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The Volcano Disaster Assistance Program—Helping to Save Lives Worldwide for More Than 30 Years

What do you do when a sleeping volcano roars back to life? For more than three decades, countries around the world have called upon the U.S. Geological Survey's (USGS) Volcano Disaster Assistance Program (VDAP) to contribute expertise and equipment in times of crisis. Co-funded by the USGS and the U.S. Agency for International Development's Office of U.S. Foreign Disaster Assistance (USAID/OFDA), VDAP has evolved and grown over the years, adding newly developed monitoring technologies, training and exchange programs, and eruption forecasting methodologies to greatly expand global capabilities that mitigate the impacts of volcanic hazards. These advances, in turn, strengthen the ability of the United States to respond to its own volcanic events.

VDAP was formed in 1986 in response to the devastating volcanic mudflow triggered by an eruption of Nevado del Ruiz volcano in Colombia. The mudflow destroyed the city of Armero on the night of November 13, 1985, killing more than 25,000 people in the city and surrounding areas. Sadly, the tragedy was avoidable. Better education of the local population and clear communication between scientists and public officials could have allowed warnings to be received, understood, and acted upon prior to the disaster.

VDAP strives to ensure that such a tragedy will never happen again. The program's mission is to assist foreign partners, at their request, in volcano monitoring and empower them to take the lead in mitigating hazards at their country's threatening volcanoes. Since 1986, team members have responded to over 70 major volcanic crises at more than 50 volcanoes and have strengthened response capacity in 12 countries. The VDAP team consists of approximately 20 geologists, geophysicists, and engineers, who are based out of the USGS Cascades Volcano Observatory in Vancouver, Washington. In 2016, VDAP was a finalist for the Samuel J. Heyman Service to America Medal for its work in improving volcano readiness and warning systems worldwide, helping countries to forecast eruptions, save lives, and reduce economic losses while enhancing America's ability to respond to domestic volcanic events.

Cotopaxi erupting in 2015, southeast of Mejía Canton, Ecuador. Photograph copyright Henri Leduc, used with permission.

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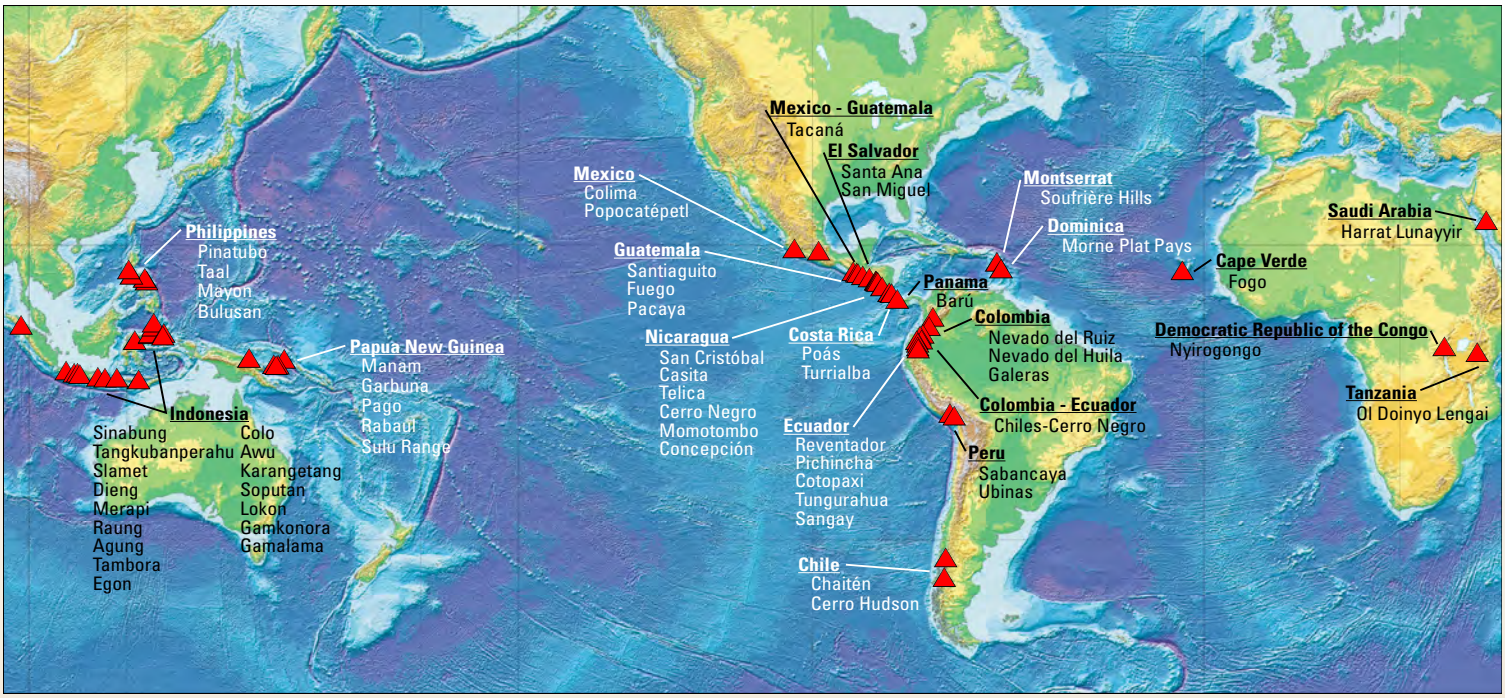


World map with locations of volcanoes (red triangles) at which the Volcano Disaster Assistance Program (VDAP) has responded during the more than 30 years since the program's inception.

VDAP Responses—Timely Warnings Save Lives

Successful volcano responses rely on a combination of geophysical data, fieldwork, satellite observations, historical analysis, and effective communications. VDAP's first major test was in 1991 in the Philippines, where Mount Pinatubo threatened two U.S. military bases, as well as villages and towns around the volcano where hundreds of thousands of Filipinos lived. Swarms of earthquakes and small explosions spurred the Philippine Institute of Volcanology and Seismology to request assistance from VDAP. Together, they installed monitoring networks and estimated the potential for a cataclysmic eruption. With input from VDAP, the U.S. military opted to evacuate more than 15,000 service personnel and dependents from Clark Air Force Base. Evacuations of nearby towns and villages saved between 5,000 and 20,000 lives, and hundreds of millions of dollars worth of equipment was moved or protected before the volcano erupted just days later.

On November 20, 2008, a volcanic mudflow swept through the town of Belalcázar, Colombia, as a result of eruptive activity on the nearby Nevado del Huila volcano. Prior on-site and remote support from VDAP allowed the Colombian Geological Survey to successfully avert a repeat of the earlier Armero tragedy through timely warnings, an aggressive education program, and effective communications. The local people were aware that the volcano posed a threat and were prepared to act; when the warning came, 12,000 people evacuated the town at night.

VDAP incorporates satellite imagery data as another form of monitoring shared with international partners. On October 22, 2010, Indonesian scientists recognized that the frequently active Merapi volcano was experiencing earthquakes, gas emissions, and ground movements far more intense than usual. All available satellites were tasked to track growth of a lava dome at the volcano's summit, and radar images penetrated the clouds that normally block visibility. The images helped VDAP's partners at the Indonesian Center for Volcanology and Geologic Hazard Mitigation (CVGHM) to forecast deadly pyroclastic flows (scorching clouds of ash and rock particles that sweep downhill). On October 25, local authorities evacuated everyone living within 10 kilometers (6 miles) of the summit. Twenty-three hours later, explosions sent the first searing pyroclastic flows as far as 8 kilometers (5 miles) away. Over the following 10 days, VDAP and its Indonesian partners used satellite radar data to track the rapid extrusion of a lava dome at the summit and forecast the potential for an even larger event. On November 4, based on the remote sensing information and increased seismicity, CVGHM called for evacuations to be extended to 20 kilometers (12 miles) from the summit. Just hours later, the largest eruption at Merapi in 100 years generated pyroclastic flows and surges that decimated the landscape,

traveling as far as 15 kilometers (9 miles) from the summit. The timely warnings and evacuations during the 2010 eruptions saved between 10,000 and 20,000 lives.

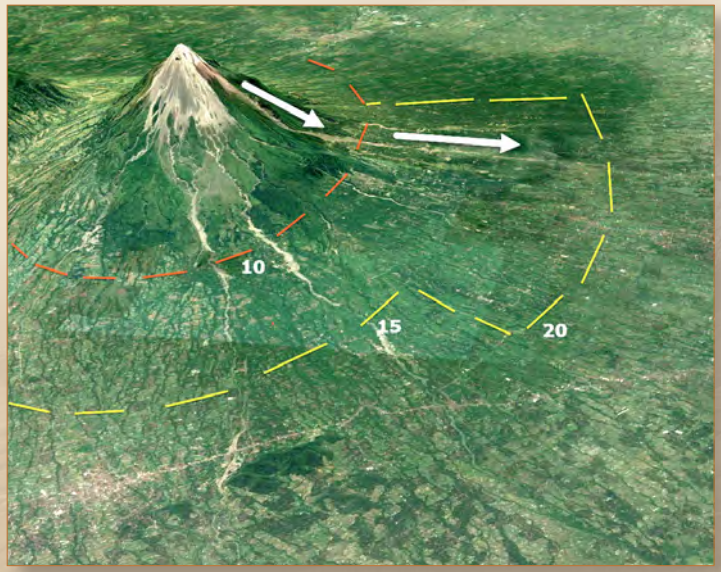
Designing Equipment That Makes a Difference

To support worldwide volcano monitoring efforts, VDAP engineers assemble robust instruments that are simple to install, easy to maintain, and last for many years. Seismic and Global Positioning System (GPS) stations are positioned to detect and locate subtle earthquakes and ground movements that may signal an awakening volcano; they are designed to run on solar energy and relay their data in real time through low-power radios. Field engineers from partner agencies improve their skills in installing and maintaining the systems, either at home on their volcanoes, or during a visit to the Cascades Volcano Observatory. With experience, they can assist neighboring countries, enhancing VDAP's secondary goal of science diplomacy (see sidebar "Science as a Path to Diplomacy").

VDAP also develops new systems to better and more frequently quantify the amounts and types of gas emitted from volcanoes, which are key indicators used to forecast volcano behavior. In the past, volcano scientists have had to make measurements in unsafe locations or fly through the volcanic plume in expensive helicopters or small aircraft. Today, VDAP scientists and engineers deploy scanning ultraviolet spectrometers to measure the volcanic output of sulfur dioxide—a key indicator of shallow magma—from afar. They also designed robust gas "sniffers" (called MultiGAS) to determine the ratio of sulfur dioxide to other key gases such as carbon dioxide, which reveals magma depth and the pathways by which gas reaches the surface. Both technologies can send data directly to the volcano observatory, without the need for frequent servicing of the instruments.

VDAP Training Courses Offer Advanced Education Opportunities

Many countries simply lack the resources to educate and train scientists in the highly specialized tasks related to volcano monitoring and interpretation. VDAP champions a multi-pronged approach to bridge this knowledge gap. Travel grants bring scientists from around the world to the annual seven-week training course at the University of Hawai'i's Center for the Study of Active Volcanoes on Hawai'i Island and in Vancouver, Washington. USGS staff and university partners serve as instructors and mentors for this unique training program. VDAP also sponsors focused workshops at home and abroad on topics including seismology, volcanic gas emissions, lahar (mudflow) modeling, hazards mapping, volcano deformation, remote sensing, and monitoring of crater lakes. USGS mentors also assist partners in writing and publishing their research so that they become the acknowledged experts for their local volcanoes.



Merapi volcano towers above this densely populated part of central Java (approximately 4 million people live nearby). In 2010, the decision to extend the evacuation zone from 10 kilometers (red dashed line) to 20 kilometers (yellow dashed line) likely saved more than 10,000 lives when pyroclastic flows and floods (arrows) raced down the mountain. Base map data from Google, DigitalGlobe, 2017.

Workshops allow VDAP partners and collaborators to discuss best practices for a wide variety of situations. Here, VDAP staff and their Indonesian colleagues review seismic data to uncover earthquake characteristics that may be useful as eruption precursors. Photo by Jeffrey Marso, USGS.

Working Towards Better Eruption Forecasts

Having tools to monitor and evaluate the signals that volcanoes produce is necessary to make successful eruption and hazard forecasts. Besides its role in equipment development, VDAP creates and distributes software that is used globally, to assist volcano observatories with data assessment and interpretation. Yet, forecasts also depend upon understanding the outcomes of past activity at volcanoes around the world. Statistical models and supporting data serve as the tools required to make reliable forecasts. VDAP staff work with academic researchers, volcano observatories, and the body of scientific publications to create new tools to predict volcano behavior. In 2015, VDAP staff worked with Indonesian partners to estimate the likely duration of ongoing lava emissions at Sinabung volcano in northern Sumatra. Looking at global statistics and using a statistical model developed by university colleagues for similar eruptions, it was determined that activity at Sinabung would likely continue at least another three years. This forecast was instrumental in helping Indonesian authorities decide to permanently evacuate villages that were certain to remain in harm's way in the future.

Another important VDAP role is to develop methods to interpret volcanic signals such as earthquakes. Through years of monitoring, VDAP seismologists have observed and documented patterns of earthquakes that occur prior to different kinds of volcanic activity. Their pioneering research is now incorporated into eruption forecasts, and helps seismologists around the world understand the causes and implications of commonly observed seismic phenomena.

Installation of a telemetered, solar-powered scanning spectrometer in 2016 at Sinabung volcano in Sumatra, Indonesia, which has been continuously erupting since 2013. The instrument measures the amount of sulfur dioxide gas emitted from the volcano, which helps forecast volcanic activity. Photograph from Christoph Kern, USGS.

Fostering Best Practices

Each year, new lessons are learned during volcano crises around the world. VDAP works with volcano observatories to develop best practices for responses, communications, and alerts. Representatives meet periodically to discuss new insights, challenges, and developments. The USGS and the Istituto Nazionale di Geofisica e Vulcanologia in Italy work with VDAP and others to sponsor representatives from many countries that would otherwise lack funding to attend. VDAP also contributes to best-practices workshops at international volcano conferences, which bring together civil authorities, emergency responders, and volcanologists who specialize in dangerous volcanoes around the world.

Exchanges Bring Emergency Responders Together

Without clear communication of hazards and risks, even the best science is insufficient to mitigate the threats from volcanic eruptions. Communications protocols are developed and refined in response to lessons learned at volcano crises around the world to ensure that emergency responders have the information they need to make wise decisions in time to make a difference. VDAP sponsors international exchanges where emergency managers, first responders, and land managers from the United States visit the sites of foreign volcano disasters and learn directly from their counterparts. Foreign counterparts, in turn, visit the United States and learn about the Incident Command System, multi-agency response plans, and how new monitoring tools are implemented into U.S. volcano observatory operations. Participants gain insights into the potential hazards and societal effects of volcanic events, and learn how to prepare for and respond to volcanic activity.

"When we went to Armero, something I'd seen and talked about, it really drove home the point of how similar the volcano of Mount Rainier is to the Nevado del Ruiz volcano and the hazards that both volcanoes share. And it really opened my eyes to the things the Colombians had done that worked really well and continue to this day to work really well, and the ways that we can improve our emergency systems to make sure that the tragedies that happened in Armero in 1985 are not replicated here at Mount Rainier."

—U.S. participant in the U.S.-Colombia binational exchange

International Responses Contribute to Readiness at Home

VDAP strengthens the USGS Volcano Hazards Program and the Nation's volcano disaster risk reduction capabilities in numerous ways. By participating in foreign volcano responses, USGS experts continually hone their skills, gaining the experience required to react to domestic eruptions. Equipment is continuously modified and improved to address new challenges encountered around the globe. Close collaboration with the suite of global volcano observatories results in the development of best practices that serve as templates for observatory protocols at home. Observations at erupting volcanoes provide insights that inform conceptual models of how volcanoes work, spark new research efforts, and spur improvements of equipment and forecasting methods that can then be applied in the United States. Through VDAP, the USGS earns credibility, worldwide recognition, and otherwise unobtainable experience. Yet VDAP would be an impossible dream without the infrastructure, personnel, and financial support provided by USAID/OFDA and USGS. More than 30 years after its inception, this unique program continues to be a critical element of global volcano disaster risk reduction.

Science as a Path to Diplomacy

By providing critical monitoring infrastructure, training, and ongoing consultation, VDAP aims to mitigate the risks posed by dangerous volcanoes. Close collaboration with international partners and their stakeholders inevitably results in secondary benefits: friendship, mutual trust, and goodwill. For example, after an unexpected eruption in 2008 at Chaitén volcano (Chile), VDAP assisted with the creation of a seismic network at this previously unmonitored volcano. This led to collaborative research on the volcano's history and hazards, and a shared assessment project to prioritize needs for a national Chilean volcano monitoring system. VDAP scientists were called on to advise the government of Chile at the highest levels regarding volcano hazards monitoring and mitigation. The emergence of Chile's volcano expertise and development of a robust volcano monitoring infrastructure followed, and has also fostered engagement with Argentinean geologists to understand risks from some of the dangerous volcanoes that straddle the Chile-Argentina border. By pursuing a program of science and public safety, VDAP fosters an environment that engenders international cooperation and diplomacy.

In May 2008, heavy rains remobilized ash laid down by the recent eruption of Chaitén volcano, in southern Chile. Though the town of Chaitén (visible in photo) had been evacuated, the floods rendered much of the town uninhabitable. All streets and the nearby airport were buried in 3–6 feet of mud, and the city harbor was destroyed. During the eruption aftermath, VDAP assisted Chile with equipment installation and later co-funded an international research effort to understand the history of the volcano and the effects of the eruption on the nearby environment. In addition, VDAP advised the government of Chile on a new national strategy to reduce risk from volcanic eruptions. Satellite photograph from NASA earth observatory through the FORMOSAT-2 satellite, May 26, 2008.

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The city of Arequipa, Peru, is situated on the flanks of Misti volcano. VDAP works with the Instituto Geofísica del Perú and the Instituto Geológico, Minero y Metalúrgico to mitigate volcanic hazards in the volcano-dense south of Peru. U.S. Geological Survey photograph by John Pallister.

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