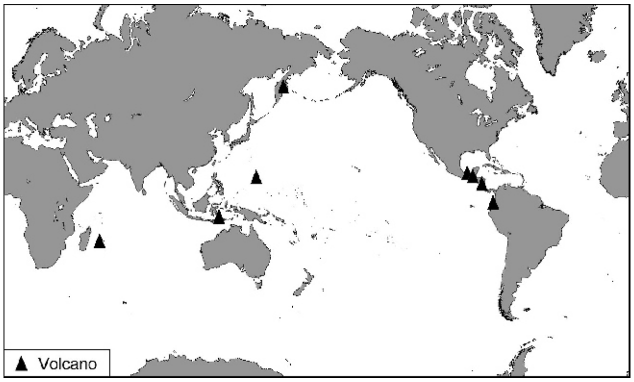
# Bulletin of the Global Volcanism Network



*Volume 32, Number 12, December 2007*

Smithsonian
*National Museum of Natural History*







**Global Volcanism Program · National Museum of Natural History, Room E-421, PO Box 37012 · Washington, DC 20013-7012 · USA**
**Telephone: (202) 633-1800 · Fax: (202) 357-2476 · Email: gvn@si.edu · URL: http://www.volcano.si.edu/**



The text of the *Bulletin* is also distributed through the Volcano Listserv (volcano@asu.edu).

# Piton de la Fournaise

Western Indian Ocean
21.231°S, 55.713°E; summit elev. 2,632 m
All times are local (= UTC + 4 hours)

A caldera collapse occurred at this massive, dynamic shield volcano during early April 2007, displacing the 0.8 x 1.1 km floor of the elliptical Dolomieu caldera downward by ~ 330 m (figure 1). This was both the largest collapse at this volcano since 1760, and one of the few large collapse events seen at this volcano. Worldwide, such events are rarely documented by eyewitness or instrumental observations, with best known examples of collapses including those in 1968 at Fernandina (Simkin and Howard, 1970) and in 2000 at Miyake-jima (Kaneko and others, 2005).

The collapse at this Piton de la Fournaise occurred in association with the early stages of one of the largest historical discharges of lava flows ever seen here. The resulting lavas traveled E to reach the sea where they built a delta. Concurrent with collapse, the seismicity and deformation were cyclic in nature, suggesting collapse proceeded in a step-by-step manner. These and other events are explained by in a recent paper by Michon and others (2007), the source used to compile this report. Our last report, *BGVN* 32:01, discussed events through 22 February 2007.

Piton de la Fournaise has undergone intense eruptive activity since 1998, with two to four eruptions per year typically venting at the summit and proximal areas. Five distal eruptions occurred during 1998-2007, chiefly concentrated along the NE rift zone, and in particular, on the Plaine des Osmondes. Pahoehoe lava flows had completely filled Dolomieu's floor, accumulating during an August 2006-January 2007 eruption to a thickness of 20-30 m.

***Prelude to collapse.*** On 26 February 2007 seismicity started below the summit zone. It progressively increased and over 100 events took place daily during 28-30 March. Seismicity reached anomalously high levels on 30 March at 2025 local time. About 2.4 hours later, a fissure began erupting at 1,900 m elevation SE of Dolomieu and Bory craters and the central cone (at the point labeled 1, figure 1). Discharges continued for 10 hours. Tremor ceased early the next day.

The 30-31 March eruption included lava fountains up to 50 m in height feeding voluminous lava flows. This event was the debut of a new phase of volcanism that presaged the Dolomieu caldera collapse seen in April.

***Collapse.*** A new eruptive phase began 2 April, venting at ~ 600 m elevation ESE of the central cone (at point 2, figure 1). The venting took place along a NW-trending, 1-km-long fissure.

During the next few days, seismicity rates rose to ~ 3-fold larger than in the previous (26 February) episode. As seismicity grew on 5 April, the permanent GPS instrument SNEG situated just NE of Bory crater's rim (figure 1) started to displace inward. The vertical component of motion began with a jolt around noon and markedly progressed during 1900-2300. Next, at 0048 the next day, an Md 3.2 earthquake occurred below the summit (Bory) crater. After that earthquake, seismic station Takamaka (Tkr, figure 1) registered a signal increase of ~ 50%. Coincident with the earthquake, the GPS instrument displaced ~ 15 cm outward. What followed was a series of cyclic deformation events, episodes composed of displacements progressively inward followed by ones sharply outward.

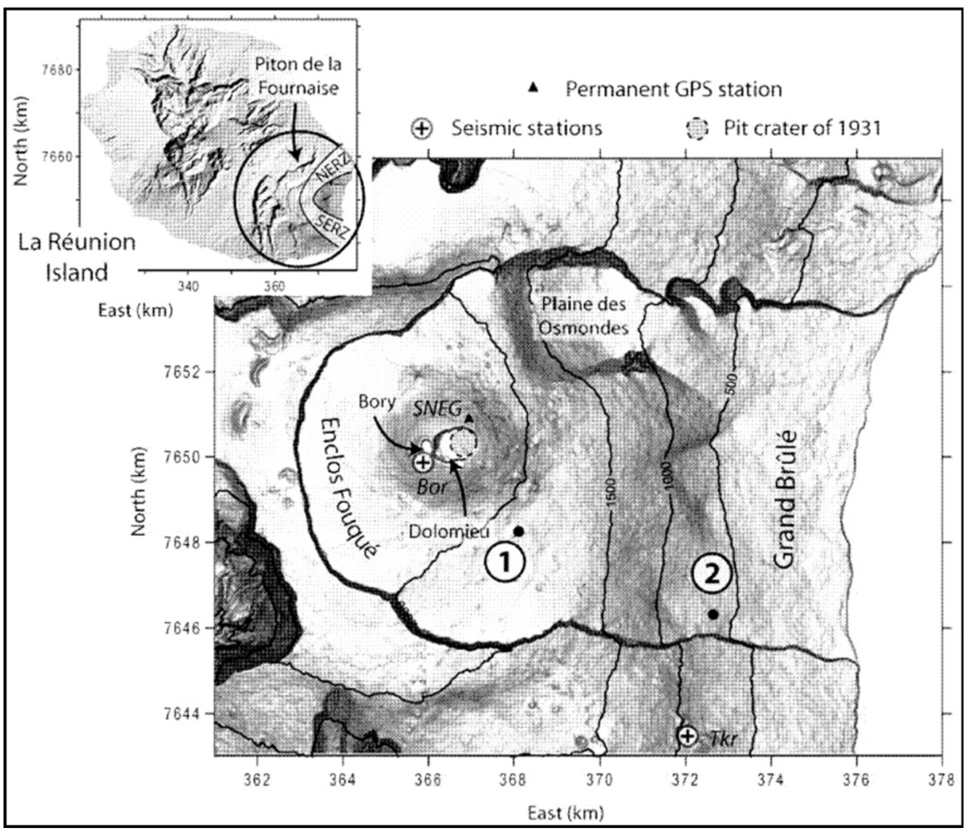



Figure 1. Maps taken from Michon and others (2007) showing location and key geography of Piton de la Fournaise volcano on Reunion island. The inset shows the volcano at the island's E end and indicates the volcano's two major NE- and SE-trending rift zones (NERZ and SERZ). The larger map indicates major features, including the Bory and Dolomieu craters (arrows with heads to respective crater rims), two seismic stations, GPS station SNEG, and key vents in the 30-31 March and April eruptive episodes (1, and the main vent, 2). Note the scales on the frame indicate distance in kilometers.

The displacements linked closely to a series of cyclical seismic and tremor episodes. Each of those consisted of a sharp, post collapse tremor increase, followed by intervals of stable tremor. Many of these initial tremor cycles occurred on roughly two-hour intervals (through the first hours of 6 April), but gradually (with approach to dawn on 6 April) these cycles occurred at about half-hour intervals. On 6 April there occurred a paroxysmal phase during which 200 m high lava fountains vented.

Tremor descended to initial levels before the paroxysmal phase, but cyclical seismic signals

Figure 2. Lava flows at Piton del la Fournaise during the eruption of 6 April 2007. Courtesy of OVPF.

remained until 0100 on 7 April. Venting continued until 1 May, accompanied then by fluctuating tremor.

Estimating the volume of lava emitted was complicated by abundant lava having entered the sea at the coast, where it built a large platform, but based on topography and bathymetry before and after the event, the authors' rough estimate, in millions of cubic meters, was ~ 100-140. This makes this one of the most voluminous eruptions at this volcano during the 20th and 21st centuries (figure 2).

***Collapse morphology and structure.*** The first summit zone observations on the afternoon of the 6th (~ 16 hours after the beginning of the seismic cycles) revealed that the previous geophysical observations and intense eruptions coincided with caldera collapse (figure 3). The 6 April collapse affected the Dolomieu's N part, descending the zone shaded in figure 3 (b) along sub-vertical scarps to the E, N, and W, with a net offset of 200-300 m. The pre-existing floor remained intact on the E and S, forming arc-shaped plateaus there.

On 10 April the caldera had enlarged to engulf most of the Dolomieu structure. It had deepened to a maximum offset (determined from triangulation and confirmed with ASTER stereo images) of 320 to 340 m. Perched plateaus were restricted to the indicated zones. Subsequent morphologic changes were minor. The post-collapse caldera had diameters of 800 x 1,100 m and encompassed 82 x $10^4$ $m^2$, an area 11% larger than it was prior to the April eruptions.

The authors estimated that the post-collapse caldera's downward movement displaced a volume of 100-120 million cubic meters. This displacement was comparable to their estimated volume of emitted lava (~ 100-140 million cubic meters). The initial stage of collapse (seen 6 April; figure 3b) accounted for ~ 80% of the total volume displaced in the offset.

The April collapse may have followed pre-existing arcuate faults. It may also have described a magma chamber, the size and location of which were recently determined from a GPS inversion (Peltier and others, 2007). That study suggested a shallow chamber with diameters of 1.4 km and 1.0 km in the respective E-W and N-S directions.

***References:*** Kaneko, T., Yasuda, A., Shimano, T., Nakada, S., and Fujii, T., 2005, Submarine flank eruption preceding caldera subsidence during the 2000 eruption of Miyakejima Volcano, Japan: Bull. Volcanol., v. 67, p. 243-253, doi: 10.1007/s00445-004-0407-1.

Michon, L., Staudacher, T., Ferrazzini, V., Bachélery, P., and Marti, J., 2007, April 2007 collapse of Piton de la Fournaise: A new example of caldera formation: Geophysical Research Letters, v. 34, p. L21301, doi:10.1029/2007GL031248,2007.

Peltier, A., Staudacher, T., and Bachélery, P., 2007, Constraints on magma transfers and structures involved in the 2003 actity at Piton de La Fournaise from displacement data: J. Geophys. Res., v. 112, p. B03207, doi: 10.1029/2006JB004379.

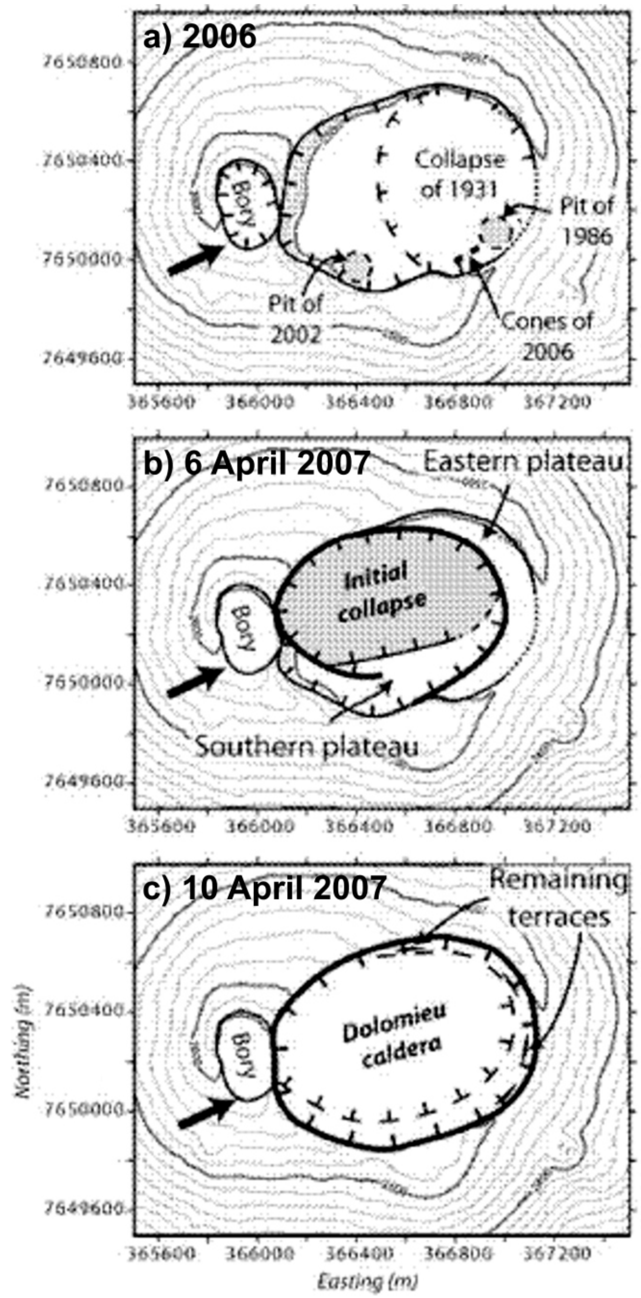



Figure 3. Piton de la Fournaise's Dolomieu caldera depicted in sketch maps both prior to the April 2007 eruption and at two stages during the eruption. The first part (a) represents 31 October 2006. The arrow indicates a fracture network (Carter and others, 2007). After Michon and others (2007).

Simkin, T., and Howard, K. A., 1970, Caldera collapse in Galapagos Islands, 1968: Science, v. 169, p. 429-437.

***Geologic Summary.*** The massive Piton de la Fournaise basaltic shield volcano on the French island of Réunion in the western Indian Ocean is one of the world's most active volcanoes. Much of its >530,000 year history overlapped with eruptions of the deeply dissected Piton des Neiges shield volcano to the NW. Three calderas formed at about 250,000, 65,000, and less than 5000 years ago by progressive eastward slumping of the volcano. Numerous pyroclastic cones dot the floor of the calderas and their outer flanks. Most historical eruptions have originated from the summit and flanks of Dolomieu, a 400-m-high lava shield that has grown within the youngest caldera, which is 8 km wide and breached to below sea level on the eastern side. More than 150 eruptions, most of which have produced fluid basaltic lava flows, have occurred since the 17th century. Only six eruptions, in 1708, 1774, 1776, 1800, 1977, and 1986, have originated from fissures on the outer flanks of the caldera. The Piton de la Fournaise Volcano Observatory, one of several operated by the Institut de Physique du Globe de Paris, monitors this very active volcano.

***Information Contacts:*** *Laurent Michon* and *Patrick Bachélery*, Laboratoire GéoSciences Réunion, Institut de Physique du Globe de Paris, Université de La Réunion, CNRS, UMR 7154-Géologie des Systèmes Volcaniques, La Réunion, France; *Thomas Staudacher* and *Valérie Ferrazzini*, Observatoire Volcanologique du Piton de la Fournaise, Institut de Physique du Globe de Paris, 14 route nationale 3, 27 ème km, 97418 La Plaine des Cafres, La Réunion, France (URL: http://ovpf.univ-reunion.fr/); *Joan Marti*, Institute of Earth Sciences "Jaume Almera," Consejo Superior de Investigaciones Cientificas, Barcelona, Spain.

## Batu Tara

Lesser Sunda Islands, Indonesia
7.792°S, 123.579°E; summit elev. 748 m
All times are local (= UTC + 8 hours)

On 1 July 2006 a pilot reported an ash cloud from Batu Tara drifting NW at 1.5 km altitude, but the Darwin VAAC could not identify ash in MTSAT satellite imagery around the same time. No other evidence or reports could confirm a renewal of activity at this small uninhabited island volcano, which last erupted during 1847-1852. Starting in January 2007, there were satellite thermal anomalies suggesting an eruption. Two months later observers issued reports of ash plumes from explosive activity.

MODIS infrared satellite data, compiled and analyzed by the Hawai'i Institute of Geophysics and Planetology (HIGP) Thermal Alerts System, first showed anomalies at Batu Tara on 17 January 2007. For almost a year thermal signatures typically were detected every 1-3 days, sometimes every 4-5 days, with rare gaps of 6-7 days. After no anomalies during 9-17 January 2008, regular hotspots returned and were continuing at the end of the month.

The Darwin VAAC reported that an ash cloud seen in MTSAT and Terra MODIS imagery at 1633 on 13 March 2007 reached an altitude of 4.3 km and drifted N. By 0833 on 14 March the plume was seen extending about 90 km NE, after which it dissipated. Later that day the low-level plume was 55 km long towards the ENE.

A continuous low-level plume, at or below summit level, was observed on imagery on 15 March extending SE from the summit to a distance of 65 km. The plume later shifted around towards the E, to a distance of ~ 37 km, on 16 March. Imagery on 17 March showed another direction change, to the NE, extending a maximum of 74 km. Government officials, residents, and fishermen on Lembata Island (formerly known as Lomblen), ~ 50 km S, observed plumes rising from Batu Tara during 17-19 March, but there was no night glow. The plumes on 19 March were reportedly 500-1,500 m high and blowing E. Although meteorological clouds interfered with satellite observations, the Centre of Volcanology and Geological Hazard Mitigation (CVGHM) reported continuous eruptions with ash to 500 m above the summit on 20 March. A continuous thin plume was also seen on satellite imagery extending 37 km NE on 20 March. Similar activity continued through 21-22 March, with low-level plumes identified in imagery out to distances of 46-56 km towards the E and SE.

High waves on 22 March prevented a science team from landing on the island, where CVGHM had hoped to install instruments that could be monitored from the observation post at Lewotolo volcano, ~ 52 km SSW. Observations on 22 March described ash plumes from the summit crater rising as high as 2 km and ashfall killing trees within a 500-m radius of the summit on the southern and eastern slopes. White emissions with intermittent dense gray plumes also originated from a location on the E foot of the mountain, with the clouds rising up to 250 m. A small cone grew there with a crater diameter of ~ 10 m. From a vantage point on Lembata, other observers reported minor ashfall, smelled sulfur odors, heard explosion noises, and saw incandescent blocks ejected to heights of ~ 500 m that landed in the sea.

Meteorological clouds continued to intermittently obscure satellite observations during 23-30 March, but available clear imagery and CVGHM reports indicated continuing plumes at low altitudes extending as far as 90 km downwind (figures 4 and 5). Infrared anomalies also continued to be recorded during this time. On the morning of 31 March a plume was seen extending about 150 km NNW.

CVGHM reported observations from 30 March that indicated the E side of the volcano had been most impacted by recent activity. Plant life on the E side was affected by hot ashfall. White plumes rose from the summit to an altitude of ~ 1.7 km and drifted E. Incandescent rockslides and cooled lava flows were observed at the E foot of the volcano. Steam and occasional ash plumes rose from the area where hot material interacted with the sea.

Semi-continuous eruptions through 3 April produced low-level plumes, generally to altitudes of 1.5-3 km, reported by ground observers and seen in satellite imagery to distance of 37-56 km downwind in various directions. On 5 April, plumes rose to 3 km altitude. Based on satellite imagery the CVGHM reported that on 5 April a lava flow on the E slope created a central levee with debris fans on either side. The delta-like shape spanned about 450 m across. A lava flow also extended 100 m into the water. Diffuse plumes seen in satellite imagery rose to altitudes of 1.5 km and drifted W and NW during 4-11 April. Explosive activity producing noticeable ash plumes generally declined in April, and on the 12th the hazard status was lowered to

Figure 4. Aerial photograph of Batu Tara erupting in late March 2007 with an ash plume blowing NE. View is towards the SSE from a Garuda Boeing 737 flight between Timika, Papua New Guinea and Bali, Indonesia. Lembata Island is in the right background. Courtesy of Michael Thirnbeck.

Figure 5. Aerial photograph of Batu Tara erupting in late March 2007 showing a steam plume and a smaller ash puff. View is towards the SE from a Garuda Boeing 737 flight between Timika, Papua New Guinea and Bali, Indonesia. The bay on the left opens to the E. Courtesy of Michael Thirnbeck.

Alert Level 2. However, hotspots continued to be recorded on an almost daily basis.

A pilot reported a low-level ash plume extending 90 km W on 27 April, but ash could not be identified in satellite data. Based on satellite imagery and CVGHM, the Darwin VAAC issued reports of diffuse low ash plumes drifting W during 5 and 10-12 May. On 19 June an ash plume rose to an altitude of 1.7 km. Clouds inhibited visual observations on the other days during 18-25 June. However, on 19 June, a dense white plume rising to 1,000 m high was observed. Between 28 June and 1 July, diffuse white plume was observed rising to 50-150 m. An ash column reached 750 m above the summit.

Based on observations of satellite imagery, the Darwin VAAC reported that on 18 September, diffuse ash plumes rose to an altitude of 2.4 km and drifted W for 140 km. CVGHM lowered the Alert Level to 1 on 9 October. During 3 September-9 October, plumes rose to an altitude of approximately 1.4 km, 700 m above the summit. Satellite imagery showed an ash plume on 13 October that rose to an altitude of 3 km and drifted N and W. Despite time gaps when plumes were not seen and the decreased frequency of explosion plumes, MODIS data recorded thermal anomalies at least every few days throughout April-October 2007, and continuing into February 2008.

***Geologic Summary.*** The small isolated island of Batu Tara in the Flores Sea about 50 km N of Lembata (formerly Lomblen) Island contains a scarp on the eastern side similar to the Sciara del Fuoco of Italy's Stromboli volcano. Vegetation covers the flanks of Batu Tara to within 50 m of the 748-m-high summit. Batu Tara lies N of the main volcanic arc and is noted for its potassic leucite-bearing basanitic and tephritic rocks. The first historical eruption from Batu Tara, during 1847-52, produced explosions and a lava flow.

***Information Contacts:*** *Centre of Volcanology and Geological Hazard Mitigation (CVGHM)*, Diponegoro 57, Bandung, Jawa Barat 40122, Indonesia (URL: http://portal.vsi.esdm.go.id/joomla/); *Darwin Volcanic Ash Advisory Centre (VAAC)*, Bureau of Meteorology, Northern Territory Regional Office, PO Box 40050, Casuarina, Northern Territory 0811, Australia (Email: darwin.vaac@bom.gov.au; URL: http://www.bom.gov.au/info/ vaac/); *Michael Thirnbeck*, Jakarta, Indonesia (http://www.flickr.com/photos/thirnbeck/); *Hawai'i Institute of Geophysics and Planetology (HIGP) Thermal Alerts System*, School of Ocean and Earth Science and Technology (SOEST), Univ. of Hawai'i, 2525 Correa Road, Honolulu, HI 96822, USA (URL: http://hotspot.higp.hawaii.edu/).

# Anatahan

Mariana Islands, Central Pacific
16.35°N, 145.67°E; summit elev. 790 m
All times are local (= UTC +10 hours)

During mid 2007 and into early February 2008, Anatahan (figure 6) discharged occasional significant plumes, as restless seismicity associated with intermittent eruptions continued. Key source data for this report came from the U.S. Geological Survey (USGS), the Emergency Management Office of the Commonwealth of the Northern Mariana Islands (EMO), NASA Earth Observatory, and the Washington Volcanic Ash Advisory Center (VAAC).

The same day MODIS acquired this image, the U.S. Air Force Weather Agency reported an odor of sulfur on the island of Guam, ~ 200 km SW of Saipan, which also suggests the presence of vog. USGS and EMO air quality instruments on Saipan recorded a maximum 5-minute average of 959 ppb sulfur dioxide ($SO_2$) and 99 ppb hydrogen sulfide ($H_2S$) on 18 March. Although such plumes can cause closure of the Saipan airport and result in health risks to Saipan residents, such problems were not mentioned in reports of this incident.

***Crater lake disappears.*** Seismicity remained restless and intermittent plumes continued to discharge from Anatahan during late 2007 and into 2008. By 31 January 2008 the crater lake had disappeared.

Distinct increases in amplitude of seismic tremors occurred on 26 and 28 November 2007. Explosions were also observed, with rates peaking on 28 November at several per minute. This increase prompted raising the alert level to Yellow/Advisory on 29 November.


Figure 6. Satellite image of Anatahan in early 2008. Bright white areas are clouds. A diffuse plume dirfting NW appears to be originating from fumaroles in the eastern crater. Courtesy of Google Earth and Digital Globe, accessed 20 February 2008.

On 14 December 2007 the Washington Volcanic Ash Advisory Center (VAAC) reported a steam plume visible in satellite data, but no indication of ash. There was a small surge in seismic activity recorded on 16 December that decreased to previous levels by the following day. According to the U.S. Air Force Weather Agency, a plume on 30 December consisted primarily of steam and gas, with little ash content. Seismic tremor levels increased 16 January 2008 and persisted.

On 31 January 2008, satellite data showed that the lake in the E crater, a water body whose level had been dropping since September 2007, had disappeared. According to the USGS, the tremor indicated that the volcano may have entered a new phase within its current episode of unrest, and the disappearance of the lake suggested that the magmatic heat source may have moved closer to the surface.

Ash emissions occurred at Anatahan on 3 February 2008. Satellite images showed a diffuse ash plume extending W for ~ 100 km. It was not possible to determine precisely the altitude of this ash plume from the currently available data, but it was likely less than 1,500 m. On 5 February, the USGS reported persistent elevated seismic tremor and continued detection of $SO_2$ in satellite data. The USGS changed the Aviation Color Code to Orange and the Alert Level to Watch as a result of the ash emissions.

A satellite image (figure 7) shows the volcanic island on 6 February 2008. Dwarfed by clouds overhead, the island released a faint plume (presumably bearing little if any ash) blowing WNW. Data from the satellite-based Ozone Monitoring Instrument (OMI) showed a low-level $SO_2$ plume extending W to SW from the volcano.

No thermal anomalies have been measured by MODIS satellites over Anataham since June 2006. In a recent publication, Hilton and others (2007) reported on newly derived $SO_2$ emission rates for Anatahan.

***Reference:*** Hilton, D. R., Fischer, T. P., McGonigle, A. J. S., and de Moor, J. M., 2007, Variable $SO_2$ emission rates for Anatahan volcano, the Commonwealth of the Northern Mariana Islands: Implications for deriving arc-wide volatile fluxes from erupting volcanoes: Geophysical Research Letters, v. 34, p. L14315, doi:10.1029/2007GL030405.

***Geologic Summary.*** The elongate, 9-km-long island of Anatahan in the central Mariana Islands consists of a large stratovolcano with a 2.3 x 5 km, E-W-trending compound summit caldera. The larger western portion of the caldera is 2.3 x 3 km wide, and its western rim forms the island's 790-m high point. Ponded lava flows overlain by pyroclastic deposits fill the floor of the western caldera, whose SW side is cut by a fresh-looking smaller crater. The 2-km-wide eastern portion of the caldera contained a steep-walled inner crater whose floor prior to the 2003 eruption was only 68 m above sea level. A submarine volcano, NE Anatahan, rises to within 460 m of the sea surface on the NE flank of the volcano, and numerous other submarine vents are found on the NE-to-SE flanks. Sparseness of vegetation on the most recent lava flows on Anatahan had indicated that they were of Holocene age, but the first historical eruption of Anatahan did not occur until May 2003, when a large explosive eruption took place forming a new crater inside the eastern caldera.

***Information Contacts:*** *Emergency Management Office of the Commonwealth of the Northern Mariana Islands (EMO-CNMI)* and *USGS Hawaii Volcano Observatory*, PO Box 100007, Saipan, MP 96950, USA (URL: http://www.cnmiemo.gov.mp/ and http://volcano.wr.usgs.gov/cnmistatus.php); *U.S. Air Force Weather Agency (AFWA)/XOGM*, Offutt Air Force Base, NE 68113, USA (Email: Charles.Holliday@afwa.af.mil); *NASA Earth Observatory* (URL: http://earthobservatory.nasa.gov/); *Washington Volcanic Ash Advisory Center (VAAC)*, Satellite Analysis Branch (SAB), NOAA/NESDIS E/SP23, NOAA Science Center Room 401, 5200 Auth Rd., Camp Springs, MD 20746, USA (URL: http://www.ssd.noaa.gov/); *Google Earth* (URL: http://earth.google.com/).

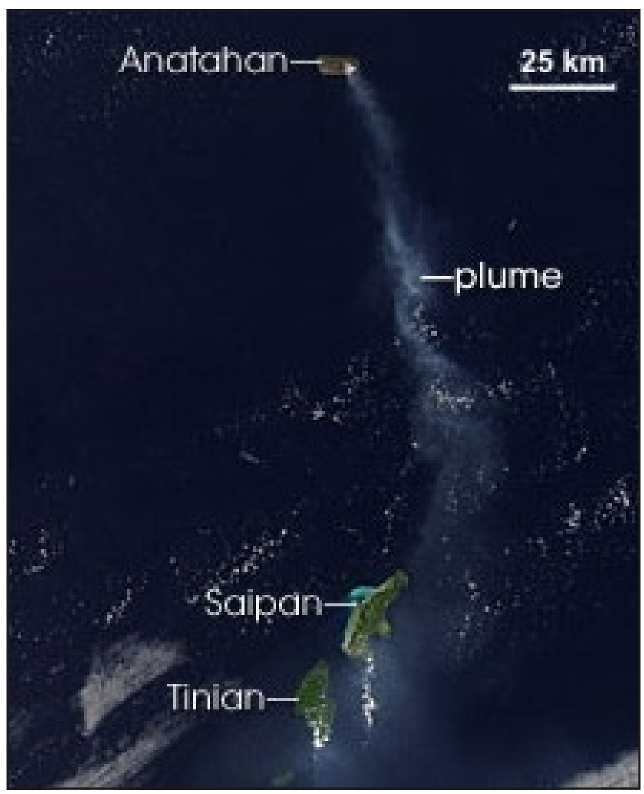



Figure 7. Anatahan released plumes of ash and steam in early February 2008, continuing a pattern of intermittent activity from the previous December. The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite captured this image on 6 February 2008. In this image, a diffuse pale gray plume blows W from the volcanic island and over the Pacific Ocean. NASA image courtesy the MODIS Rapid Response Team at NASA GSFC.

## Bezymianny

Kamchatka Peninsula, Russia
55.978°N, 160.587°E; summit elev. 2,882 m

In *BGVN* 32:11, we erroneously reported a cloud height of 35 km from Bezymianny on 10 November 2007. The plume on that day was a steam plume that extended ~35 km *downwind*.

***Reference:*** Cergey Ushakov, Kamchatkan and Northern Kuriles Volcanic Activity, KVERT INFORMATION RELEASE 57-07, Saturday, November 10, 2007, 03:30 UTC (15:30 KDT).

## El Chichón

México
17.360°N, 93.228°W; summit elev. 1,050 m
All times are local (= UTC - 6 hours)

On 4 November 2007, at midnight, a landslide along the Grijalva river buried a settlement (Juan de Grijalva, Municipio de Ostuacán, Chiapas) located ~ 25 km WSW from the 1982 crater. The event, the subject of a report in the newspaper *La Jornada*, was reported to have buried 40-60 dwellings and killed at least 10, but more likely 200-300 residents.

Concern arose as to whether the event was triggered by El Chichón volcano. The scientists authoring this report, which included those from the Instituto de Geofísica of the Universidad Nacional Autónoma de México (UNAM), noted that low-frequency rumbling (presumably tremor) can clearly be felt inside the active crater. They associated these perturbations with the hydrothermal system.

The authors considered the perturbations too small to cause the distant landslide. According to the authors, the landslide at the Grijalva river was probably the result of morphological instability after heavy rainfall, rather than associated with El Chichón behavior.

However, in the aftermath of the 1982 eruption, El Chichón's nearby flanks still contain abundant unstable slopes, and the new vegetation fails to keep up with the erosion rate. Also, intracrater avalanches still occur, particularly after heavy rainfall. According to co-author Dmitri Rouwet, the rumbling beneath the crater often triggers small intracrater avalanches.

El Chichón was the scene of large Plinian eruptions in 1982, and the crater hosts a shallow crater lake that has drastically varied in size since January 2001. Figure 8 shows the lake in 2005, the smallest volume at this crater lake yet observed. In March 2007 (figure 9) the lake contained the largest volume yet observed (~ 6 x $10^5$ $m^3$).

***Boiling springs.*** The changes in lake volume stem largely from variable discharges at a boiling spring, rather than merely reflecting direct input from rainfall and evaporation.

During 2001, 2004 and 2007 a large-volume lake was associated with a high discharge (over 10 kg/s) into the lake. Saline, near-neutral pH water pours from a boiling geyser-like spring on the lake's N coast. This took place in months such as January, only a few months after the end of the June-October rainy season. The salinity was greater when the lake had higher volume. This observation implies that the direct input of rainwater is not a major contributor to lake volume. Instead, rainwater is thought to infiltrate into the crater floor and then discharge into the lake through the boiling springs.

These springs alternate between periods of high- and low-water discharge feeding the lake. The periods of high discharge at the springs correspond to periods when the lake grows. The periods of low discharge at the springs correspond to vapor discharge there, intervals when the lake shrinks.

In general, ongoing measurements suggest decreasing concentrations for the boiling spring and crater lake waters with time. This suggest an absence of new magmatic input

Figure 8. The crater lake at El Chichón when it contained the smallest water volume ever recorded here (5 June 2005). The crater diameter is ~ 1 km. Courtesy of L. Rosales.

Figure 9. The crater lake at El Chichón when it contained the largest water volume ever recorded here (26 March 2007). Courtesy M. Jutzeler.

Figure 10. The crater lake at El Chichón crater lake as seen on 20 December 2007. Courtesy A. Mazot.

since 1982. After the 2007 rainy season the lake volume decreased, coinciding with a change to pure vapor emission from the geyser-like spring since August 2007 (figure 10).

***Tremor, gas fluxes, inferences, and ongoing monitoring.*** The authors of this report inferred that the low-frequency tremor and rumbling beneath the crater floor stemmed from fluid migrations inside the boiling aquifer, sometimes causing small intra-aquifer phreatic explosions. Nevertheless, crater floor inspection during December 2007 found it unbroken (without evidence of rupture or breaching). The crater morphology, notably the distribution of fumarolic fields, has on the whole remained stable since shortly after the 1982 eruptions.

The $CO_2$ gas fluxes from the crater lake's surface and floor were recently sampled using a floating accumulation chamber to measure the output. The calculated mean emission rate at the lake's surface in March 2007 was 1,500 g / ($m^2$ · day), and in December 2007 a preliminary estimate was 860 g / ($m^2$ · day). A preliminary flux rate from the crater floor in October 2007 was 1,930 g / ($m^2$ · day).

In addition, infrared camera images proved useful to quantify the thermal output. A good correlation appeared between gas flux and ground temperature. This may offer potential for future monitoring.

The authors inferred that future El Chichón volcanism might take the form of intracrater dome growth. Such growth could follow changes in chemistry, temperature and dynamics of the crater lake, the degassing regime, seismicity, geomagnetism, crater morphology, or other unrest such as the onset of phreatic explosions. Such processes can occur very rapidly, as recently shown by the dome growth at Kelud, Indonesia, in November 2007. However, the authors' investigation found no evidence to support current dome growth.

Future updates on the activity of El Chichón can be found on the CVL-IAVCEI website (http://www.ulb.ac.be/sciences/cvl/index.html).

***Geologic Summary.*** El Chichón is a small, but powerful trachyandesitic tuff cone and lava dome complex that occupies an isolated part of the Chiapas region in SE México far from other Holocene volcanoes. Prior to 1982, this relatively unknown volcano was heavily forested and of no greater height than adjacent non-volcanic peaks. The largest dome, the former summit of the volcano, was constructed within a 1.6 x 2 km summit crater created about 220,000 years ago. Two other large domes are located on the SW and NW flanks. A horse-shoe shaped explosion crater on the SE flank of El Chichón witnesses past explosive activity, now hosting the Agua Caliente thermal springs. Eleven large explosive eruptions have occurred during the last 8,000 years. The powerful 1982 explosive eruptions of high-sulfur, anhydrite-bearing magma destroyed the summit lava dome and were accompanied by pyroclastic flows and surges that devastated an area extending about 8 km around the volcano. The eruptions created a new 1-km-wide, 300-m-deep crater that now contains an acidic crater lake.

***Information Contacts:*** *Dmitri Rouwet*, Istituto Nazionale di Geofisica e Vulcanologia (INGV-Palermo), Sezione di Palermo, Via Ugo La Malfa 153, CAP 90146, Palermo, Italy (URL: http://www.pa.ingv.it/); *Agnes Mazot*, *Loic Peiffer*, and *Yuri Taran*, Instituto de Geofisica, Universidad Nacional Autonoma de Mexico, Ciudad Universitaria, Circuito Exterior s/n, Col. Copilco, Del. Coyoacan, CP 04510, Mexico DF, Mexico (URL: http://www.geofisica.unam.mx/vulcanologia/spanish/personal.html); *Nick Varley*, Centre of Exchange and Research in Volcanology, Faculty of Science, University of Colima, Av. 25 de Julio #965, Col. Villas San Sebastián, C.P. 28045 Colima, Colima, México (URL: http://www.ucol.mx/ciiv/nick/personal_en.htm); *Martin Jutzeler*, Centre for Ore Deposit Research (CODES), University of Tasmania, Australia; and *Laura Rosales Lagarde*, Earth and Environmental Science Department, New Mexico Tech, Socorro, NM, USA; *La Jornada* (URL: www.jornada.unam.mx/).

# Fuego

Guatemala
14.473°N, 90.880°W; summit elev. 3,763 m
All times are local (= UTC - 6 hours)

Eruptive activity has continued at Fuego between January 2007 and early February 2008. Typical activity during this interval consisted of explosions that generated ash plumes up to ~ 2 km above the summit (~ 6 km altitude) and caused local ashfall (reported up to ~ 15 km away, but from one eruption, ~ 25 km away). Strombolian eruptions, avalanches, and lava flows up to ~ 1.5 km long were also commonly reported. Pyroclastic flows traveled up to ~ 2 km. Blocks detaching from the front of the flows and bouncing downslope were often incandescent. Satellite imagery often detected hotspots. Shock waves and rumbling or loud noises, sometimes described as similar to a passing airplane, were commonly noticed. Out last report discussed events through December 2006 (*BGVN* 32:11).

Details included in the text below were provided by the Instituto Nacional de Sismologia, Vulcanología, Meteorología e Hidrologia (INSIVUMEH), the Coordinadora Nacional para la Reducción de Desastres (CONRED), and the Washington Volcanic Ash Advisory Center (VAAC).

The photographs included in this report are by Richard Roscoe, who on his website (www.photovolcanica.com) features more Fuego photos than we can include here. He also includes a brief animation of a small Fuego eruption. His site also provides a beginner's guide to volcano photography as well as cautions about safety and trekking in the area. All of his photos are used with his permission. They were taken during 29-31 December 2007. A companion site by his colleagues M. Rietze and Th. Boeckel also describes their photo excursion. Figures 11-13 are broadly representative of the kinds of eruptions common at Fuego during the reporting interval, and they provide a feel for the regional setting and geography.

During 4-5 January 2007 gas-and-ash clouds rose to 4.2-4.8 km altitude and constant incandescent avalanches from the central crater and a lateral crater ~ 70 m from the S edge of the central crater descended SW towards Taniluyá ravine. Fine ashfall was noted in areas S and ~ 9-15 km SW of the summit. On 12 January there was explosive ejecta and ash plumes up to 4 km altitude. Incandescent material was propelled up to 75 m above the summit and incandescent blocks rolled W towards Taniluyá ravine and Santa Teresa ravine, and S towards Cenizas ravine. Explosive activity was reported again during 21-29 January when incan-

Figure 11. A view of Fuego in eruption as seen from the city of Antigua. Note twin church spires along the photo's lower margin. Fuego (erupting at left) is only one of several volcanoes in this photo; progressively farther towards the right peaks consist of Meseta, Acatenango (highest), and Yepocapa. This copyrighted photo is from around 29-31 December 2007. Used with permission of photographer Richard Roscoe.

Figure 12. An explosive plume rising vertically above Fuego's summit on 29 December 2007, with wisps of falling ash visible on the right side. The photo was taken from Antigua. Copyrighted photo by Richard Roscoe.

descent material and blocks were ejected 100 m above the summit; blocks rolled ~ 500 m S and SW. On 26 and 29 January glowing blocks from lava-flow fronts rolled S towards Cenizas ravine. During an overnight visit to a neighboring summit, Craig Chesner and Sid Halsor saw Strombolian eruptions at roughly half-hour intervals.

No activity was reported after late January until 9-13 March 2007, when lava flows were noted extending ~ 100-150 m W toward Taniluyá ravine and explosive ash plumes rose to 4-4.2 km altitude. On 12 March glowing material was ejected ~ 15-20 m above the central crater. Lava flows on 15 March and explosive incandescent ejecta thrown 200 m above crater rim were accompanied by an ash plume. The longest lava flows traveled ~ 1.5 km W toward Taniluya ravine. Similar activity continued the next day, with previous lava flows advancing and new flows seen in different ravines. Pyroclastic flows also occurred, ash plumes rose to 4-6 km altitude. Shockwaves were felt ~ 15 km away, and Strombolian eruptions propelled glowing tephra 300 m above the summit. Two pyroclastic flows traveled about 800 m; one NW, and another W and SW. During most days 21-27 March Fuego emitted explosive gas-and-ash plumes that rose to ~ 4.7-5.1 km altitude, causing ashfall in areas 5-8 km SSE and 9 km W. On 24 March explosions were followed by lava blocks rolling down the W flank toward Taniluyá ravine. Similar activity on 26 March caused ashfall in areas 10-25 km to the W and SE.

The next reports of activity, during 20-23 April, were of lava flows, pyroclastic flows, explosive incandescent ejecta 50-75 m above the vent, and a gas-and-ash plume up to 4 km altitude. Incandescent material descended 300 m

Figure 13. Incandescent ejecta from Strombolian eruptions of Fuego taken from the N on Acatenango volcano (~ 4 km elevation). The exact date was surmised from text as 30 December 2007. The shape of Fuego's summit has been modified by the growth of a sharp peak, presumably due to the accumulation of spatter and cinder. The night-time exposure also captured in the background the lights of towns on the Pacific coastal plain to the S. Copyrighted photo by Richard Roscoe.

down the S and W flanks. The Washington VAAC reported that an intense hotspot seen on satellite imagery on 21 April was likely caused by a lava flow to the SW. On 23 April a pyroclastic flow and incandescent avalanches traveled down SE and SW ravines; ash explosions caused light ashfall in areas S.

Observations during 17-19 May were of fumarolic emissions ~ 600 m high along with active lava flows extending ~ 100 m SW toward the Taniluyá ravine and ~ 500 m SW toward the Cenizas ravine. The lava flow from the edge of the central crater continued on the S flank (~ 150 m long); landslides of blocks of incandescent material spalled from the front of the flow into the Taniluya ravine. Activity the following week, 26-27 May, consisted of explosive ejecta ~ 100 m above vent, gray steam-and-ash plumes up to 4-4.6 km altitude, and block avalanches to the S and SW. On 28 May the lava flow on the S flank continued to advance and produce incandescent blocks that rolled W in Taniluya ravine. Explosive incandescent ejecta was seen on 29 May, along with lava flows that extended ~ 400 m SW toward Cenizas ravine and incandescent material rising tens of meters above the vent.

On 1-2 August, pyroclastic flows occurred and explosive ejecta was thrown 50-75 m above the crater rim; an ash plume rose to 5.3 km altitude. Incandescent avalanches traveled 500-700 m down the S and W flanks. On 2 August, a moderate eruption produced a pyroclastic flow that traveled ~ 2 km SSW down the Cenizas ravine. A resultant plume produced ashfall S, SW, and W for several minutes.

On 8-9 August, pyroclastic flows and explosive Strombolian activity occurred with a gas-and-ash cloud to 4.4-5.6 km altitude. This eruption was visible from the city of Antigua, even though the resulting lava flows primarily traveled down the S and W flanks, which were on the side opposite from Antigua. Clouds obscured the view of possible E-flank lava flows. Ashfall was reported in areas to the W. Lava flows and related detached blocks traveled 1.5 km down Cenizas ravine to the SW. Several pyroclastic flows descended the flanks. Ashfall was reported in villages to the W, SW, and S.

On 10-13 August, small explosions and ash plumes rose up to 4.3 km altitude. 11 August behavior was characterized by weak explosions that expelled gray ash to 500 m above the crater. On 27 August, lahars carried tree trunks, branches, and blocks down the Lajas drainage to the SE. On 28 August, explosive ash plumes rose to 4.1 km altitude. On 31 August, a lahar 8 m wide and 1.5 m thick descended W down the Santa Teresa ravine.

On 3-4 September, explosive ash plumes rose to 4.5 km altitude. On 3 September, fumarolic plumes rose to 4 km altitude and a 300 m lava flow traveled W down the Taniluya drainage. There were also avalanches in the Cenizas ravine. On 21 September explosions of gray ash rose to ~ 5.8 km altitude and incandescent pulses in the crater rose to 75 m with avalanches in the S and SW flank. On 24 September 2007, moderate and strong explosions occurred, accompanied by ash plumes extending up to 900 m above the crater, and constant degassing sounds for periods of up to 20 min. On 5 October, weak to moderate incandescent explosions occurred, accompanied by ash plumes up to 800 m above the crater, and degassing sounds. Block avalanches were noted in the Taniluyá and Santa Teresa ravines.

On 10 October, weak to moderate explosions occurred, the largest accompanied by ash plumes that rose to 4-5 km altitude. Avalanches from cone building in the inner crater went W into the Taniluyá and Santa Teresa ravines.

On 12 October, INSIVUMEH reported that explosions from Fuego produced ash plumes that rose to altitudes of 4. 2-4.8 km and caused ashfall in areas to the W. The explosions were accompanied by rumbling, and degassing sounds; shock waves were detected up to15 km away. The Washington VAAC reported a thermal anomaly on satellite imagery along with ash plumes that drifted W and NW.

According to Washington VAAC, satellite imagery detected multiple ash "puffs" emitting from the volcano between 24-30 October. They also reported ash plumes on 20 November (4.6 km in altitude) and 29 November. Additional weak to moderate explosions occurred on 7 December and 12 December, expelling ash and causing degassing sounds. Shock waves were noticed up to 15 km away.

On 15 December, Fuego generated a significant ash-and-steam plume that was observed from Antigua and Guatemala. It also produced a considerable flow of ash (and possibly lava) down its E slopes. According to the Washington VAAC, satellite imagery detected a thermal anomaly on 15-16 December. Thereafter, Fuego's activity declined to normal levels, although a few moderate explosions continued, along with an occasional ash plume. An ash cloud from Fuego was observed on 21 December and 26 December 2007.

For 11 January and 24 January 2008, INSIVUMEH reported weak explosions from Fuego that produced ash plumes that rose to altitudes of 4-5 km. Small avalanches of blocks traveled W toward the Taniluyá ravine. Based on reports from INSIVUMEH, CONRED reported on 28 January that the Alert Level was lowered to Green. On 30 January, satellite imagery detected a narrow plumes of gas and possible ash. On 4 February, satellite imagery detected ash plumes that rose to an altitude of 5 km.

***Geologic Summary.*** Volcán Fuego, one of Central America's most active volcanoes, is one of three large stratovolcanoes overlooking Guatemala's former capital, Antigua. The scarp of an older edifice, Meseta, lies between 3,763-m-high Fuego and its twin volcano to the N, Acatenango. Construction of Meseta volcano dates back to about 230,000 years and continued until the late Pleistocene or early Holocene. Collapse of Meseta volcano may have produced the massive Escuintla debris-avalanche deposit, which extends about 50 km onto the Pacific coastal plain. Growth of the modern Fuego volcano followed, continuing the Sward migration of volcanism that began at Acatenango. In contrast to the mostly andesitic Acatenango volcano, eruptions at Fuego have become more mafic with time, and most historical activity has produced basaltic rocks. Frequent vigorous historical eruptions have been recorded at Fuego since the onset of the Spanish era in 1524, and have produced major ashfalls, along with occasional pyroclastic flows and lava flows.

***Information Contacts:*** *Instituto Nacional de Sismologia, Vulcanología, Meteorología e Hidrologia (INSIVUMEH)*, Ministero de Communicaciones, Transporto, Obras Públicas y Vivienda, 7a. Av. 14-57, zona 13, Guatemala City 01013, Guatemala (URL: http://www.insivumeh.pagina.de); *Coordinadora Nacional para la Reducción de Desastres (CONRED)*, Av. Hincapié 21-72, Zona 13, Guatemala City, Guatemala; *Washington Volcanic Ash Advisory Center (VAAC)*, Satellite Analysis Branch (NOAA/NESDIS), 4700 Silver Hill Road, Stop 9910,

Washington, DC 20233-9910, USA (URL: http://www.ssd.noaa.gov/); *Richard Roscoe*, PhotoVolcanica.com (URL: http://www.photovolcanica.com/); *M. Rietze*, *R. Roscoe*, and *Th. Boeckel*, (website) Volcanoes of Central America, Volcan Fuego, Guatemala 29th-31st of Dec. 2007 (URL: http://www.tboeckel.de/EFSF/efsf_wv/fuego_07/fuego_07_e.htm); *Craig Chesner*, Eastern Illinois University, Charleston, Illinois, USA; *Sid Halsor*, Wilkes Barre University, Wilkes Barre, PA 18766, USA.

## Poás

Costa Rica
10.20°N, 84.233°W; summit elev. 2,708 m
All times are local (= UTC - 6 hours)

A small phreatic eruption took place from the crater lake at Poás (figure 14) on 13 January 2008. Various changes such as the loss of fumaroles and minor mass wasting have also occurred at the intracrater dome. The 13 January eruption was described in a report by Eliecer Duarte of the Observatorio Vulcanologico Sismologica de Costa Rica-Universidad Nacional (OVSICORI-UNA). Our previous report discussed September 2006-September 2007 and noted hydrothermal variations and a minor phreatic eruption (*BGVN* 32:09).

A small phreatic eruption occurred at 0900 on 13 January from the hot, acidic Laguna Caliente. Carlos Cordero, a park ranger who witnessed the event, indicated that the event ejected water and sediments from the lake's center to a height of ~ 200 m. This material mainly fell back into the lake, changing its color from a dark green to an intense white (figure 15). The event was also seen by a group of tourists who watched from the main viewpoint ~ 1 km S of the lake. The eye-witness report emphasized the calm conditions of the lake and dome before the eruption.

Post-eruption inspection of the crater by OVSICORI staff revealed that the explosion left a 1.5-m-wide band of sediment up to 10 cm thick along the entire rim of the lake (figure 16). Some sediment also extended about 8 m from the shore at the S rim, near the terrace of the dome. The deposits, clearly debris from the lake bottom, included many shining crystals; larger clasts were absent. After the expulsion, water flowing back into the lake seemingly scoured or removed some sediment.

During a visit of OVSICORI staff, the lake's color changed over about a 3-hour period as a result of gas expulsion. The rapid degassing of thick columns of toxic gases obscured visibility of the other side of the lake. Compared to measurements at the end of November 2007, the lake's temperature had dropped (to 45ºC) and the water level had risen 1.5 m.

The OVSICORI's staff also found a small landslide (8 x 20 m) on the dome's N face (figure 17). They described the landslide as a chaotic deposit of heavily altered angular blocks in a gray matrix that had been altered by hydrothermal activity. A slurry of yellowish materials reached the edge of the lake. Based on field evidence, the team concluded that the small landslide took place immediately after the emission of sediments.

Figure 18 shows a photo of the dome's steep E cliff face. Fumaroles had recently ceased emerging. Cracks and crevices on top of that terrace were also rapidly widening as joint blocks detach.

***Geologic Summary.*** The broad, well-vegetated edifice of Poás, one of the most active volcanoes of Costa Rica, contains three craters along a N-S line. The frequently visited multi-hued summit crater lakes of the basaltic-to-dacitic volcano, which is one of Costa Rica's most prominent natural landmarks, are easily accessible by vehicle from the nearby capital city of San José. A N-S-trending fissure cutting the 2,708-m-high complex stratovolcano extends to the lower northern flank, where it has produced the Congo stratovolcano and several lake-filled maars. The southernmost of the two summit crater lakes, Botos, is cold and clear and last erupted about 7,500 years ago. The more

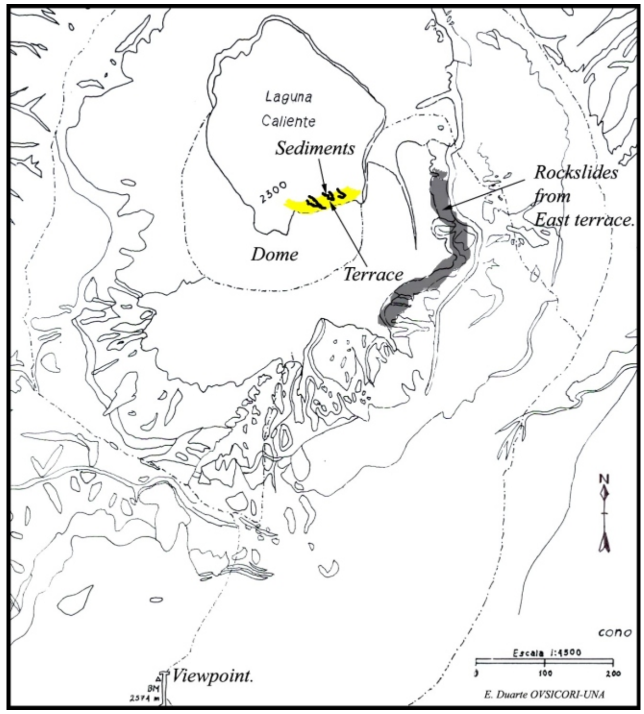



Figure 14. Topographic map of Poás and environs emphasizing the crater lake, scene of a 13 January phreatic eruption. Note the dome and the area labeled 'terrace' on its margin. Map by E. Duarte, OVSICORI-UNA.


Figure 15. A picture of the active crater of Poás taken a short time after the phreatic eruption had ended and the main column had collapsed on 13 January 2008. The dome is in front of the steam-covered lake. The shot was captured by park ranger Carlos Cordero who stood at the main viewpoint S of the lake. Courtesy of OVSICORI-UNA.

prominent geothermally heated northern lake, Laguna Caliente, is one of the world's most acidic natural lakes, with a pH of near zero. It has been the site of frequent phreatic and phreatomagmatic eruptions since the first historical eruption was reported in 1828. Poás eruptions often include geyser-like ejections of crater-lake water.

Figure 16. A remnant of the dried and solidified sediments expelled during the 13 January eruption at Poás. The sediments, fine grained and light in color, appeared to have come directly from the bottom of the crater lake. Note pocket knife for scale. Courtesy of OVSICORI-UNA.

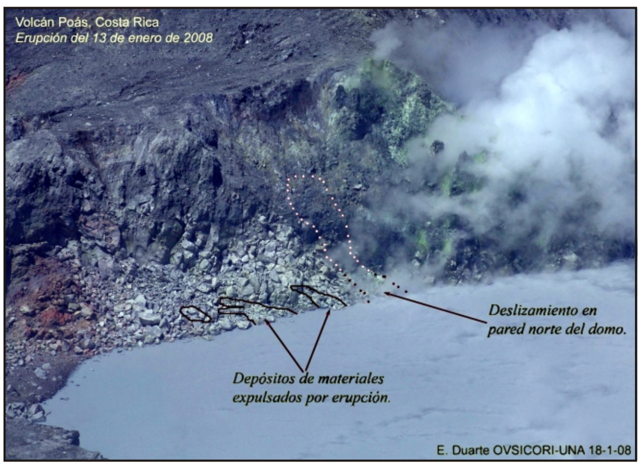



Figure17. This 18 January photo of the crater lake, shoreline, and adjacent dome at Poás, indicates the location of several small areas where 13 January deposits still remained. In addition, a small portion of the dome had detached and moved downslope in a minor landslide that reached the lake. Courtesy of OVSICORI-UNA.

Figure 18. A photo of the E wall of the dome at Poás, a zone of active slope failure. In this area previously active springs and fumaroles had recently disappeared leaving only native sulfur deposits at the mouth of former fumaroles. At the foot of the cliff lies a terrace of debris from mass wasting. Courtesy of OVSICORI-UNA.

***Information Contacts:*** *E. Duarte* and *E. Fernández*, Observatorio Vulcanologico Sismologica de Costa Rica-Universidad Nacional (OVSICORI-UNA), Apartado 86-3000, Heredia, Costa Rica (URL: http://www.ovsicori.una.ac.cr/).

# Guagua Pichincha

Ecuador
0.171°S, 78.598°W; summit elev. 4,784 m
All times are local (= UTC - 5 hours)

Following December 2007 seismicity, Guagua Pichincha generated phreatic eruptions multiple times on 1 February 2008. The summit lies only ~ 8 km W of the limits of Ecuador's capital, Quito. Our last report summarized events through January 2004 (*BGVN* 29:06).

In lead-up to the phreatic eruptions, the Instituto Geofísico Escuela Politécnica Nacional (IG-EPN), reported that an M 4.1 earthquake occurred in the vicinity on 6 December 2007, followed a week later by an increase in fracture earthquakes. These events, continuing through 23 December, were below M 3 and occurred at shallow depths within the volcano. On 24-30 December 2007, IG-EPN indicated that the fumaroles were stable.

IG-EPN reported that a slight increase in activity had been observed over a few weeks at the end of January 2008. This activity culminated on 1 February with seven phreatic explosions of moderate size. IG-EPN went on to say that these phreatic eruptions generally occur during rainy periods, so these explosions are not necessarily indicative of any increase in activity. Since this type of event may occur again, however, IG-EPN recommended that visitors not descend into the caldera. This was mentioned in a 2 February news report in *El Pais*, which further mentioned that strong rains that had recently fallen in Quito and the crater.

As of 14 February, Ash Advisories cataloged by the Washington VAAC's lacked reports describing the 1 February, or any subsequent, phreatic eruptions.

***Geologic Summary.*** Guagua Pichincha and the older Pleistocene Rucu Pichincha stratovolcanoes form a broad volcanic massif that rises immediately to the W of Ecuador's capital city, Quito. A lava dome is located at the head of a 6-km-wide breached caldera that formed during a late-Pleistocene slope failure of Guagua Pichincha about 50,000 years ago. Subsequent late-Pleistocene and Holocene eruptions from the central vent in the breached caldera consisted of explosive activity with pyroclastic flows accompanied by periodic growth and destruction of the central lava dome. Many minor eruptions have occurred since the beginning of the Spanish era at Guagua Pichincha, which is one of Ecuador's most active volcanoes. The largest historical eruption took place in 1660, when ash fell over a 1,000 km radius, accumulating to 30 cm depth in Quito. Pyroclastic flows and surges also occurred, primarily to the W, and affected agricultural activity, causing great economic losses.

***Information Contacts:*** *Instituto Geofísico Escuela Politécnica Nacional (IG-EPN)*, Apartado 17-01-2759, Quito, Ecuador (URL: http://www.epn.edu.ec/~igeo/).