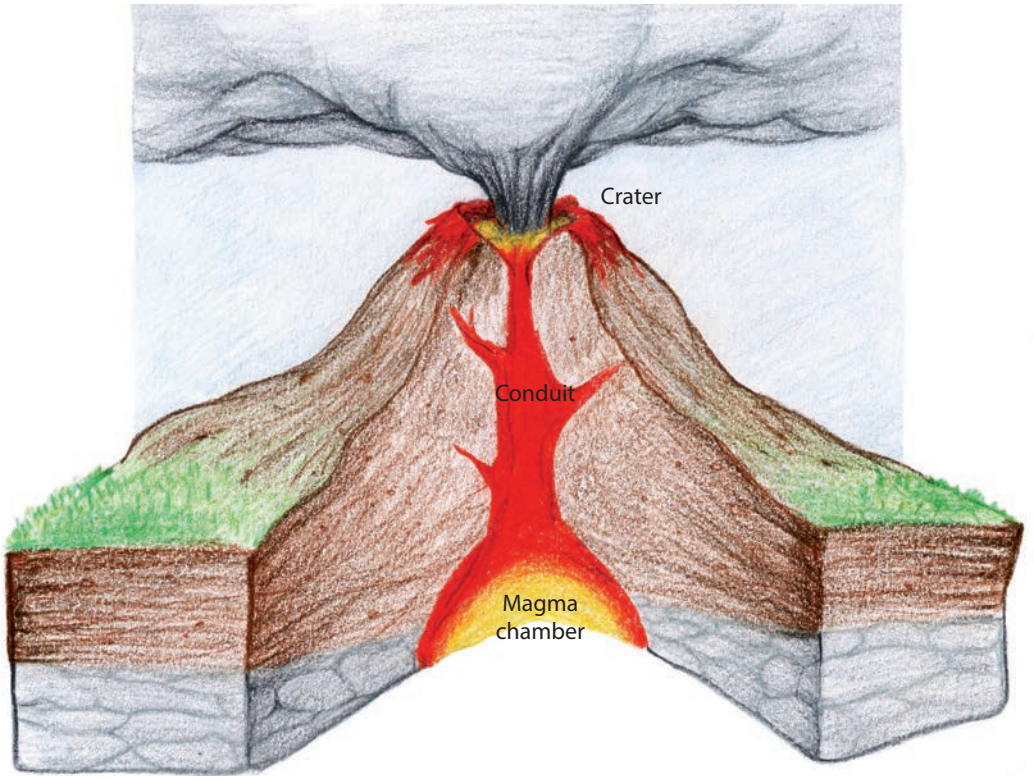
Introduction	7
What Is a Volcano?	9
Why Are They Called Volcanoes?	12
Origin of Volcanic Theories	13
Myths and Legends About Volcanoes	17
What Are Volcanic Hazards?	21
How Do You Monitor a Volcano?	23
What to Do During an Ashfall?	26
How Can One Live Among Volcanoes?	29
Bibliography	32

Introduction

It's safe to say that volcanoes have been an important part in creating life as we know it today. When our planet was still in formation, volcanoes provided heat, water, and a powerful mix of organic compounds to the terrestrial surface which were key to the beginning of life; therefore, they are the most evident manifestation that planet Earth is alive.

A fairly accepted theory suggests that oceans were formed somewhere around 4 billion years ago, after a significant period of volcanic activity. A large quantity of volcanic craters discharged magma, fumaroles, and burning gases: upon cooling, the steam of the water and the rest of the gases started to condense, and just like that, abundant rain fell over the oceans. The accumulated water on the terrestrial surface provoked huge collapses of materials which ended up dissolving in the oceans.

The volcanic activity made the life of the first organisms not only possible, but also caused the heat of the Earth to last in our atmosphere. Thanks to volcanic activity, the atmospheric conditions necessary for life started to develop since large quantities of lava segregated gases into the atmosphere, which started to convert it into the environment that we inhabit at present.


Crater
Conduit
Magma
chamber

What is a volcano?

A volcano is a place where rocks that are melted or fragmented by heat and hot gases emerge in a relatively violent manner through an opening from the internal parts of the Earth to the surface. This material, occasionally, generates a mountain in the shape of a cone, made from lava, ashes, and other materials, which we call a volcano. Volcanoes are the result of a complex process that includes the formation, ascent, evolution, magma emission, and deposit of these materials.

The formation of volcanoes is tried to be explained by way of a theory called plate tectonics; which tells us that this geologic structure is born from the limit of a convergent plate which penetrates, subducts, or slides under another. In this process, the material of the subducted plate is dragged towards the Earth's interior, until it reaches a depth where it melts due to pressure and temperature. From this moment on, it starts to ascend through vertical cracks and is expelled toward the surface, giving origin to a volcano.

The melted rock that rises inside the volcano is called magma; however, when this rock reaches the surface, it is called lava. All the lava that sprouts out from the volcano is extremely hot and may reach temperatures that go from 700 to 1200 degrees Celsius. This process is known as a volcanic eruption; on some occasions, it can be very big and violent, it also releases vapors and gases that, sometimes, can damage the health of living beings.

It´s important to mention that volcanoes aren't exclusive to our planet; recently, thanks to technological advances, it has been demonstrated that on other planets and satellites of the solar system such as Mercury, Venus, the Moon, Mars, and one of the moons of Jupiter called Io, some kind of vulcanism still exists or has existed. So, we can say that vulcanism is a present phenomenon in our solar system.

Commonly, volcanoes have a circular depression in their highest part which is called a crater and which is the part that works as an opening. This opening connects through a conduit with an interior deposit called a magmatic chamber that contains the magma, which afterwards will come out to the surface. It's like a type of stomach of the volcano that, on occasion, expels what's inside when an eruption happens.

A volcano that has an activity considered effusive acts in a way really similar to a milk pot being heated; when the temperature increases, the milk rises and spills. This is the same thing that occurs with the volcanoes: the magma inside rises like the milk, when it gets to the crater, it fills it up and spills over on all sides of the volcano, generating lava flows and, on occasions, hot flows of ashes and rocks, also called pyroclastic flows.

We know there are thousands of volcanoes spread throughout the world, in fact, even in the South Pole, in Antarctica, there are volcanoes under the ice. Even in the depths of the oceans, there are volcanoes. Many of them grow throughout thousands of years and make it to the surface, giving form to islands such as Hawaii, the Revillagigedo Islands, the Canaries, the Galapagos, the Azores, and Iceland, among many others.

There are over 1,500 registered names of volcanoes. Some of them are really hard to pronounce, for example, the Akita-Komagatake, the Alney-Chashakondzha, the Barkhatnaya Sopka, the Brennisteinsfjöll, Kita-Fukutokutai, the Popocatépetl, and the Eyjafjalla, among others.

It is also known that there are more than 30 volcanoes in the world currently in eruption. Not all the eruptions are big; some can last a few days, and others remain active for many years. Since 1964, over 280 volcanoes have been registered with some kind of eruption.

On the other hand, it is considered that the tallest volcanoes are found in the Andes Mountain Range, between Chile and Argentina. The highest volcano in the world, known as Ojos del Salado (Eyes of the Salty One) is there, located 6,891 meters above sea level.

In Mexico, we also have a lot of volcanoes, more than 2,000, some of them are 5.000 meters above sea level, like the Citlaltépetl or Pico de Orizaba with 5,676 meters. Followed by El Popocatépetl with 5,452 masl, El Iztaccíhuatl with 5,286; and a bit smaller, there's La Malinche with 4,461, El Nevado de Toluca with 4,392, El Nevado de Colima with 4,330, El Cofre de Perote with 4,28,2, and El Volcán de Fuego de Colima with 3,860 masl.

Why Are They Called Volcanoes?

The word volcano comes from the Latin Volcanus, which refers to the god Vulcan, god of fire and metals in Roman mythology; this same identity comes from the god Hephaestus of Greek mythology. The Spanish word "vulcan", with the absence of the final o, was used in the 13th century by Alfonso X, the Wise. The term "vulcán" comes from the passing of the Latin word through Arabic (burkân), being used as an appellation for the mountains of fire, and not as a toponym, by various medieval Arab authors such as Al-Qazwînî. It is said that the word "volcano" was used in the 16th century among the Spanish explorers who used the name of this god to designate the mountains of fire discovered in America. It is from this word that the adjective volcanic proceeds, among other derivatives. The original form is kept, nevertheless, in other words like vulcanite, vulcanism, vulcanologist, or vulcanology.

Moreover, vulcanization is a term of English origin used during the 19th century; this term is also derived from the name of the god Vulcan. It is a process that involves adding sulfur and applying pressure to rubber to improve its strength and maintain its elasticity. The rubber is used for the fabrication of tires and, thanks to this process, in modern day, all automobiles can move.

The Origin of Volcanic Theories

In the 5th century B.C., the ancient world had two words for the explanation of the volcanic phenomenon: wind and fire. The Greek philosopher Empedocles believed that the world was governed by four elements which he called "roots of all things", these were underground fire, water, wind, and earth.

For Plato, "The subterranean regions were connected through numerous channels where endless rivers of hot and cold water flowed"; likewise, he also claimed that in the depths of the Earth, an enormous and stormy river of fire, the Phlegethon, fed the volcanic craters. According to records, Plato was the first to describe the formation of lava: "sometimes, when the earth is melted by fire and cools again, it forms a blackish rock".

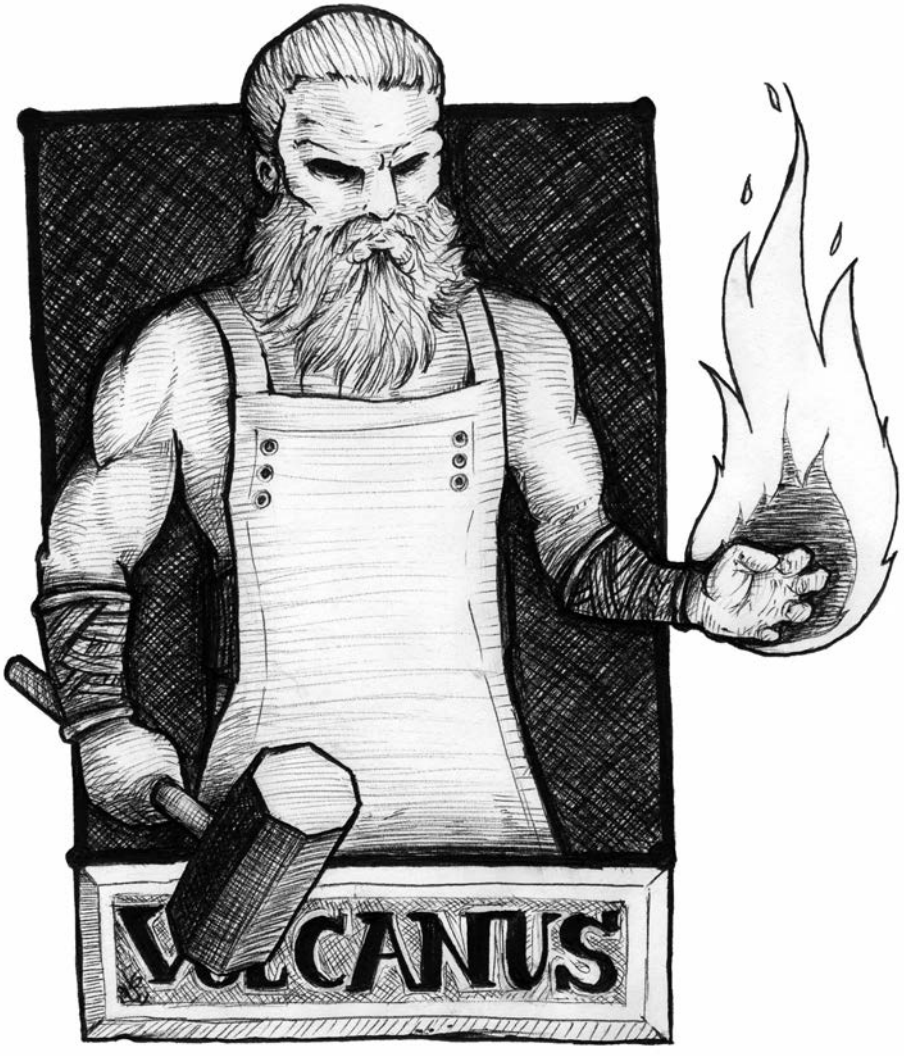
For his part, Aristotle compared the earth to an organism that was born, had lived, and died. Its convulsions, tremors and volcanoes, were attacks of fever accompanied by gasping and trembling. The subterranean fire was caused since "the compressed air shatters into particles that burst into flames due to the effects of the impact and friction of the wind as it plunges into narrow passages". It was Aristotle who called the depression at the top of the volcanic cones a crater (a word from Greek origin which means cup).

The first extensive account of a volcano's eruptive activity was written to describe the eruption of the Italian volcano, Vesuvius, on August 24 and 25 of year 79 A.C., which ended the life of the population of the cities of Pompeii and Herculaneum.

These chronicles came to us thanks to Pliny the Younger, who was the first to describe the volcanic eruption through his own experience and the letters left to him by his uncle, Pliny the Elder, who died asphyxiated because of the gases and ashes of the volcano, a victim of his scientific curiosity after observing the eruption.

However, the origin of volcano observatories can be traced back to studies made in Italy at the end of the 18th century, which were related and inspired by the eruptions of the Vesuvius Volcano. Nonetheless, the conditions for the creation of a scientific structure destined to permanent study of the volcanic phenomenon did not occur until 1841, when construction began on the Vesuvian Observatory (the first vulcanological observatory of the world), which was officially inaugurated on the 16th of March, 1848. These modest Italian observatories also developed the first instruments for the knowledge of volcanic activity.

Without a doubt, the people of pre-Hispanic Mexico had to live with the volcanic phenomenon; on more than one occasion, they were witnesses to the devastating consequences that the eruptions of a volcano provoked. Such was the case with the activity of the Xitle Volcano, which directly affected important sites such as Cuicuilco, a place that is currently part of Mexico City. Likewise, the ancient inhabitants of Colima were eyewitnesses to the activity of the Volcan de Fuego, even though there is still no evidence that describes the way the people were affected by the eruptions.


VULCANUS

Myths and Legends About Volcanoes

The myths and legends regarding volcanoes have existed for almost as long as humans have inhabited the Earth. They constitute traditional stories through which attempts were made to convey and understand "prodigious" phenomena observed by people. The myths and legends associated to volcanism intend to explain the existence of volcanic forms or the activity of some specific volcano. Myths are narrations of wonderful events, almost always led by supernatural or extraordinary beings, such as gods, heroes, or monsters.

The ancient Romans recognized Vulcan as a savior god in times of war, and he was considered a useful god who was to be worshipped since gifts and presents regarding practical and material matters were expected of him. Depending on the region, Vulcan had one specific meaning or another; for example, in the regions of Lipari, Sicily, and Etruria, it was believed that Vulcan lived on the island of Hiera (now called Vulcano), located in the Tyrrhenian Sea, north of Sicily (Italy) and was recognized as the god of fire and forger of iron as, down on Earth, he created the weapons of the gods and the thunderbolts of Jupiter whom no one could imitate. Others say that he lived in the very bowels of Mount Etna, and that in its depths, he had a fiery forge fueled by countless furnaces in which the fire was continually stoked. In some of the conquered territories by the Romans, for example, Gaul, Vulcan was

also worshipped as the god of fire, even as a personification of volcanoes, or the Sun's blinding light. Thus, from a divinity like Vulcan, the Greco-Latin word was adopted to designate "volcanoes" for these geological structures.

In turn, the Mexican culture is also rich in the description of natural phenomena, since Mexico is a country where mystical and religious beliefs coexist with the scientific world. Within the Náhuatl mythology about the creation of the universe, it is said that there were five suns which were destroyed by different causes of natural origin; in the third sun, which was called nahui quiahuitl (fourth rain), "the men died when it rained fire from the sky and the sun burned as well as all the houses."

It is said that this sun lasted for 312 years, until it was destroyed in just one day, on which it rained fire. If we relate this story to a natural phenomenon, it would seem like they were talking about fire raining, possibly caused by a volcanic eruption.

Even though this cannot be proven, it is possible that this kind of event, gathered by pre-Hispanic mythology, is a reflection of the manifestations of nature that these towns suffered and to which they gave a mythological meaning.

There is a legend related to the creation of the Popocatépetl and Iztaccíhuatl volcanoes, which bases its story on the love of two youths. It says that a beautiful princess named Xochiquetzal swore eternal love to the most handsome and proud warrior of the Mexica army which was setting out for war against the Zapotecs. Xochiquetzal awaited the victory and the return of the man she loved. The days passed by and there was no news about the victory of the Mexicas aga-

inst the brave Zapotec men. While the battle was taking place, Xochiquetzal was courted by a Tlaxcalan man who had settled in the city when manly arms were needed for the daily work. It was this same suitor who brought the news of the beloved warrior's death, plunging the princess into a state of great sadness.

After some time had passed, Xochiquetzal agreed to marry the Tlaxcalan man, but it is said that she was never happy at his side. Afterwards, the Aztec warriors came back, defeated and embarrassed.

When Xochiquetzal saw that her loved one was still alive among them, she got furious and accused the Tlaxcaltecan of being a liar for having fabricated the death of the man she loved. The woman ran off and was followed by her husband and by the brave warrior, whom engaged in a fierce dispute.

After fighting, the wounded Tlaxcalan man fled to his place of origin. Meanwhile, the warrior searched for his beloved, but when he found her, she was already dead. She had taken her own life after becoming the wife of a man whom she had not sworn eternal fidelity to. The warrior wept, picked flowers, and covered Xochiquetzal's body with them. It is said that on that day, the Earth shook, and tremors and clouds darkened the skies. At dawn, two snow-capped mountains had emerged in the valley. One, in the shape of a recumbent woman covered in white flowers (Iztaccíhuatl), and the other, tall and impressive, like an Aztec warrior kneeling at her feet (Popocatépetl).

The *Volcan de Fuego de Colima* also has its myths and legends. According to some studies, the name Colima comes from "Colliman," a Nahuatl word used to designate the ancient kingdom or dominion. The hypothesis holds that colli means hill, volcano, or grandfather; and ma or maitl means hand or dominion, that is: "place conquered by our grandparents" or "where the elder god or the god of fire dominates", probably referring to the volcano.

Other legends that were kept were originated after the arrival of the Spaniards and tell what happened during the time of the conquest. One of them tells us that King Colimán found himself surrounded by his maidens and warriors, since the conquistadors had cut off their supply of water and food. Unable to live this way, the king escaped one night with his contingent, leaving a warrior as bait. At dawn, the king and his people found themselves at the top of the volcano, and when the Spanish realized their deception, they climbed in order to capture him. The king threw himself into the crater of El Volcán de Fuego with his maidens and warriors, only to be devoured by the flames that rose from the crater before the conquistadors were able to capture them. Tradition tells us that the volcano erupts when it realizes its descendants are being mistreated.

Other hundreds of myths and legends related to the volcanoes, the large part of them taken from places where the volcanic activity is constant, as happens in Japan, Indonesia, Hawaii, Iceland, Italy, New Zeland, New Guinea, Mexico, Central and South America, though it also happens west of Russia, where myths provide us excellent narrations about the eruptive activity of the volcanoes.

What Are Volcanic Hazards?

The danger is the probability of the occurrence of a potentially destructive phenomenon in a determined lapse of time. Volcanic hazards are the probability of a specific area being affected by the process or products of volcanism, which may cause potentially destructive damage that could affect people's lives and health, their daily activities, and their property.

Volcanic hazards include lava flows, the growth of volcanic domes, pyroclastic flows, pyroclastic surges, directed explosions, mud and rock flows (lahars), ash falls and ballistic missiles, volcanic gases, volcanic earthquakes, atmospheric shock waves, landslides, and tsunamis. Some of these volcanic events are capable of affecting large areas around the volcanoes and even cause damage in areas located hundreds or thousands of kilometers away from the eruption site.

How Do You Monitoring a Volcano?

Before an eruption, most volcanoes present diverse changes that can be detected with highly sophisticated instruments. Volcanic vigilance or monitoring is, without a doubt, the key for the population to be safe in the case of an eruptive event.

In present day, many active volcanoes are monitored by scientists. This monitoring has made it possible to predict volcanic eruptions with a few hours of anticipation, allowing the residents to evacuate areas near the volcano, thus saving their lives.

One of the essential types of monitoring at a volcano is seismic activity. Earthquakes are the product of magma and gases that rise through the volcano, breaking down the rocks that they find in their path. In addition, they generate other vibrations, all of which can be measured with an instrument called a seismometer.

In the monitoring, the volcano's deformation and inclination are also measured, as if we were dealing with a balloon that inflates and deflates according to its activity, or tilts to one side or the other. This type of monitoring is known as geodetic monitoring.

Another type of volcanic monitoring is through the measurement and analysis of the gases escaping from the reservoir and the changes in the chemical composition of the water in nearby springs. This type of monitoring is known as geochemical monitoring.

In the same way, there's also a visual monitoring, using video footage, photographs, and satellite images, which can observe changes in the volcano's exterior and monitor the ash clouds that travel across the sky after an eruption, or the gradual growth of lava domes.

For the interpretation of all this vigilance or monitoring to be effective, there must be a Volcano Observatory, which is the place where the information is collected, as well as the scientists who interpret the data obtained to generate a diagnosis and prognosis of the activity.

Nonetheless, even after all the technological advances related to vulcanology, to this day, no one can accurately predict the day, time, and place where the next eruptive activity will occur.

What to Do During an Ashfall?

When a volcano erupts, the main cause of inconvenience is the falling ash, which can remain in the air for several hours and even days after the eruption. Since this can damage your eyes and respiratory tract, here are some tips you can put into practice and recommend to your friends in case of ashfall:

- If you are at home, close your doors and windows. Place damp towels in doorways and wherever drafts may occur.
- If you suffer from chronic bronchitis, emphysema, or asthma, stay indoors and, if possible, away from the ash.
- If you are outside your home, look for shelter indoors and remain there until the phenomenon has passed.
- Breathe through a handkerchief or cloth. This will prevent the passage of volcanic gases and dust. If you have a face mask, use it.
- Protect your eyes by closing them as much as possible or use goggles.
- Clean your eyes and throat with uncontaminated water.
- If possible, cover yourself with a hat and long-sleeved clothing, as ash mixed with sweat may irritate the skin.
- In case of strong ashfall, vehicles should not be used.

- The only protection against ashfall and volcanic material of considerable size are reinforced shelters and roofs.
- Wrap electronic devices in plastic in order to keep them free of ash, and do not use them if you notice ash in your home environment.
- Do not eat or drink any food that you suspect may be contaminated.
- Have brooms, shovels, and a vacuum cleaner ready. The latter is very useful for absorbing ash without spreading it into the environment; you'll just need to clean the bag carefully.

How Can One live Among Volcanoes?

When volcanoes erupt, they can cause death and destruction; however, in the long run, the lava, ash, and minerals deposited in the ground create highly fertile land that is beneficial to the population. Therefore, the relationship between humans and volcanoes is complicated, but it can be a relationship of coexistence as long as humans learn to respect risk areas and do not attempt to build housing and infrastructure within a few kilometers of the volcano, or in riverbeds, ravines, or gullies, as these are the predominant sites through which the materials generated in an eruption flow down.

For these reasons, it's important to be well-informed. The authorities can teach you which the risk zones are that exist around a volcano, as well as show you the volcanic hazard maps for the area. This will allow you to know the places you should avoid during an eruption.

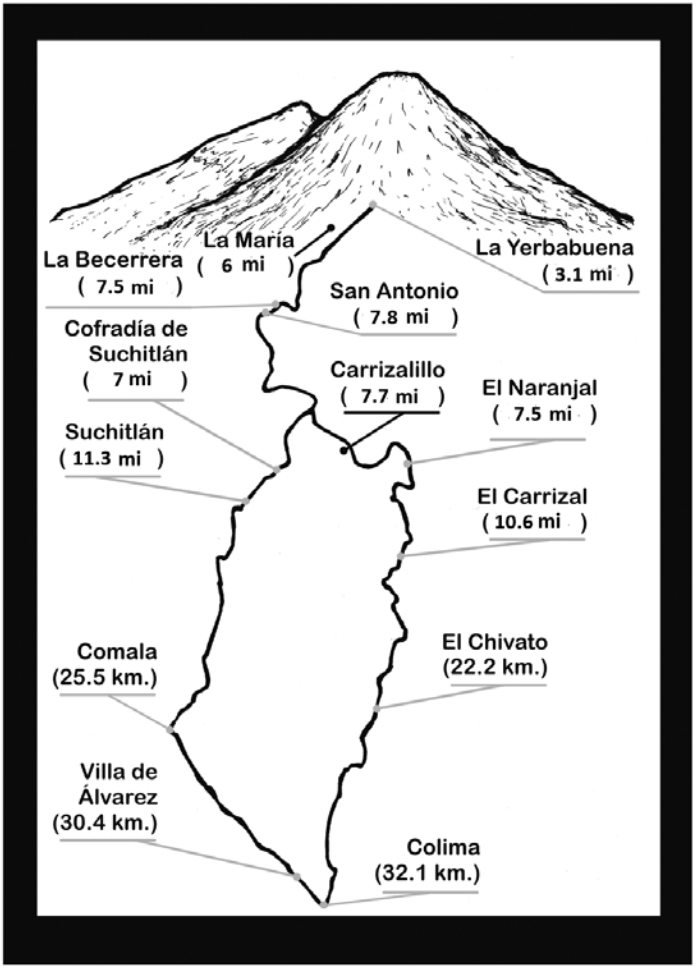
You should also know the warning signaling in case of danger, the established evacuation routes, the meeting points in your area, shelters, and temporary shelters.

Living with volcanoes is easy if we are informed. Ignore rumors and stay informed through the bulletins that your

local Civil Protection system will send you in the event of an eruption. Always stay informed. It's the best way to stay protected!

Remember, millions of people in the world live and coexist close to an active volcano. You need not be afraid, volcanoes are one of the most beautiful spectacles of nature. Learn how to admire them, coexist with them, and with their environment.

Distance in miles in a straight line from the summit of the *Volcan de Fuego de Colima*.



*Lagoons

*Towns

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Mauricio Bretón González

Holds a doctorate in seismicity and volcanism from the University of Granada, Spain. Since 1988, he has served as a full-time research professor at the University Center for Volcanological Studies of the University of Colima. He is a member of the National System of Researchers (SNII) in the area of physics, mathematics, and Earth sciences, and leads the UCOL-CA-30 academic group. He is a member of the Mexican Society of Geography and Statistics. He created and directs La Casa del Volcán (The House of the Volcano), a volcanological museum and observatory whose objective is to educate the public about volcanic processes and the mitigation of their risks. He has participated in more than 25 national and international projects in the areas of volcanology, seismology, geophysics, geomatics, and risk management, which have taken him to various volcanic regions around the world, notably his participation in three scientific expeditions to Antarctica. He has over 30 publications in peer-reviewed journals, in addition to being the author of three books published by the University of Colima on the volcanic subject.

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