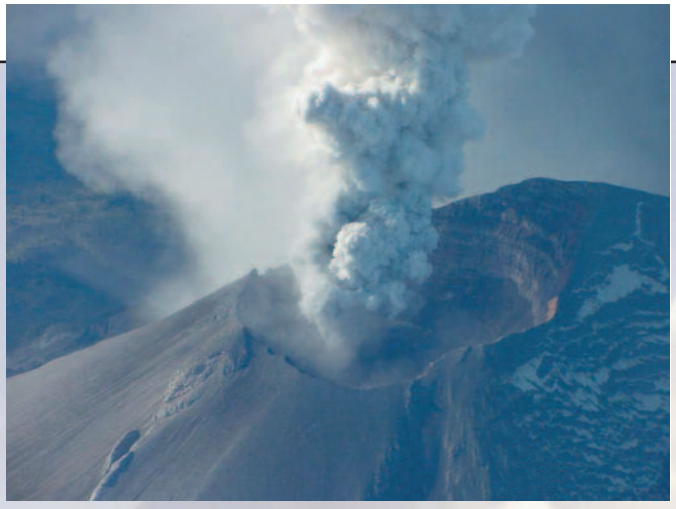

Federal Highway Division of the Transportation and Communications Ministry/Cenapred

Henry Romero/Reuters

In the Shadow of the Volcano

Popocatépetl Volcano gave signs of life in December 1994 with an emission of ash that covered the nearby city of Puebla in a fine film. This simple reminder put citizens and authorities alike on notice about the risks of living on the flanks of a volcano. Alerting scientists, it was the signal needed to prompt joint work by them and authorities to monitor volcanic activity and evaluate the risks of an eruption for nearby towns.

Six years later, between February and September 2000, Popocatépetl once again showed signs of disquiet. Then, from October on, volcanic activity increased until mid-December. The magnitude of the signals were monitored and the very high rate of lava production –by December 18, it was estimated between 15 million and 19 million cubic meters– formed the largest dome observed in the episode and gave rise to the fear of an imminent eruption. Municipal and state authorities stepped up the alert and established a security radius of 13 kilometers where they began to evacuate towns between December 15 and 16, including a few outside the security radius. On December 18 and 19, in three episodes, the volcano ejected large amounts of hot debris onto its flanks hurtling them, scientists believe, a maximum of 5 to 6 kilometers from the crater. After December 19, activity decreased and the next expected period of activity –around December 23 according to the time-predictable model– did not occur, indicating that the magma supply had changed. What is believed to be the first dome-destruction explosion occurred on December 24, ejecting incandescent debris 3.5 kilometers from the volcano and producing an ash plume 5 kilometers above the crater. This was the largest energy-release eruption of Popocatépetl ever monitored with instruments.

Authorities reduced the security radius to 12 kilometers and since no towns are located in that area, people returned to their homes.

An estimated 10 to 20 percent of the new dome volume has been destroyed by the activity since December 18. Because the dome mass has been removed by small to moderate explosions in many of the previous dome growth-and-destruction episodes since 1996, a similar scenario is expected in the near future.

Fortunately, the crisis was not as severe as predicted. But no one knows what Popocatépetl –or "Don Goyo," as local residents call the volcano– has in store.

Note: Based on a Cenapred report, published by *Bulletin of Global Volcanology Network* 12 (Smithsonian National Museum of Natural History, December 2000).

Special thanks to Dr. Carlos Valdés González of Cenapred.

Popocatépetl Living in Danger[1]

Juan Marcial*

Ramiro Ramírez/Reuters

Mexico is situated in a region of great volcanic activity. Of its approximately 3,000 volcanoes, 14 have recently been active, including the Paricutín (1943), Chichón (1982), Tacaná (1986), the Colima volcano, with great activity in recent years, and Popocatépetl (December 2000). Every year between 50 and 65 volcanoes in the world become active, but only a few cause loss of human life and property damage. The effects on the population are not necessarily proportional to the size or violence of eruptions, but rather to the proximity and number of human settlements surrounding the volcano.

Popocatépetl, 5,452 meters above sea level and more than 700 million years old, with its majestic, ancestral beauty, is undoubtedly a high-risk volcano. Throughout its long history, it has had numerous minor eruptions, a few major ones and has produced great paroxysmal events that

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Henry Romero/Reuters

The situation would be more dangerous if the volcano did not continuously liberate energy.

are more dangerous because they liberate a great deal of energy in a short time. Between 1993 and 1995, the kind of activity the "Popo" has shown seems similar to that of 12 other episodes reported since the sixteenth century: underground eruptions that liberate great quantities of magmatic gases along with old material deposited in the volcanic cone.

The Invisible

The volcano has been stable since January 1995 because the possible source of disturbance in the deeper areas has been smaller than the volcano's ability to liberate its energy. Until now, there has been no extreme danger. If the volcano did not have the capacity to benignly liberate accumulated energy, as it does now, the balance would be disturbed and the scenario would be much more dangerous.

The possible break in that equilibrium will depend on the reasons why energy is being generated in the depths of the volcano. One reason would be the introduction of new magma into that area. A mix of new and old magma rapidly cause an accumulation of energy that could lead to a major eruption.

Continuous monitoring —every few days or weeks— is carried out to observe the processes taking place in the volcano's depths. Based on these observations, scientists attempt to detect sufficiently ahead of time whether this mix of magma is occurring, if it is accelerating or if new magma is being introduced. Apparently, in the depth of the volcano and its conduits today, there is no serious accumulation of energy. As Dr. Servando de la Cruz from the UNAM Geophysics Institute says, however, we can predict nothing in the long run. We cannot even assign statistical probabilities since we do not know what is happening at a deeper level, more than 10 kilometers down, and no equipment can give us more precise data.

Dr. De la Cruz defines Popocatépetl as a mature stratovolcano capable of remaining dormant

Daniel Aguilar/Reuters

Despite the danger, the view of the volcano can also be spectacular. December 19, 2000.

for long periods or evolving toward more dangerous phases. He also says that no periodicity is possible in volcanology. The current eruptive activity of the volcano reminds us, he says, that the risk is there, has been there and will continue to be there, because it is always possible that the volcano will reactivate. If it became more actively eruptive, however, he concludes, fortunately today we have better scientific and technical resources to lower the risk and reduce the vulnerability of surrounding inhabitants, as was shown in December 2000.

The Visible

The moderate seismic and fumarolic activity that began in 1993 prompted authorities to set up monitoring stations. Today, joint work by the UNAM Institutes of Engineering and Geophysics and the National Center for Disaster Prevention (Cenapred) is done at 11 telemetric stations. Cenapred also has a center for data gathering and processing and carries out four kinds of monitoring: visual observation and seismic, geodesic and geochemical monitoring.[2]

Visual observation consists of watching for physical changes in the volcano, like rock or mud slides, deformations, fumaroles, emissions of ash or gases, or any other indication of perceptible change. To accomplish this, a video camera has been aimed at the north flank of the volcano, transmitting day and night directly to Cenapred, where the information is analyzed.

Seismic monitoring is one of the most important kinds of observation. The vibrations it registers and measures make it possible to infer where the hypocenters are generated and located, the points inside the volcano where energy is liberated. This makes it possible to locate bodies of magma underneath the volcano and to discern whether the magma tends to rise or open up new avenues toward other conduits, how it will evolve and how deep the seismic activity is. In the case of Popocatépetl, this activity is developing between 3 and 10 kilometers underneath

Daniel Aguilar/Reuters

Pyroclastic flows, explosions, a rain of incandescent material and lava emissions are the potential dangers to nearby settlements. November 29, 1998.

the crater, basically directly beneath it, slightly to the east (in the direction of the city of Puebla).

The volcano's seismic activity is only local and should not create concern that it will shift or cause major earthquakes because it is the result of magma that is attempting to escape, the pressure of which creates fractures and sometimes gas emissions.

Geodesic monitoring is carried out at three stations, each equipped with tiltmeters that register the slope or deformation of the soil as a result of pressure from inside the volcano.[3] This data is useful, based on the hypothesis that a large eruption will be preceded by significant deformations in the volcanic edifice.

Geochemical monitoring is the chemical analysis of gases, fumaroles, geothermal springs, the composition of ash, lava and other products of the volcano. Other variables associated with volcanic activity that are also monitored are winds, temperatures, precipitation, PH and radon gas and sulfur dioxide emissions.

The Theory

Based on the studies of deposits derived from Popocatépetl Volcano, the following potential dangers to nearby settlements have been identified: pyroclastic flows and waves and explosions; mud slides, gigantic slides of parts of the volcanic edifice (avalanches of debris); a rain of pyroclastic material and ballistic projectiles; the emission of lava spills and possible associated domes.[4] In the case of Mexico City, the greatest risk would come from the air pollution caused by great amounts of volcanic ash being expelled from the mountain.

Preventive Measures

Since the moderate eruption of December 1994, significant advances have been made in civil and disaster prevention. In June 1994, the government began a campaign directed at local residents through pamphlets, leaflets and videos. At the same time, Cenapred called on civic authorities in charge of public safety in Puebla, the State of Mexico, Morelos, Tlaxcala and Mexico City to develop a joint plan to facilitate their own coordination in the case of a high-risk scenario. Out of those efforts came the Popocatépetl Volcano Operational Plan which delineates each state's responsibilities in case of an emergency and instructions on how to proceed. The plan has been perfected to the point of developing its Emergency Planning Map, dividing the whole area into different risk zones so that the population can be evacuated according to the risks in each area. The scientific community developed a code for a volcanic alert, dubbed "the volcanic alert stoplight" by Cenapred. For practical purposes, the alert system has been likened to a traffic stoplight: green represents a normal situation and causes no change to people's day-to-day activities; yellow is an alert, meaning that normal activities can go on as usual, but everyone must keep informed of any changes; and red is an alarm, signalling the need to begin getting people away from the high-risk areas and protect them.

What Really Happens

Even though authorities carry out the campaign to inform the public about how to differentiate between a normal and an alert situation, what to do and where to go in case of danger, on the slopes of the volcano, people cling to a glimmer of hope to convince themselves day in and day out that there is no danger at all; the threat of death has always been part of their lives.

For Professor Teodoro Romero Carreón, principal of National Anthem Primary School, "the public has been overwhelmed with information" from official sources. For that reason they see things in the long term. They understand that a danger exists, but they do not accept the idea that it is imminent. Their attachment to their homes and their religion make them insensible to the threat and are two of the reasons why many local residents refuse to abandon their homes despite the danger. Professor Romero thinks people with a different attitude should go house to house explaining the risks involved "and not frightening people because they're not frightened anyway, and most people are willing to die on their land no matter what happens." VM

Notes

[1] This is an abbreviated version of the article "Popocatépetl, vivir en peligro," first published in the UNAM School of Science magazine *Ciencias* 41 (January-March, 1996), pp. 50-55.

[2] Cenapred's web site provides up-to-date information: http://www.cenapred.unam.mx/mvolcan.html [Editor's Note.]

[3] Tiltmeters are set on a concrete base and measure variations in slope caused by any kind of pressure to a thousandth of a degree.

[4] Initially, pyroclastic and mud flows are considered the most dangerous threats to surrounding towns. Giant avalanches and mud slides can only happen if part of the volcanic edifice collapses; they would travel at 100 kilometers per hour for 80 kilometers, destroying everything in their path.

Did you know...?

Magma is a word coined in the nineteenth century by the Englishman George Poulett Scrope, and refers to the molten material found underneath the earth's crust and from which igneous rock is formed by cooling and crystallization.

A volcanic eruption is simply the emission of certain materials from inside the Earth. The different kinds of eruptions are named after typical volcanos which become models for the others. Therefore, geologists speak of Hawaiian, Icelandic, Merapean and Pelean eruptions (the latter is named after Mount Pelé in Martinique, a French possession in the Caribbean).

All eruptions fall between two extremes: **effusive eruptions**, with the emission of large quantities of lava, and **explosive eruptions**, in which most of the material is expelled from the volcano as hot, solid fragments. Among the explosive eruptions are the Plinian and Pelean, and among the effusive are the Hawaiian and Icelandic. Vulcanean and Strombollian eruptions are considered intermediate.

Eruptions differ with regard to the chemical composition and varied gas content of the materials involved. The gas content is very important because it determines the viscosity of the magma: non-viscous magma makes for an effusive eruption, while highly viscous magma causes an explosive eruption.

Explosive eruptions are the more dangerous of the two. Hawaiian-type effusive eruptions emit great lava flows that form rivers and lakes, but cause little loss of human life, although they may well cause great economic and social damage. Pelean-type explosive eruptions expel solid fragments known as pyroclasts (from the Greek *piros*, for fire and *clastos*, for broken) along with a mixture of hot gas and water. They may even tear off part of the volcanic cone or form an enormous column that will spill over the sides of the volcano. This kind of an avalanche is highly mobile and can move at several kilometers an hour. Explosive eruptions can also create huge columns and clouds of gases and particles, capable of traveling long distances and depositing ash in far-off places.

The Risks

The greatest risk is from volcanoes that have remained dormant for long periods since inactivity makes people forget the danger.

The old definition of volcanoes as extinct or active is not very precise, since it is difficult to establish a time limit that would make it possible to classify any volcano as extinct. Previously, scientists considered that if a volcano had not erupted within human history, it could be classified as extinct. However, history begins at different times for different continents and regions and the eruption of volcanoes previously considered extinct has shown how wrong this criterion was. Today, scientists think in terms of probabilities, and volcanoes are classified as high risk if they have erupted in the last few tens of thousands of years.

Volcanic Activity in Mexico

In Mexico the great majority of the large stratovolcanoes (volcanos composed of explosively erupted cinders and ash with occasional lava flows) and many fields of monomagnetic volcanism (volcanism includes all phenomena connected with the movement of heated material from the interior to or toward the surface of the Earth) are concentrated in the Trans-Mexican Volcanic Band, a 1,200-kilometer long, 20- to 150-kilometer wide volcanic elevation facing east-west. Another volcanic region is the peninsula of Baja California. Our country also has solitary volcanoes, whose origin is less clear, like the Chichón, San Martín Tuxtla and the Tacaná, which we share with Guatemala and is part of the Central American chain.

The most disastrous volcanic event in Mexico in historical times was the eruption of the Chichón or Chichonal in 1982. The volcano shot up a column of gas, steam and smoke almost 18 kilometers high, showering ash and pyroclasts for miles around, covering some towns close to the volcano with meters of debris. About 2,000 people died as a result, and the region's economy was severely damaged after 153 square kilometers were completely devastated and 30,000 square kilometers were covered with at least one millimeter of ash.

Note: Fragments taken from the article by Juan Manuel Espíndola and José Luis Macías Vázquez, "El vulcanismo," *Ciencias* 41 (Mexico City), January-March 1996, pp. 12-22.