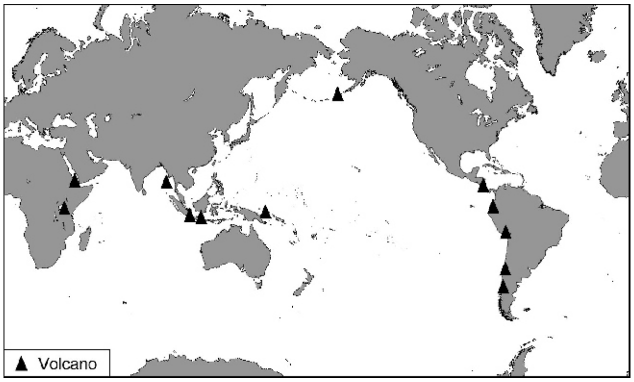
Bulletin of the Global Volcanism Network



Volume 33, Number 6, June 2008

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

Chaitén

Southern Chile
42.833°S, 72.646°W; summit elev. 1,122 m
All times are local (= UTC - 4 hours)

Follow previous reports of May 2008 activity (*BGVN* 33:04, 33:05), this report summarizes Chaitén's behavior from 31 May through 25 July 2008. The bulk of this report came from SERNAGEOMIN (Servicio Nacional de Geología y Minería) and to some extent ONEMI (Oficina Nacional de Emergencia - Ministerio del Interior). A web camera located on a tower in Chaitén town and aimed upstream along the Blanco (Chaitén) river has helped authorities assess both the state of the volcano's plumes and the river (see URL in Information Contacts). In a later section are included some descriptions and photos by Richard Roscoe taken on 9 July.

On 3 June it was reported that lateral blasts or surges (or related processes) had devastated ~ 25 km^2 of native forest. Other behavior during this interval included consistent ash plumes, which were generally present when the volcano was visible, and continued growth of the intracrater dome and tephra cone. Vent areas and the dome and tephra cone's morphology changed as the dome grew more elongate.

The late May to early June behavior included a short-term seismic decrease, and a weakened eruptive column. During the reporting interval, the column was often noticeably weaker than in early May, but the seismicity was still relatively high. The two main seismic instruments monitoring the volcano (figure 1) registered numerous sustained events through late July, which began to cluster NNE of Chaitén. Some of the earthquakes were up to M 2.6.

SERNAGEOMIN repeatedly interpreted the earthquakes to signify magma ascending from depth. If this magma reached the surface, they noted, vigorous eruptions might return. The high-viscosity of rhyolitic magmas seen here increases potential explosivity. This rhyolitic eruption at Chaitén is the first historically at a monitored volcano. The last significant rhyolitic eruption was at Novarupta volcano in Alaska in 1912.

Chaitén town has largely survived the lahars thus far. A deeper concern is that the growing dome and tephra cone sent bouncing rocks and smaller debris into the caldera's moat. In an early July SERNAGEOMIN report, the authors noted that the caldera's breach, located on the S, appeared blocked by recently eroded products. Small lakes were also then seen on the crater floor. Since the moat area drains to the S through this breach and feeds into the Blanco river, temporary dams in the moat area might seal the caldera's outflow, only to suddenly fail and release large volumes of debris towards the town. Despite this concern, as of 25 July such an event had been absent; however, on 12 July a sudden flood struck Chaitén town (see below).

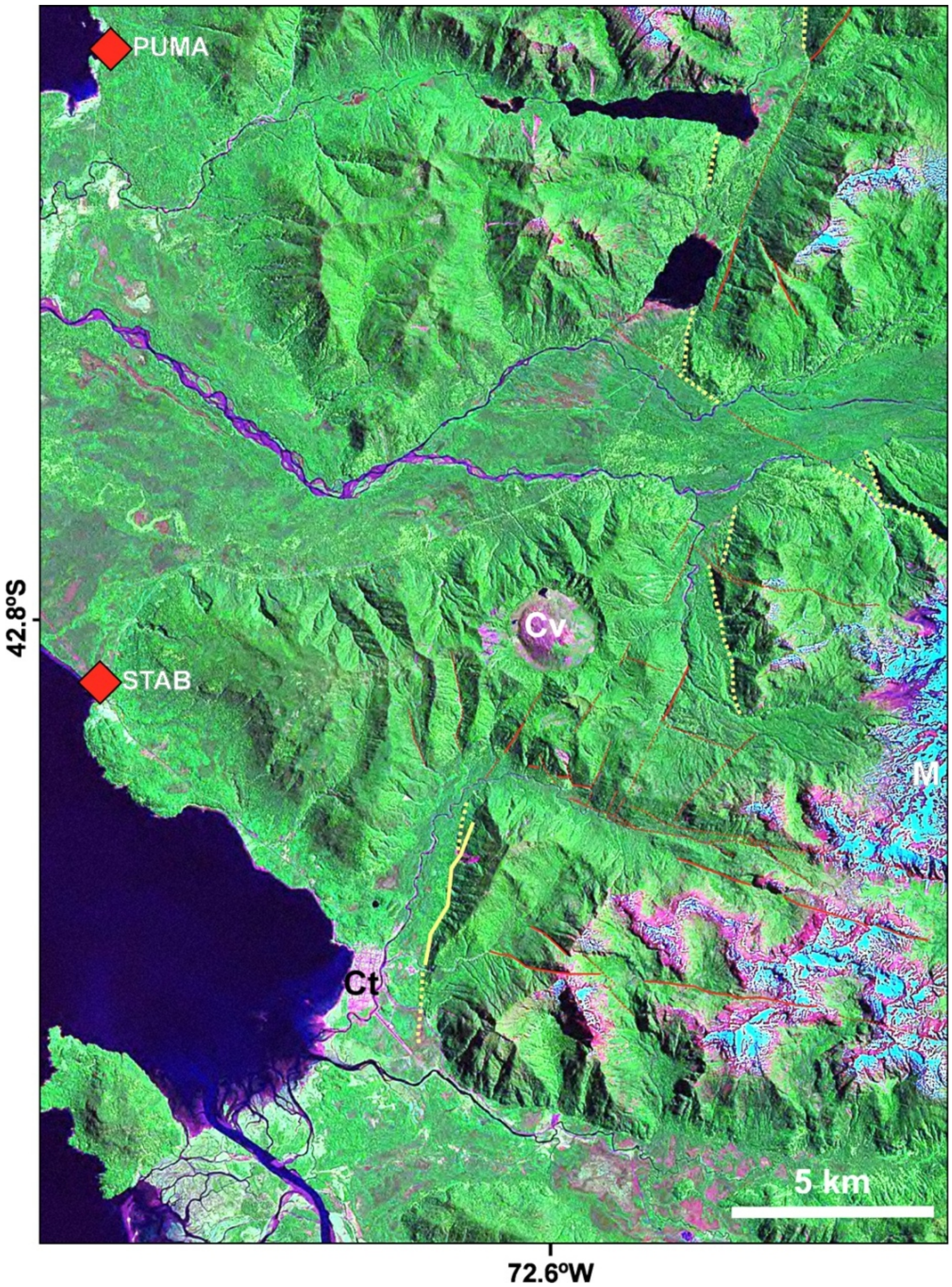

Figure 1. Monitoring instrumentation includes two telemetered seismic stations, PUMA (short for Pumalín) and STAB (short for Santa Barbara), which sit adjacent the coast and monitor Chaitén volcano (Cv). On 12 July the stations detected two earthquakes centered NE of the volcano along a major fault trace there (the Liquiñe-Ofqui fault system). The colored versions of the map distinguish second-order faults, which mostly have left-lateral kinematics (red lines), and eroded scarps (yellow lines). Snow-covered Michinmahuida stratovolcano is also a prominent feature (M, along the E margin of map), as is the town of Chaitén (Ct). Courtesy of Luis E. Lara.

Activity during June 2008. On 1 June, Chaitén's plume blew W, affecting Chiloé island (including the towns of Queilen, Lebjn, Chonchi, Dalcahue, and Castro, the island's capital). These conditions thwarted work on the seismic network. On 2 June dense fog affected the Gulf of Corcovado, especially adjacent Chiloé island, an atmosphere attributed to remobilization of air-fall ash by wind. That day, a helicopter managed to take off and the view enabled scientists to see an eruptive column to no higher than 3.0 km altitude dispersing SSE.

Seismicity on 2 July was higher than the previous days. Abundant were VT earthquakes, followed by long- period (LP) earthquakes. Between 1 and 2 July, seismic stations registered an average of 5 VT earthquakes per hour (below M 2). At some stations, some of the LP signals were sporadic, lasting less than a minute.

A 5 June SERNAGEOMIN report noted that explosions diminished gradually. Although ash was present, vapor dominated the emissions. A 3 June aerial inspection revealed that the dome's volume and footprint had increased, although it still had not reached the caldera's N wall.

The effects of N and NE flank blasts (or surges, pyroclastic flows, or related processes) were noted during aerial observations from the 3 June flight. The surges had scorched and burned an area of native forest. On this day observers computed an estimate of the damaged area, ~ 2,500 hectares (~ 25 km^2). An undated photo looking down on part of the destruction appeared in BGVN 33:05 and more photos appear below. Several SERNAGEOMIN reports mentioned small pyroclastic flows during early and mid-May (12 May in particular, *BGVN* 33:05). Bulletin editors take the 3 June estimate as reflecting the sum of all devastation to that point in time.

On 3 and 4 June the plume's top stood below 3 km altitude. A 10 June SERNAGEOMIN report noted the continued lowered eruptive and seismic intensity through that time. Plumes continued to remain under 3 km altitude and they still affected air travel.

On 12 June observers at Chaitén town noticed tephra-bearing emissions. Noises had emanated from the volcano that day and the previous one. The SERNAGEOMIN report associated these emissions with two new vents seen on the S flank of the old dome, where craters had developed. Vapor-rich plumes had emerged from these areas and the observers inferred that the vents were possibly due to magma-water interactions. In addition, sudden floods swept into Chaitén town in the afternoon on 12 June, despite a lack of evidence for greater rains across the region. They were inferred as related to the emissions the same day.

Seismicity beneath the volcano on 12 June increased in the morning both in terms of the number of earthquakes and their magnitudes. Most of these events were less than M 2. Two prominent earthquakes struck ~ 5 km farther NE of the volcano, along the Liquiñe-Ofqui fault zone.

The 22 June report noted that observers looking at the contact between the old and new domes had seen two craters there that emitted ash plumes. The observers also noted near-source falls of both blocks and ash.

The same report said that a 17 June aerial inspection documented an ash plume to over 2 km over the volcano's summit that blew N and NW. Roars and associated noise from the eruption included the sound of an explosion at 1430 on 17 June. The resulting column rose to a height above the summit of over 3 km but later dropped to 2 km. Emissions continued from a crater S of the contact between the old and new domes. Immediately to the W of this crater, a new and growing crater issued increasingly large emissions of ash and gas. Numerous smaller vents were also apparent, chiefly emitting steam. Loose material covered parts of the old dome, forming a ring-shaped structure (a tephra cone). That structure's steep sides and inner and outer walls occasionally underwent mass wasting. Poor weather during 19-25 June halted aerial inspections then, but ash fell in Chaitén town and to the W and SE, as well as Queilen and other portions of E Chiloé island.

Following 20 June, seismicity remained stable with ~ 40-45 earthquakes per day. Sporadic numbers of VT earthquakes took place; there was no change in the number of LP earthquakes. Investigators inferred a lack of pressure increase in the volcanic system. During bad weather on 23-25 June some earthquakes again occurred on the Liquiñe-Ofqui fault zone, with epicenters in an area 2-3 km E of the volcano. A power outage struck midday on 25 June. A back-up power supply (UPS) worked for a while, but ultimately the outage caused several hours of lost seismic data at the Queilen processing center. Available data suggested a small increase in both the number and amplitudes of earthquakes during 24-25 June. During 0000-1200 on 25 June, instruments recorded 35 VT earthquakes, and four of those were M 2.2; LP earthquakes were absent.

Seismicity during the days leading up the SERNAGEOMIN report issued on 27 June reflected VT earthquakes generally below M 2, reaching 50 per day. An exception was on the 25th when four earthquakes exceeded M 2.0.

July 2008. On 1 July an ash column rose ~ 3 km above the top of the new dome. It blew N and NE. An aerial observation at close hand discerned two roughly vertical, sub-parallel eruption plumes issuing from vents in the crater. One plume, most active in recent weeks, came from a sector S of the new dome. The second plume came from a sector more to the W of the new dome. A photo of the scene in the 3 July SERNAGEOMIN report also depicted the area of eruption largely engulfed in white clouds from numerous fumaroles on the dome. On 3 July SERNAGEOMIN began a series of reports on unrest at Llaima stratovolcano (which went to Red alert on 10 July). Around 16 July a weather front also moved in across the Chiloé island region. Consecutive SERNAGEOMIN reports discussing Chaitén were only issued on 3 and 21 July, with a lack of much discussion on that volcano for the interval 3-15 July.

During 15-20 July seismicity stood relatively high, with an average of 350-400 VT earthquakes per day. On 20 July more than 20 earthquakes surpassed M 2.6. The next reports noted that on 21 and 22 July VT earthquakes occurred 330 times per day; 60 of those were near M 2.6, and that the number of earthquakes decreased on 24 July. Still, some of the minor earthquakes reached M 2.6 and were detected up to 300 km away. Seismic data around this time were interpreted to reflect magma at depth moving towards the surface, possibly implying a reactivation of the system, although the earthquake's depth was poorly constrained.

Chaitén's plume blew E at ~ 2 km altitude above the summit and appeared weaker than usual when seen as the weather cleared after 1500 on 23 July. During 22-24 July, earthquakes had increased both in number and magnitude, with the largest M ~ 2.6.

A new area of epicenters appeared during 22 and 23 July at a location 6 km ENE of the volcano. Seismic stations located 176 and 296 km from Chaitén, respectively monitoring the volcanoes Calbuco and Puyehue-Cordón Caulle, recorded these events, the first such occurrence since the eruption began. Previously, conspicuous epicenters had mainly occurred to the S and SE. Preliminary hypocenter calculations suggested the larger earthquakes in this NNE area were deeper, at 10-15 km depth.

Arrival times of S- and P-waves at stations Pumalín and Santa Bárbara indicated that the smaller magnitude earthquakes still occurred S and SE of Chaitén, whereas the larger magnitude earthquakes struck in the area 6 km ENE. An inspection flight carried viewers to the N and NE of the volcano on 24 July where they saw that the single active central vent sat to the S of the new dome. The emissions then were intermittent, white, and ash poor. When strongest, a thin plume rose to under 2 km altitude, with strong winds causing dispersion to the S and SE. When viewed on 24 July, the new dome also contained a significant depression in the S sector, at a point immediately N of the main active vent mentioned above. This depression emitted steam and gases. The new dome seemed to have decreased its growth rate, at least in the N sector. Strong steaming emerged from base of the dome's E sector. The observers looked around the new dome on the NW, N and NE sides, and they saw neither ponded areas nor lakes. During 24-27 July, the ash column rose to 2.5 km and occasionally 3.0 km altitude. The most active vent was the previously mentioned one located S of the new dome. The plume blew N and NW where it affected various localities along the coast.

Floating pumice. By early June, the white pumice from the eruption accumulated at river mouths to the volcano's W. Some fragments of pumice were as large as 40 cm in diameter. In addition to the Blanco river, those carrying the pumice included the Yelcho and Negro (respectively entering the sea 2 km and 5 km S of Chaitén town). Pumice rafts in the Gulf were seen in May (*BGVN* 33:05). During June and at least early July, along beaches of Chiloé (and particularly at Lelbjn, 12 km N of Queilen, a town almost directly W of Chaitén town) floating pumice continued to arrive. This area lies 60-100 km across Corcorvado gulf from the mouth of the Blanco river at Chaitén town. The pumice deposits, which included tree trunks and other debris, covered a thin zone along the shoreline stretching ~ 20 m from the sea's edge when photographed the afternoon of 1 July.

Figure 3. Drainages redirected by Chaitén's eruption caused erosion of this road to the volcano's N. Courtesy of Richard Roscoe, PhotoVolcanica.com.

Roscoe's July 2008 photos. One of the subjects Roscoe presented on his *PhotoVolcanica* website was Chaitén's N devastated area, and some of those photos appear here (figures 2 and 3). The captions were brief and omitted the direction the camera was aimed. He visited the devastated area on 9 July 2008.

Roscoe noted that in the area he photographed, "Most trees were snapped off a couple of meters above the ground. The [pyroclastic] flow does not appear to have been hot enough to burn the leaves off the trees at the point we visited at the base of the volcano. Many branches with brown leaves were lying around. Very little pumice was found in the area although much of it may have been swept away during subsequent heavy rainfall."

In Chaitén town, Roscoe documented damage-mitigation and salvaging efforts (figure 4). Two of Roscoe's photos showed heavy equipment (a large backhoe and a bulldozer) reshaping the lahar deposits in an attempt to control encroaching lahars. Other scenes included people retrieving belongings, excavating lahar deposits covering the floor and

Figure 2. One of the parts of the devastation zone containing large lithic blocks (~ 1 m across), the most conspicuous being the one at left, which may have been perched above fallen timber. Trees here fell away from the viewer. Courtesy of Richard Roscoe, PhotoVolcanica.com.

lower shelves of a grocery store, and improving drainage from and access to their homes.

Geologic Summary. Chaitén is a small, glacier-free caldera with a Holocene lava dome located 10 km NE of the town of Chaitén on the Gulf of Corcovado. A pyroclastic-surge and pumice layer that was considered to originate from the eruption that formed the elliptical 2.5 x 4 km wide summit caldera was dated at about 9,400 years ago. A rhyolitic, 962-m-high obsidian lava dome occupies much of the caldera floor. Obsidian cobbles from this dome found in the Blanco river are the source of prehistorical artifacts from archaeological sites along the Pacific coast as far as 400 km away from the volcano to the N and S. The caldera is breached on the SW side by a river that drains to the bay of Chaitén, and the high point on its southern rim reaches 1,122 m. Two small lakes occupy the caldera floor on the W and N sides of the lava dome.

Information Contacts: *Servicio Nacional de Geología y Minería (SERNAGEOMIN)*, Avda Sta María No 0104, Santiago, Chile (URL: http://www.sernageomin.cl/); *Oficina Nacional de Emergencia - Ministerio del Interior (ONEMI)*, Beaucheff 1637 / 1671, Santiago, Chile (URL: http://www.onemi.cl/); *Luis E. Lara*, Departamento de Geología Aplicada, SERNAGEOMIN; Richard Roscoe, Photovolcanica.com (URL: http://www.photovolcanica.com/).

Figure 4. Work in Chaitén town to strengthen river banks to protect town from lahars. Although laden with tree trunks, the lahars appear quite uniform in color and character, devoid of coarse lithics or large rafted pumices. Courtesy of Richard Roscoe, PhotoVolcanica.com.

Llaima

Central Chile
38.692°S, 71.729°W; summit elev. 3,125 m
All times are local (= UTC - 4 hours)

A report from OVDAS-SERNAGEOMIN (Volcanological Observatory of the Southern Andes – National Service of Geology and Mining) by Naranjo, Peña, and Moreno (2008) summarized the eruption at Llaima of January through February 2008. This and other reports from OVDAS-SERNAGEOMIN supplements earlier reports (*BGVN* 33:01) and extends observations through late April 2008..

Summary of January-February 2008 eruption. Shortly after 1730 (local time) on 1 January 2008, Llaima began a new eruptive cycle that was very similar in character to a large eruption that had occurred in February 1957. The 2008 activity was centered at the principal crater, a feature 350 x 450 m in diameter with the major axis trending NW-SE. This new continuous eruptive phase began with strong Strombolian eruptions. Strong ejections of lava fragments fell on the glaciers on the high flanks NE and W of the principal cone (figure 5), generating lahars that flowed ~ 15 km to reach the Captrén River to the N and the Calbuco River to the W (figure 6). The eruptive plume rose to an altitude of ~ 11 km and blew ESE; ash accumulated to a depth of ~ 11 cm at a distance of 7 km from the crater.

The 1 January 2008 phase was preceded by a slight increase in tremor and a swarm of low frequency earthquakes, but with an absence of volcano-tectonic (VT) or hybrid (HB) events. On 2 January 2008, the activity began to decline. However, a plume of sulfur dioxide (SO_2) was tracked by satellite (figure 7).

An explosion on 7 January 2008 resulted in an ash plume that rose 5 km above the crater and traveled E toward Argentina. This explosion was associated with a low frequency, large magnitude event.

On 9 January, a series of explosions occurred. The seismicity included a swarm of low frequency, high-amplitude events and an abrupt increase in microseismicity that decreased gradually until 14 January and more slowly thereafter. On 18 January, after discrete low frequency tremors, explosions from the crater resulted in a pyroclastic flow on the upper E flank (figure 8).

On 21 January seismic activity increased. This was followed on 25 January by continuous Strombolian activity in the main crater. During the night of 26 January, a significant increase in activity occured. Pyroclastic-flow deposits were noted during 28 January on the E flank.

A lava lake that had formed in the main crater began to overflow the W rim on 3 February and a lava flow descended for 2.5 km, making channels in the ice tens of meters deep. The 'a'a lava flow, which was 30-40 m wide and 10 m thick, lasted until 13 February.

Between 8-13 February, explosions in the main crater propelled incandescent material 200-500 m in the air. Explosions occasionally alternated between N and S cones in the main crater. On 9 February, the Calbuco River was about 1 m higher than the normal level, likely due to melt water from the lava and glacier interaction. Strombolian eruptions from the main crater were observed during an overflight on 10 February. A strong explosion ejected

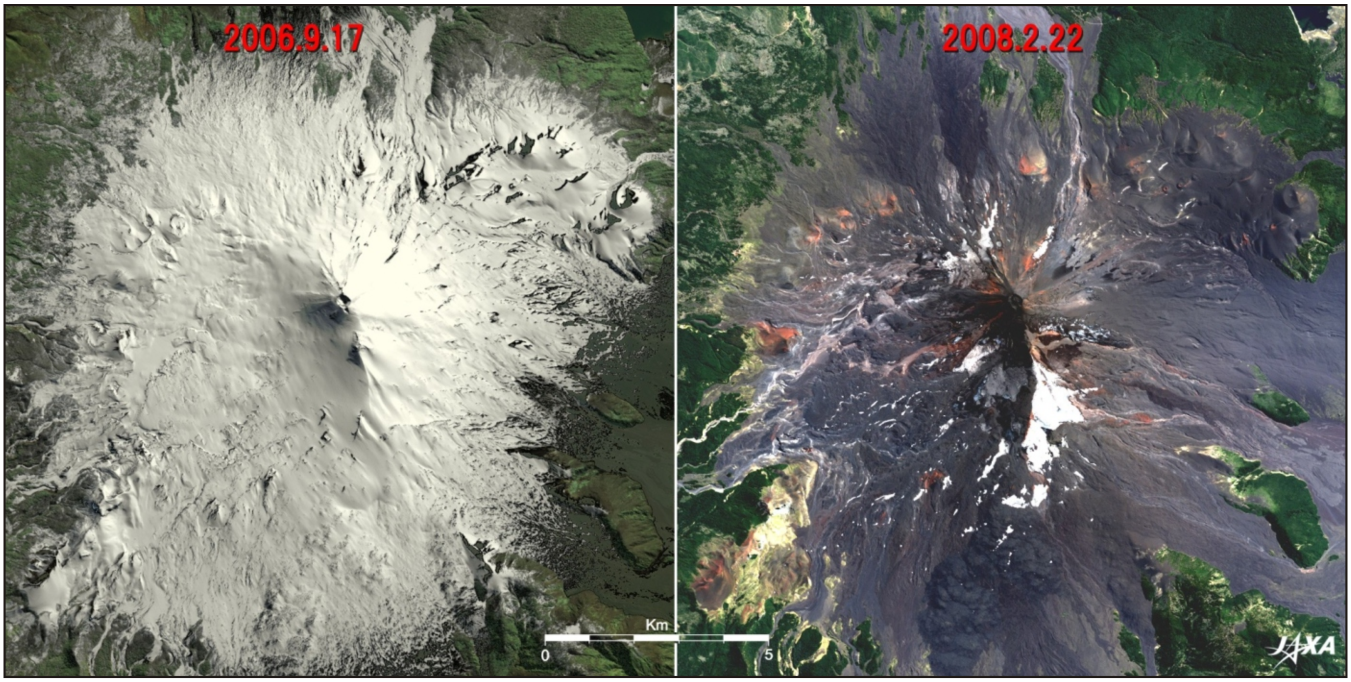

Figure 5. Satellite images depicting Llaima before and after the recent eruptions. The left image shows Llaima on 17 September 2006 covered with a white blanket of snow and ice; the right image shows Llaima on 22 February 2008 after numerous eruptions, with ash covering the remnants of the glacier. Courtesy of the Japan Aerospace Exploration Agency-Earth Observation Research Center (JAXA-EORC) Advanced Land-Observing Satellite (ALOS) website.

bombs onto the E and NE flanks of the volcano on 12 February. Then, on 13 February, incandescence at the summit was noted. Thereafter seismic activity decreased, with only sporadic low frequency signals. The volcano was quiet until 21 February, when a small explosion occurred. Pyroclastic flows were also observed on 21 February descending the E and possibly the W flanks.

During the January-February eruptive phase, various types of plumes were observed, including steam plumes, sulfur dioxide plumes, small ash plumes, and ash-and-gas plumes. The Alert Level remained at Yellow.

March-April 2008. Fumarolic activity from the central pyroclastic cone in Llaima's main crater reactivated on 13 March and intensified during 15-17 March. SO_2 plumes rose to an altitude of 3.6 km and drifted E. During 20-21 March, incandescent material propelled from the crater was observed at night.

During 28 March-4 April, fumarolic plumes from Llaima drifted several tens of kilometers, mainly to the SE. Explosions produced ash and gas emissions, and on 4 April, incandescence was reflected in a gas-and-ash plume. An overflight of the main crater on 2 April revealed pyroclastic material and ash and gas emissions, accompanied by small explosions, that originated from three cones.

On 24 April 2008, seismicity from Llaima again increased. Bluish gas (SO_2) rose from the main crater, and ash-and-gas plumes associated with explosions rose to an altitude of 4.6 km. No morphological changes to the summit were observed during an overflight on 25 April except for a small increase of the diameter of the SE crater.

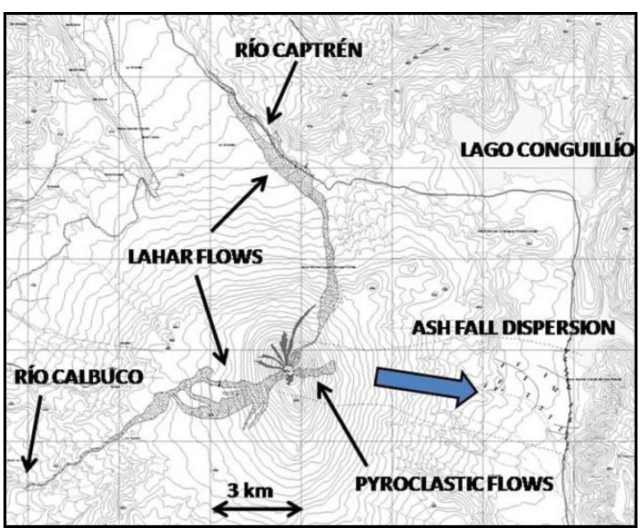

Figure 6. Map showing areas of principal effects of the eruption at Llaima on 1 January 2008. Courtesy of OVDAS-SERNAGEOMIN.

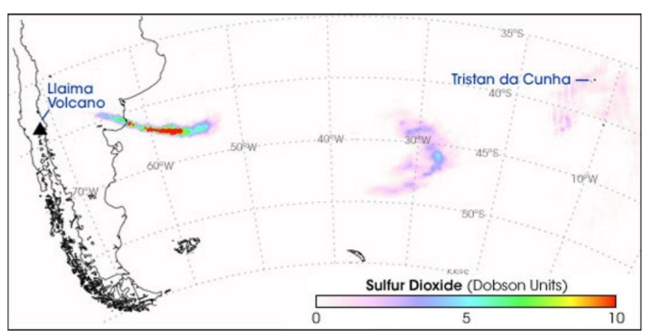

Figure 7. A plume of sulfur dioxide (SO_2) was released on 2 January 2008. The initially intense plume thinned as it moved E. On 4 January 2008, the plume passed over Tristan da Cunha. This image, acquired by the Ozone Monitoring Instrument (OMI) on NASA's Aura satellite, shows the progress of that plume from 2-4 January 2008. OMI measures the total column amount of SO_2 in Dobson Units. (If all the SO_2 in a column of atmosphere is compressed into a flat layer at standard temperature (0°C) and pressure (1 atmosphere), a single Dobson Unit of SO_2 would measure 0.01 mm in thickness and would contain 0.0285 grams of SO_2 /m^2.) Courtesy, NASA Earth Observatory website.

Figure 8. Pyroclastic flow on Llaima's E flank on 18 January 2008. Courtesy, OVDAS-SERNAGEOMIN and Gentileza M. Yarur.

Thermal Anomalies. Thermal anomalies measured by MODIS in 2008 began with an eruption on 1 January 2008 (*BGVN* 33:01) and continued almost daily through 13 February (table 1). Following a brief period of no measured anomalies, a new group occurred 30 March through 4 April, after which none were recorded through 1 June 2008. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) images and reports by ground observers from Projecto Observación Visual Volcán Llaima (POVI) indicated incandescence at the volcano during periods when no anomalies were measured by the MODIS satellites (19-21 March and 24 April 2008), perhaps due to cloud cover. All periods of reported incandescence by ground observers during January 2008 were substantiated by MODIS measured thermal anomalies.

Reference. Naranjo, J.A., Peña, P., and Moreno, H., 2008, Summary of the eruption at Llaima through February 2008: National Service of Geology and Mining (Servico Nacional de Geologia y Mineria - SERNAGEOMIN).

Geologic Summary. Llaima, one of Chile's largest and most active volcanoes, contains two main historically active craters, one at the summit and the other, Pichillaima, to the SE. The massive 3,125-m-high, dominantly basaltic-to-andesitic stratovolcano has a volume of 400 cu km. A Holocene edifice built primarily of accumulated lava flows was constructed over an 8-km-wide caldera that formed about 13,200 years ago, following the eruption of the 24 cu km Curacautín Ignimbrite. More than 40 scoria cones dot the volcano's flanks. Following the end of an explosive stage about 7,200 years ago, construction of the present edifice began, characterized by strombolian, hawaiian, and infrequent subplinian eruptions. Frequent moderate explosive eruptions with occasional lava flows have been recorded since the 17th century.

Information Contacts: *OVDAS-SERNAGEOMIN (Observatorio Volcanológico de los Andes del Sur-Servico Nacional de Geologia y Mineria) (Southern Andes Volcanological Observatory-National Geology and Mining Service)*, Avda Sta María 0104, Santiago, Chile (Email: oirs@sernageomin.cl; URL: http://www2.sernageomin.cl/ovdas/); *NASA Earth Observatory web site* (URL: http://earthobservatory.nasa.gov/); *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/); *Buenos Aires*

Date	Time (UTC)	Pixels	Satellite
01 Feb 2008	0305	2	Terra
	0620	2	Aqua
	1405	1	Terra
	1820	1	Aqua
02 Feb 2008	0345	2	Terra
	0525	1	Aqua
	1450	2	Terra
03 Feb 2008	0250	4	Terra
	0430	4	Terra
	0605	2	Aqua
	1355	1	Terra
	1535	2	Terra
	1810	1	Aqua
04 Feb 2008	0335	4	Terra
	0510	6	Aqua
	1850	2	Aqua
05 Feb 2008	0415	2	Terra
	0555	4	Aqua
	1520	2	Terra
06 Feb 2008	0320	3	Terra
	0500	3	Aqua
	0640	4	Aqua
	1425	2	Terra
07 Feb 2008	0405	4	Terra
	0545	2	Aqua
	1510	2	Terra
08 Feb 2008	0625	6	Aqua
	1415	3	Terra
09 Feb 2008	0350	3	Terra
	0530	6	Aqua
	1455	2	Terra
	1910	2	Aqua
10 Feb 2008	0255	4	Terra
	0435	4	Aqua
	0615	5	Aqua
	1540	4	Terra
11 Feb 2008	0340	4	Terra
	0520	4	Aqua
	1445	5	Terra
	1855	1	Aqua
12 Feb 2008	0425	4	Terra
	0600	7	Aqua
	1525	5	Terra
	1940	4	Aqua
13 Feb 2008	0330	2	Terra
	0645	2	Aqua
30 Mar 2008	0340	1	Terra
01 Apr 2008	0505	1	Aqua
02 Apr 2008	0550	1	Aqua
04 Apr 2008	0400	1	Terra
	0535	2	Aqua

Table 1. MODIS thermal anomalies over Llaima from February through 1 June 2008; data processed by MODVOLC analysis. Daily anomalies were measured from 1-13 February 2008, followed by no anomalies through 29 March. After a period of anomalies from 30 March through 4 April 2008, none were measured through 1 June 2008. Some absences may be due to weather. Courtesy of HIGP Thermal Alerts System.

Volcanic Ash Advisory Center (VAAC), Servicio Meteorológico Nacional-Fuerza Aérea Argentina, 25 de mayo 658, Buenos Aires, Argentina (URL: http://www.meteofa.mil.ar/vaac/vaac.htm); *POVI (Projecto Observación Visual Volcán Llaima) (Project of Visual Observation of Llaima Volcano)* (URL: http://www.povi.cl/llaima/); *Japan Aerospace Exploration Agency-Earth Observation Research Center (JAXA-EORC)* (URL: http://www.eorc.jaxa.jp/); *ONEMI* (Oficina Nacional de Emergencia - Ministerio del Interior) (National Bureau of Emergency - Ministry of Interior), Chile (URL: http://www.onemi.cl/).

Ubinas

Perú
16.355°S, 70.903°W; summit elev. 5,672 m
All times are local (= UTC - 5 hours)

Our most recent report on Ubinas (*BGVN* 33:01) discussed ongoing eruptions with continuous emissions of volcanic ash, rock, and gases during 2006-2007. During that previously discussed interval, ash plumes sometimes reached ~ 9 km altitudes at times, posing a hazard to aviation, ashfall was heavy. The current report discusses activity from the end of the previous report (17 December 2007) through 15 July 2008. During this period, ash plumes were frequent, as indicated in table 2. No thermal alerts have been detected by the University of Hawaii's Institute of Geophysics and Planetology (HIGP) MODIS satellite-based thermal alert system since 27 December 2006.

According to the ash advisories issued from the Buenos Aires VAAC, the aviation warning color code for Ubinas during the reporting period was variously orange or red. In terms of hazard status on the ground, a news article on 30 June 2008 indicated that local civil defense officials had maintained the Alert level at Yellow. They noted that small explosions and ash-and-gas emissions had continued during the previous two months. Families at immediate risk from the village of San Pedro de Querapi in the vicinity of the volcano have been relocated but have returned to their fields to pursue their agacultural activities. The population of local communities and their livestock had suffered the effects of gas and ash emissions, and local authorities had begun to discuss the possible relocation of about 650 affected families from six towns (Escacha, Tonoaya, San Migues, San Pedro de Querapi, Huataga and Ubinas). The article noted that officials recognized that the relocation process could take several years and should be the villager's decision and not one forced on them.

Geologic Summary. A small, 1.4-km-wide caldera cuts the top of Ubinas, Peru's most active volcano, giving it a truncated appearance. Ubinas is the northernmost of three young volcanoes located along a regional structural lineament about 50 km behind the main volcanic front of Perú. The growth and destruction of Ubinas I volcano was followed by construction of Ubinas II volcano beginning in the mid-Pleistocene. The upper slopes of the andesitic-to-rhyolitic Ubinas II stratovolcano are composed primarily of andesitic and trachyandesitic lava flows and steepen to nearly 45 degrees. The steep-walled, 150-m-deep summit caldera contains an ash cone with a 500-m-wide funnel-shaped vent that is 200 m deep. Debris-avalanche deposits from the collapse of the SE flank of Ubinas about 3,700 years ago extend 10 km from the volcano. Widespread plinian pumice-fall deposits from Ubinas include one of Holocene age about 1,000 years ago. Holocene lava flows are visible on the volcano's flanks, but historical activity, documented since the 16th century, has consisted of intermittent minor-to-moderate explosive eruptions.

Date	Plume altitude (km)	Plume direction
19-25 Dec 2007	5.5-7	NE, SW
23 Feb 2008	5.5-8.5	SE
02 Mar 2008	5.5-6.1	SE
09 Mar 2008	7	W, SW
17 Mar 2008	5.5–6.1	N
26 Mar 2008	3.7-6.7	SW
01 Apr 2008	3.7-6.7	NW
06 Apr 2008	5.5-6.7	E
15 Apr 2008	5.5-7	ENE
19-22 Apr 2008	5.5-7.6	ESE, NE
23 Apr 2008	5.5-9.1	SE, S
30 Apr-3 May 2008	5.5-9.1	NE, E, SE
09 May 2008	5.5-7	E
12 May 2008	5.5-7	SE
15 May 2008	5.5	E, SW
19 May 2008	8.5	E, SW
22-24 May 2008	4.9-7.9	S, E, NE, SE
26 May 2008	5.4	SSE
28-29 May 2008	5.5-6.1	NE, SE
03 June 2008	4.6	SSW
07 June 2008	7.3	S
13 June 2008	6.7	S
18 June 2008	5.5-5.8	S, SE, and NE
22 June 2008	5.5-7.6	S, SE, and NE
26 June 2008	5.5-6.1	NE
07 July 2008	5.5-5.8	NE
09-10 July 2008	5.5-5.8	E
15 July 2008	5.5-5.8	E

Table 2. Compilation of Volcanic Ash Advisories for aviation from Ubinas during 19 December 2007 through July 1, 2008. Courtesy of the Buenos Aires Volcanic Ash Advisory Center (VAAC) and the Instituto Geológical Minero y Metalúrgico (INGEMMET).

Information Contacts: *Instituto Geológical Minero y Metalúrgico (INGEMMET)*, Av. Canadá 1470, San Borja, Lima 41, Perú (URL: http://www.ingemmet.gob.pe/); *Buenos Aires Volcanic Ash Advisory Center (VAAC)*, Argentina (URL: http://www.ssd.noaa.gov/VAAC/OTH/AG/messages.html); *La República Online* (URL: http://www.larepublica.com.pe).

Tungurahua

Ecuador
1.467°S, 78.442°W; summit elev. 5,023 m
All times are local (= UTC - 5 hours)

Our previous report on Tungurahua (*BGVN* 32:08) discussed the volcano's activity during March-July 2007. During that period, Ecuador's Instituto Geofisico (IG) reported significant, but variable eruptive behavior, along with many lahars, ash plumes that reached 4 km above the summit, and semi-continuous ashfall.

Table 3 presents a brief summary of the weekly activity at Tungurahua between 18 July 2007 and 19 February 2008. The plumes were described variously as ash, ash-and-gas, steam-and-gas, steam, or steam-and-ash. They rose up to 13 or 14 km altitude (25-26 October 2007 and 7 February 2008, respectively) but more typically, for many weeks, to below 8 km altitude. Around December 2007 IG stated a caution. They likened Tungurahua's behavior as similar to after its explosive phase of 14 July 2006. In that case, volcanic activity kept going, and this lead to the most explosive phase on 16 August 2006. That dramatic pattern was not repeated the next month, but the pace of volcanism kept up and led to the vigorous 7 February eruption.

Geologic Summary. Tungurahua, a steep-sided andesitic-dacitic stratovolcano that towers more than 3 km above its northern base, is one of Ecuador's most active volcanoes. Three major volcanic edifices have been sequentially constructed since the mid-Pleistocene over a basement of metamorphic rocks. Tungurahua II was built within the past 14,000 years following the collapse of the initial edifice. Tungurahua II itself collapsed about 3000 years ago and produced a large debris-avalanche deposit and a horseshoe-shaped caldera open to the west, inside which the modern glacier-capped stratovolcano (Tungurahua III) was constructed. Historical eruptions have all originated from the summit crater. They have been accompanied by strong explosions and sometimes by pyroclastic flows and lava flows that reached populated areas at the volcano's base. Prior to a long-term eruption beginning in 1999 that caused the temporary evacuation of the city of Baños at the foot of the volcano, the last major eruption had occurred from 1916 to 1918, although minor activity continued until 1925.

Information Contacts: *Geophysical Institute (IG)*, Escuela Politécnica Nacional, Apartado 17-01-2759, Quito, Ecuador (URL: http://www.igepn.edu.ec/); *Washington Volcanic Ash Advisory Center*, 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/VAAC/); *Reuters* (URL: http://www.reuters.com/); *Associated Press* (URL: http://www.ap.org/); *Pan American Health Organization (PAHO)*, 525 23rd St. NW, Washington, DC 20037, USA (URL: http://www.paho.org/).

Arenal

Costa Rica
10.463°N, 84.703°W; summit elev. 1,670 m
All times are local (= UTC - 6 hours)

Our last report covered generally low-level activity at Arenal through September 2007 (*BGVN* 32:09). Behavior then included pyroclastic flows to a runout distance of ~ 1 km and a new lava flow emerging from Crater C. This report covers the interval October 2007–June 2008 and originated from those of both the Observatorio Vulcanologico Sismologica de Costa Rica- Universidad Nacional (OVSICORI-UNA) and (ICE).

Impressive incandescent avalanches (block-and-ash flows or pyroclastic flows) traveled down several flanks during June 2008. At least portions of those avalanches broke off from a cone in Crater C and active lava flows high on the edifice.

During the reporting interval, Crater C continued to produce lava flows, gases, sporadic Strombolian eruptions, and avalanches from the lava flow fronts. Observers noticed acid rain and small amounts of ejected pyroclastic material impacting the NE, E, and SE flanks. They also cited loss of vegetation, steep slopes, poorly consolidated material, and high precipitation as factors that triggered small cold avalanches in Calle de Arenas, Manolo, Guillermina, and the river Agua Caliente. Crater D remained fumarolic. Except for the June avalanches, eruptive activity generally remained modest. Some reports noted that the eruptive vigor continued to drop both in terms of the number of eruptions and the amount of ejected pyroclastic material.

OVSICORI-UNA reported that by March 2008, the flow of lava down the S flank had stopped, but a new flow that had begun in February 2008 toward the SW flank was still active. A few eruptions produced ash columns that exceeded 500 m above the vent.

During April 2008, lava moving toward the S flank descended to about 1,400 m elevation. Some blocks had detached near the border of the crater. Sporadically small avalanches occurred and some blocks managed to reach vegetation below, igniting small fires. Some April eruptions produced dark gray ash columns.

Glowing avalanches of June. Jorge Barquero sent us a report on Arenal's behavior during June 2008. Prior to the June events a distinct cone had appeared in Crater C. Its steep sides generated small avalanches of loosened rocks. At about 1000 on 6 June, that cone collapsed, causing a pyroclastic (block-and-ash) flow that descended SE, forming a gully or channel, and laying down a deposit that fanned out at the base of Arenal. Lava also descended into or towards the gully, causing small avalanches.

Some residents heard noises and felt ashfall starting at 0600 on 10 June. At about 0800 these block-and-ash flows became larger. The wind blew ash NW to 4 km from the crater.

After 1730 on 14 June, the failure of the lava flow front sent down an avalanche more violent than those earlier. An hour later the largest block-and-ash flow of the month

Figure 9. A view of the early June 2008 incandescent avalanche deposits on Arenal's S flanks. Courtesy of OVSICORI-UNA.

descended. It descended the channel and produced a large quantity of ash that blew SE and W to distances of 6 km. The area of greatest impact was in the SW portion of the Arenal National Park, where the branches of some vegetation cracked under the weight of the ash. More block-and-ash flows were also observed on 15 and 18 June.

Date	Plume altitude	Activity
18 Jul-24 Jul 2007	5.2-8 km	Roaring, noises resembling cannon shots or rolling blocks, lahars, ashfall.
25 Jul-31 Jul 2007	up to 2-3 km above crater	Many small ash-bearing explosions and several unusually large ones, blocks fell up to 0.5 km below crater's rim, ashfall.
01 Aug-07 Aug 2007	up to 5.5 km	Roaring, explosions, rolling blocks, steam emissions, ashfall.
08 Aug-14 Aug 2007	up to 6 km	Explosions, incandescent material fell inside the crater and on the flanks, ashfalls, lahars down NW drainage disrupted road traffic between Ambato and Baños.
15 Aug-21 Aug 2007	5.5 km	Cannon shot noises, explosions, ash emissions, ashfall.
22 Aug-28 Aug 2007	6-9 km	Explosions, incandescent blocks down flanks, lahars in the NW drainage disrupted road traffic, ashfall.
29 Aug-04 Sep 2007	7 km	Explosions, roaring and cannon shot noises, incandescent blocks ejected, lahars disrupted road traffic, ashfall. On 4 September incandescence and rolling blocks on the E and N flanks.
05 Sep-11 Sep 2007	5.3-8 km	Explosions, incandescent blocks rolled down flanks, ashfall.
12 Sep-18 Sep 2007	5.5-8 km	Strombolian eruption, explosions, incandescent material ejected above the summit and blocks rolled 100 m down the flanks, roaring and cannon shot noises, ashfall.
19 Sep-25 Sep 2007	5.3-7 km	Explosions, roaring and cannon shot noises, incandescent material ejected above the summit and blocks rolled 500 m down the flanks, ashfall.
26 Sep-02 Oct 2007	6-7 km	Roaring and cannon shot noises, 28 September, blocks ejected above the summit and descended 500 m down the flanks, ashfall.
03 Oct-09 Oct 2007	6-8 km	Ash plumes, roaring and cannon shot noises, noise of rolling blocks, ashfall.
10 Oct-16 Oct 2007	6.2-8 km	Ash plumes. During 11-12 October incandescent blocks ejected and descended 300 m down the W flank; roaring noises from multiple areas on 11, 13, and 14 October. Ashfall.
17 Oct-23 Oct 2007	5.5-9 km	Ash plumes. 17 October, roaring, incandescent material erupted from the summit fell onto the flanks. Fumarolic activity on NW flank, lahars closed road on NW drainage. Ashfall SW on 21 October.
24 Oct-30 Oct 2007	up to 13 km	Ash and steam plumes. 25-26 October, incandescence at summit, roaring and cannon shot noises, blocks rolling down the flanks; ashfall.
31 Oct-06 Nov 2007	5.5-8 km	Explosions, roaring, incandescent blocks at summit, lahars closed road, ashfall.
07 Nov-13 Nov 2007	6-9 km	Roaring and cannon shot noises, incandescent blocks rolled a few hundred meters (1 km on 12 Nov) down the flanks, fumarolic activity, lahar, ashfall.
14 Nov-20 Nov 2007	up to 7.3 km	Roaring and cannon shot noises, incandescent blocks rolled down flanks, thermal anomaly detected.
21 Nov-27 Nov 2007	6-8 km	Explosions, roaring, incandescent blocks 1 km down the flanks, lahars (4-5 m high in one area) closed road, ashfall.
28 Nov-04 Dec 2007	6-8 km	Elevated seismicity, explosions, continuous emissions of steam and ash, roaring and cannon shot noises, incandescent blocks 0.5-1 km down flanks, ashfall.
05 Dec-11 Dec 2007	6-8 km	Explosions, roaring and cannon shot noises, incandescent material about 1 km down flanks, ashfall.
12 Dec-18 Dec 2007	6-7 km	Explosions, roaring and cannon shot noises, almost constant emission of of ash plumes, incandescent blocks rolled down flanks, ashfall.
19 Dec-25 Dec 2007	6-8.5 km	Roaring and cannon shot noises, incandescent blocks hundreds of meters down flanks, ashfall. News reports indicated that 1,200 people from Penipe were evacuated nightly.
26 Dec-01 Jan 2008	6-8 km	Explosions, roaring, and cannon-shot noises, incandescent blocks 500 m down flanks, ashfall.
02 Jan-08 Jan 2008	5.5-8 km	Explosions, roaring and cannon shot noises, continuous ash emissions, incandescent blocks 500 m down flanks, ashfall. News reports indicated that nearly 1,000 people were evacuated for the night on 6 Jan.
09 Jan-15 Jan 2008	6-9 km	Strombolian eruption, roaring and cannon shot noises, incandescent blocks 0.5-1 km down flanks. News reports indicated that residents from two provinces evacuated at night and about 20,000 health masks were distributed in Baños and Quero.
16 Jan-22 Jan 2008	5.5-9 km	Strombolian eruption, roaring and cannon shot noises, incandescent blocks 1-2 km down flanks, small pyroclastic flow 400 m down NW side of crater, ashfall.
23 Jan-29 Jan 2008	5.5-9 km	Roaring and cannon shot noises, incandescent blocks 500-800 m down flanks, lahars blocked road to Baños, ashfall up to at least 40 km from summit.
30 Jan-06 Feb 2008	6-9 km	Explosions (65-208 per day), roaring and cannon shot noises, incandescent blocks rolled 600 m down flanks, lahar, ashfall.
06 Feb 2008		New phase of eruptions began with a moderate explosion.
07 Feb 2008	6-14.3 km	Tremors of variable intensity, ash columns to heights of 3 km beginning a new phase of eruptive activity; satellite images show a hot spot in the crater. Strombolian eruptions, explosions, strong roaring and cannon shot noises, incandescent material rolled 1.2 km down the flanks, tremors followed by pyroclastic flows on the NW and W flank, tephra fall SW, ashfall. News articles stated several hundred to 2,000 people evacuated.
08 Feb 2008		Internal volcanic activity as well as emissions of ash, incandescent material, and explosions and roaring noises slowly diminished; current eruptive episode should not be considered as finished.
09 Feb-12 Feb 2008		Strombolian eruptions, explosions, strong roaring and cannon shot noises, incandescent material rolled 1.2 km down the flanks, pyroclastic flows, tephra fall, ashfall. News articles stated several hundred to 2,000 people evacuated.
13 Feb-19 Feb 2008	6-9 km	Roaring, noises resembling blocks rolling down flanks, lahar, ashfall.

Table 3. Summary of weekly activity at Tungurahua between 18 July 2007 and 19 February 2008. Courtesy of IG.

Figure 10. Previously incandescent avalanche deposits at Arenal seen on 11 June 2008. Courtesy of OVSICORI-UNA.

Figure 11. Arenal's summit as seen looking up the new avalanche chute (steaming). At the head of the chute lies a thick black lava flow (labeled lava front "Frente de colada"). Courtesy of OVSICORI-UNA.

On 11 June Eliecer Duarte and E. Fernández (OVSICORI-UNA) visited the distal parts of the new deposits, documenting the new flow field (figures 9 and 10). The distal area occurred at ~ 900 m elevation on Arenal's outer margins where the slope changes abruptly. A series of alternating lobes contained deposits that were 500°C on 11 June. The individual lobe's thickness reached up to about 3-4 m. The heterogeneous nature of the often angular blocks contrasted with a gray and quite sandy matrix, and included both pre-existing material eroded from the valley walls and more recent juvenile material from the summit. Conspicuous blocls from the block-and-ash flow (10% were 2-3 m in diameter and ~ 20% were ~ 1 m in diameter) are mostly juvenile material from the lava flow. The margins of the fan were covered by a fine dust layer several centimeters thick. On the S flanks, the block-and-ash deposit barely reached a few meters thick. On the N flanks, the deposit reached many tens of meters thick, the result of wind carrying the abundant fine materials in that direction.

Major S-flank avalanches reported on 6 and 10 June 2008 eroded a radially oriented gully (an avalanche chute). Later avalanches down this direction tended to form channelized deposits. A dark colored thick lava flow present at the summit (figure 11) provided an important source of materials in the deposits. The S-flank avalanches funneled through the gully, fracturing particles into finer grain sizes and generating columns of ash. During the visit, the team observed several avalanches containing large blocks that were similarly reduced in volume as they bounced through the gully. Some of these blocks arrived at the lower part of the fan with temperatures between 800 and 1,000°C. The large blocks seemingly cracked as the result of thermal shock, a process accelerated during a strong rainstorm.

Geologic Summary. Conical Volcán Arenal is the youngest stratovolcano in Costa Rica and one of its most active. The 1670-m-high andesitic volcano towers above the eastern shores of Lake Arenal, which has been enlarged by a hydroelectric project. Arenal lies along a volcanic chain that has migrated to the NW from the late-Pleistocene Los Perdidos lava domes through the Pleistocene-to-Holocene Chato volcano, which contains a 500-m-wide, lake-filled summit crater. The earliest known eruptions of Arenal took place about 7000 years ago, and it was active concurrently with Cerro Chato until the activity of Chato ended about 3500 years ago. Growth of Arenal has been characterized by periodic major explosive eruptions at several-hundred-year intervals and periods of lava effusion that armor the cone. Arenal's most recent eruptive period began with a major explosive eruption in 1968. Continuous explosive activity accompanied by slow lava effusion and the occasional emission of pyroclastic flows has occurred since then from vents at the summit and on the upper western flank.

Information Contacts: *E. Fernández*, *E. Duarte*, *W. Sáenz*, *V. Barboza*, *M. Martinez*, *E. Malavassi*, and *R. Sáenz*, Observatorio Vulcanologico Sismologica de Costa Rica-Universidad Nacional (OVSICORI-UNA), Apartado 86-3000, Heredia, Costa Rica (URL: http://www.ovsicori.una.ac.cr/); *Jorge Barquero Hernandez*, Instituto Costarricense de Electricidad (ICE), Apartado 5 -2400, Desamparados, San José, Costa Rica (Email: jabarque@ice.co.cr).

Okmok

Aleutian Islands, United States
53.43°N, 168.13°W; summit elev. 1,073 m
All times are local (= UTC - 9 hours [or 8 hours early April-late October])

The Alaska Volcano Observatory (AVO) reported that on 12 July 2008 at 1143 a strong explosive eruption at Okmok began abruptly after about an hour of rapidly escalating earthquake activity. The Volcano Alert Level was raised to Warning and the Aviation Color Code was raised to Red from the previous Alert Level of Normal/Green. The last explosive eruption began on 13 February, 1997 (BGVN 22:01) from a cone on the south side of the caldera floor. Lava flowed across the caldera floor until 9 May. Ash plumes generally rose to altitudes of 1.5-4.9 km from 13 February to about 23 May, when thermal anomalies and plumes were no longer seen on satellite imagery. One ash plume rose to an altitude of 10.5 km on 11 March. In May 2001 a small seismic swarm (*BGVN* 26:08) was detected in the vicinity of the volcano. The earthquake locations could not be pinpointed because Okmok is not monitored by a local seismic network.

The initial phase of the 2008 eruption was very explosive, with high levels of seismicity that peaked at 2200 then began to decline. A wet gas-and-ash-rich plume was estimated to have risen to altitudes of 10.7-15.2 km or greater. Wet, sand-sized ash fell within minutes of the onset of the eruption in Fort Glenn, about 10 km WSW. Heavy ashfall occurred on the eastern portion of Umnak Island; a dusting of ash that started at 0345 also occurred for several hours about 105 km NE in Unalaska/Dutch Harbor. News media reported that residents of Umnak Island heard thundering noises the morning of 12 July and quickly realized an eruption had begun. After calling the US Coast Guard for assistance, they began to evacuate to Unalaska using a small helicopter. A fishing boat evacuated the remaining residents after heavy ashfall made further flights impossible.

On 13 July, reports from Unalaska indicated no ashfall had occurred in Unalaska/Dutch Harbor since the previous night. The National Weather Service reported that the ash plume rose to an altitude of 13.7 km (figure 12). Plumes drifted SE and E. Based on observations of satellite imagery, the ash plume altitude was 9.1 km and drifted SE. However, satellite tracking of the ash cloud by traditional techniques was hampered by the high water content due to interaction of rising magma with very shallow groundwater and surficial water inside the caldera.

Ash erupted from a vent or vents near composite cinder cone called Cone D in the eastern portion of the 9.7-km wide caldera. Activity during the past three significant eruptions (1945, 1958, and 1997) occurred from Cone A, a cinder cone on the far western portion of the caldera floor. Each of the three previous eruptions was generally mildly to moderately explosive with most ash clouds produced rising to less than 9.1 km altitude. Each eruption also produced a lava flow that traveled about 5 km across the caldera floor.

AVO reported that during 15-16 July seismicity changed from nearly continuous to episodic volcanic tremor, and the overall seismic intensity declined. Little to no ash was detected by satellite, but meteorological clouds obscured views. Satellite imagery from 0533 on 16 July indicated elevated surface temperatures in the NE sector of the caldera. On 16 July, a light dusting of ash was reported in Unalaska/Dutch Harbor. A plume at an altitude of 9.1 km was visible on satellite imagery at 0800. On 17 July, a pilot reported that an ash plume rose to altitudes of 4.6-6.1 km and drifted E and NE. The sulfur dioxide plume had drifted at least as far as eastern Montana (figure 13). On 18 July, the eruption was episodic, with occasional ash-producing explosions occurring every 15 to 30 minutes. The plumes from these explosions were limited to about 6.1 km.

Figure 12. Photograph of Okmok by flight attendant Kelly Reeves during Alaska airlines flight on 13 July 2008. Image courtesy of Alaska Airlines.

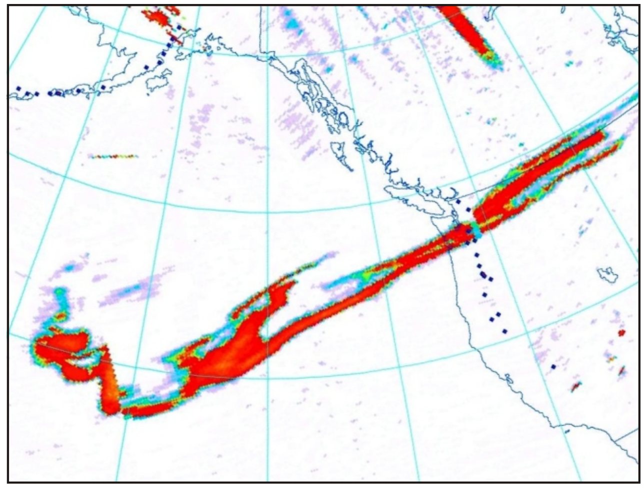

Figure 13. OMI composite image from NOAA showing the extent of the sulfur dioxide gas cloud from the eruption of Okmok imaged at about 1200 AKDT on 17 July, 2008. The large mass shows the location of the high altitude sulfur dioxide cloud from the main explosive phase on 12 July 2008. Image created by Rick Wessels (AVO); courtesy of the OMI near-real-time decision support project funded by NASA.

Geologic Summary. The broad, basaltic Okmok shield volcano, which forms the NE end of Umnak Island, has a dramatically different profile than most other Aleutian volcanoes. The summit of the low, 35-km-wide volcano is cut by two 10-km-wide calderas formed during eruptions about 8,250 and 2,400 years ago that produced dacitic pyroclastic flows that reached the coast. Numerous satellitic cones and lava domes dot the flanks of the volcano down to the coast. Some of the post-caldera cones show evidence of wave-cut lake terraces; the more recent cones, some of which have been active historically, were formed after the caldera lake disappeared. Hot springs and fumaroles are found within the caldera and at Hot Springs Cone, 20 km to the SW. Historical eruptions have occurred since 1805 from cinder cones within the caldera.

Information Contacts: *Alaska Volcano Observatory (AVO)*, a cooperative program of the U.S. Geological Survey, 4200 University Drive, Anchorage, AK 99508-4667, USA; Geophysical Institute, University of Alaska, P.O. Box 757320, Fairbanks, AK 99775-7320, USA; and Alaska Division of Geological & Geophysical Surveys, 794 University Ave., Suite 200, Fairbanks, AK 99709, USA (URL: http://www.avo.alaska.edu/); *Associated Press* (URL: http://www.ap.org/).

Pago

New Britain, Papua New Guinea
5.58°S, 150.52°E; summit elev. 742 m
All times are local (= UTC + 10 hours)

Reports about Pago early in 2006 (*BGVN* 31:02) noted small vapor emissions, but no noises or glow, and low levels of seismicity. Similar observations were reported by the Rabaul Volcano Observatory (RVO) for December 2006. A local security company reported that sometime during 27-31 October 2006 there was a single booming noise accompanied by a white-gray emissions above the summit. Volcanologists were sent to verify the activity, but no report about the event was received. A March 2007 report only noted diffuse white vapor emissions and low seismicity.

On 28 August 2007 lava fragments were observed being ejected during the daytime from one of the Upper vents (2nd Crater). People in a nearby village heard only a single booming noise in the early hours of 27 August. The residents also indicated increased white vapor emissions from 2nd Crater on the 27th that returned to normal levels the following day. Seismic activity had increased on 27-28 August, and the Real-Time Seismic Amplitude Measurement (RSAM) increased from background level (around 100 units) to a peak of about 400 units. RSAM levels began to decline on the 29th, returning to background levels on 30 August. An inspection on 1 October revealed that only the 2nd Crater of the Upper Vents was releasing diffuse white vapor, and that there were no noises or glow.

Pago remained quiet during September-November 2007. When observations were made, only diffuse white vapor was being released from the Upper Vents. A handful of high-frequency earthquakes and 18 low-frequency events were recorded during September. The daily number of earthquakes ranged from 1 to 4 from 1 to 24 September, with none after through the end of the month. There was a slight increase in gas emission during 9-11 November. The vapor plume was blown N, where villagers reported nose and windpipe irritation, and watery eyes. The daily number of high-frequency earthquakes ranged from 1 to 3, while low-frequency earthquakes ranged from 1 to 9. During January 2008 Pago was still quiet with diffuse white vapor from the upper vents and very occasional low-frequency seismic events.

Geologic Summary. Pago is a young post-caldera cone that was constructed within the 5.5 x 7.5 km Witori caldera. The Buru caldera cuts the SW flank of Witori volcano. The gently sloping outer flanks of Witori volcano consist primarily of dacitic pyroclastic-flow and airfall deposits produced during a series of five major explosive eruptions from about 5,600 to 1,200 years ago, many of which may have been assocciated with caldera formation. The post-caldera cone of Witori, Mount Pago, may have formed less than 350 years ago. Pago has grown to a height above that of the Witori caldera rim. A series of ten dacitic lava flows from Pago covers much of the caldera floor. The youngest of these was erupted during 2002-2003 from vents extending from the summit nearly to the NW caldera wall.

Information Contacts: *Ima Itikarai* and *Herman Patia*, Rabaul Volcano Observatory (RVO), P.O. Box 386, Rabaul, Papua New Guinea.

Raung

Java, Indonesia
8.125°S, 114.042°E; summit elev. 3,332 m
All times are local (= UTC + 7 hours)

In an *Antara News* report, Balok Suryadi, an observer at the Center of Volcanology and Geological Hazard Mitigation (CVGHM) Raung monitoring post at Sumber Arum village, described clouds of "smoke and ash" that occurred on 12 and 13 June. He was also quoted in the 19 June article as saying that activity was "likely" continuing but that it could not be clearly monitored from the observation post.

Another ash eruption was seen rising through the clouds on 17 June 2008 around 1500. This event was photographed by Karim Kebaili while flying from Bali to Jakarta approximately 30 minutes after take-off (figure 14). The same eruption was seen at 1430 by pilot Nigel Demery, who stated that the ash cloud initially rose to about 4.5 km altitude but had dissipated on his return flight about two hours later. The Darwin VAAC was unable to identify the plume in satellite imagery due to meteorological clouds.

Thermal anomalies were detected by the MODIS instrument aboard the Terra satellite on 23 July 2005 and 15 August 2005. No additional thermal anomalies were detected through the end of June 2008. However, ash plumes were reported by pilots on 26 July 2007 and seen in satellite imagery on 26 August 2007 (*BGVN* 32:09).

Geologic Summary. Raung, one of Java's most active volcanoes, is a massive stratovolcano in easternmost Java that was constructed SW of the rim of Ijen caldera. The

Figure 14. Ash plume rising from Raung at about 1500 on 17 June 2008. Courtesy of Karim Kebaili.

3,332-m-high, unvegetated summit of Gunung Raung is truncated by a dramatic steep-walled, 2-km-wide caldera that has been the site of frequent historical eruptions. A prehistoric collapse of Gunung Gadung on the west flank produced a large debris avalanche that traveled 79 km from the volcano, reaching nearly to the Indian Ocean. Raung contains several centers constructed along a NE-SW line, with Gunung Suket and Gunung Gadung stratovolcanoes being located to the NE and west, respectively.

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Papandayan

Java, Indonesia
7.32°S, 107.73°E; summit elev. 2,665 m
All times are local (= UTC + 7 hours)

Our last report on Papandayan (*BGVN* 29:08) described a modest surge in seismicity that began in July 2004, which rose for a short time but began to subside in mid-August 2004. We received no subsequent reports until June 2005. This report discusses non-eruptive restlessness from early June 2005 through the middle of April 2008, including wide fumarolic temperature variations, seismicity, and occasional minor steam plumes.

Beginning in early June 2005, the number of volcanic earthquakes increased in comparison to the previous months, and fumarole temperatures increased 3-9°C above normal levels. People were not permitted to visit Mas and Baru craters. On 16 June 2005, the Center of Volcanology and Geological Hazard Mitigation (CVGHM) in Indonesia raised the Alert Level at Papandayan from 1 to 2 (on a scale of 1-4) due to increased activity at the volcano. The Alert Level remained at 2 at least through 13 December 2005.

No subsequent reports were received until July 2007. On 15 July there was one volcanic earthquake; the next day 2-10 volcanic earthquakes were recorded. By 31 July, fumarole temperatures had increased 10°C above normal levels in Mas crater. On 1 August up to 53 volcanic earthquakes were recorded and a diffuse white plume rose to an altitude of 2.7 km. Residents and tourists were not permitted within a 1 km radius of the active craters.

On 2 August 2007, CVGHM raised the Alert Level from 1 to 2 (on a scale of 1-4) due to increased seismic activity at the volcano. Seismic events decreased in number after 2 August; earthquake tremors were not recorded after 14 November 2007, and on 7 January 2008, CVGHM lowered the Alert Level at Papandayan from 2 to 1 due to the decrease in activity during the previous four months. Data from deformation-monitoring instruments indicated deflation. White fumarolic plumes rose to an altitude of 2.9 km.

No subsequent reports were received until April 2008. According to the CVGHM, on 15 April the seismic network recorded one tremor signal. On 16 April, measurements of summit fumaroles revealed that the temperature had increased and water chemistry had changed since 7 April. White plumes continued to rise to an altitude of 2.7 km. CVGHM again increased the Alert Level to 2 and warned people not to venture within 1 km of the active crater.

Geologic Summary. Papandayan is a complex stratovolcano with four large summit craters. Papandayan has had three known eruption periods, which have been recorded during historic time, 1772, 1923-1925 and 1942. The youngest of the summit craters was breached to the NE by collapse during the brief eruption in 1772 and contains active fumarole fields. The broad 1.1-km-wide, flat-floored Alun-Alun crater truncates the summit of Papandayan, and Gunung Puntang to the north gives the volcano a twin-peaked appearance. Several episodes of collapse have given the volcano an irregular profile and produced debris avalanches that have impacted lowland areas beyond the volcano. A sulfur-encrusted fumarole field occupies historically active Kawah Mas ("Golden Crater"). After its first historical eruption in 1772, in which collapse of the NE flank produced a catastrophic debris avalanche that destroyed 40 villages and killed nearly 3000 persons. Since 1942 this volcano was relatively quiet for 60 years with only small phreatic eruptions occurring prior to an explosive eruption that began in November 2002.

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Barren Island

Andaman Islands, Indian Ocean
12.278°N, 93.858°E; summit elev. 354 m
All times are local (= UTC + 5 hours)

A scientific expedition in February 2008 observed that the morphology of the volcano had changed considerably since 2005. The eruption that began in May 2005 (*BGVN* 30:05) ejected lava and tephra that built a new scoria cone NE of the previous central cone. Lava flows covered all of the earlier flows, and several new spatter cones were formed. Fumarolic activity was continuing in February, with a large amount of steam from the central cone.

Activity seemingly decreased in late March 2006, as shown by a significant decline in the number and frequency of thermal anomalies (*BGVN* 32:07). However, intermittent anomalies continued until 5 October 2007, and ash plumes were seen in satellite imagery on 23 December 2007 (*BGVN* 33:02). Thermal anomalies detected by MODIS instruments began to be detected again on 12 May 2008 at 1935 (UTC), suggesting a renewal of eruptive activity. Anomalies continued to be identified on 19 days through the end of June.

During 15-30 June 2008 observers on an Indian Coast Guard patrol boat could see red glow from the central cone summit at night from a distance of about 10 km. There were also twelve earthquakes between 27 and 29 June, centered SW of Port Blair (140 km SW of Barren Island) in the Andaman Islands.

Geologic Summary. Barren Island, a possession of India in the Andaman Sea about 135 km NE of Port Blair in the Andaman Islands, is the only historically active volcano along the N-S-trending volcanic arc extending between Sumatra and Burma (Myanmar). The 354-m-high island is the emergent summit of a volcano that rises from a depth of about 2250 m. The small, uninhabited 3-km-wide island contains a roughly 2-km-wide caldera with walls 250-350 m high. The caldera, which is open to the sea on the west, was created during a major explosive eruption in the late Pleistocene that produced pyroclastic-flow and -surge deposits. The morphology of a fresh pyroclastic cone that was constructed in the center of the caldera has varied during the course of historical eruptions. Lava flows fill much of the caldera floor and have reached the sea along the western coast during historical eruptions.

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Figure 16. Folds developed in the crust of the lava lake at Erta Ale, February 2008. Courtesy of Tom Pfeiffer (Volcano Discovery).

Figure 17. Rising magmatic gases drove fountains like this one emerging above the surface of the lava lake at Erta Ale, February 2008. Courtesy of Tom Pfeiffer (Volcano Discovery).

Erta Ale

Ethiopia, Northeastern Africa
13.60°N, 40.67°E; summit elev. 613 m
All times are local (= UTC + 3 hours)

Around 2-3 February 2008, a Volcano Discovery tour visited Erta Ale (figures 15-18). Tom Pfeiffer reported that the northern pit crater contained a lake of molten lava ~ 75 m across. Strong spattering and bursting bubbles were seen. At times, the lava lake rose and flooded the lower terrace. During this phase the usual fountains ceased. Richard Roscoe, who also visited during February 2008, presents animations of the flooding on his Photovolcanica website. He also shows photos of strong fountaining associated with falling lava lake levels.

Figure 15. Wide-angle photo showing the lava lake at Erta Ale, February 2008. Taken with fisheye-lens and a digital reflex camera. Courtesy Marco Fulle.

Occasionally, magmatic gas released in the middle of the lake created a zone a few meters in diameter where fountains typically lasted ~ 1 minute (figure 17). Thin threads of lava (Pelee's hair) are visible in some lava-fountain photographs. Richard Roscoe also features similar photos. Marco Fulle noted strong spattering when lava was drawn down (subducted) into the lake.

A Volcanologique de Genève (SVG) trip on 8-9 February 2008 noted extensions of ropy lava in the N crater. The lake was little changed from the group's last visit in 2005. The group visited the N Crater, and, given its constant degassing, was able to take gas samples. They also measured the lake's surface temperature (700°C). The descent into this crater, seemingly easy, was made difficult by a mantle of very unstable lava scoria. An elevated level of the lava lake halted a subsequent descent.

References. Rivallin, P., and Mougin, D., 2008, Trip report of Pierrette Rivallin and Dédé Mougin: LAVE Bulletin, no. 79, May 2008.

Geologic Summary. Erta Ale is an isolated basaltic shield volcano that is the most active volcano in Ethiopia. The broad, 50-km-wide volcano rises more than 600 m from below sea level in the barren Danakil depression. Erta Ale is the namesake and most prominent feature of the Erta

Figure 18. Unusual egg-like sulfate structures at Erta Ale in February 2008. The delicate-looking incrustations cover an area of wet fumaroles on the rim of the North crater. Courtesy of Tom Pfeiffer (Volcano Discovery).

Ale Range. The 613-m-high volcano contains a 0.7 x 1.6 km, elliptical summit crater housing steep-sided pit craters. Another larger 1.8 x 3.1 km wide depression elongated parallel to the trend of the Erta Ale range is located to the SE of the summit and is bounded by curvilinear fault scarps on the SE side. Fresh-looking basaltic lava flows from these fissures have poured into the caldera and locally overflowed its rim. The summit caldera is renowned for one, or sometimes two long-term lava lakes that have been active since at least 1967, or possibly since 1906. Recent fissure eruptions have occurred on the northern flank of Erta Ale.

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Ol Doinyo Lengai

Tanzania, Eastern Africa
2.764°S, 35.914°E; summit elev. 2,962 m
All times are local (= UTC + 3 hours)

According to government authorities in the Ngorongoro district of Tanzania and the 22 March 2008 edition of *Arusha Times*, nine months after the mountain began continuous eruptive activity (*BGVN* 33:02), many residents had moved to other villages at a safe distance. Ngorongoro district member of parliament Saning'o Ole Telele told reporters that up to 5,000 people may have moved out of the area. The last major eruption was in August 1966. Since then there had not been an eruption of such magnitude, although notable ones were recorded in 1983, 1993, 2002 and 2006.

Date	Observer(s)	Brief observations
02 Apr 2008	Chris Daborn	(F?) (see text)
03 Apr 2008	Jurgis Klaudius	MODIS satellite thermal anomaly data from N crater indicated that eruptions continued (see table 5).
07-08 Apr 2008	Ben Wilhelmi	(A) (see text)
early Apr 2008	Ben Wilhelmi, Michael Dalton-Smith	(A) (see text)
17 Apr 2008	Matthieu Kervyn	MODIS/MODLEN data indicated a significant hotspot on Lengai on 17 April, showing that activity, although intermittent, continued (see text)
14-16 May 2008	Chris Weber, Marc Szeglat	(CV) (see text)
03, 10, 12 Jun 2008	Ben Wilhelmi	(A) no activity observed
08 Jun 2008	Ben Wilhelmi	(A) ash eruption
12 Jun 2008	Fred Belton	(A?) ash-poor plume above Lengai ~ 1500 m
17 Jun 2008	group of local Masaai from Engare Sero village	(CV) climbed Lengai via the W route through the Pearly Gates (closed to climbers for several months due to dangerous activity)
18 Jun 2008	Fred Belton, Paul Hloben, Paul Mongi, Mweena Hosa, Peter (Masaai guide)	(CV) (see text)
18 Jun 2008	Ben Wilhelmi	(A) (see text)
19 Jun 2008	Ben Wilhelmi	(A) no activity observed
30 Jun 2008	Ben Wilhelmi	(A) gray plumes emerging from crater
01 Jul 2008	Ben Wilhelmi	(A) small collapse of the S part of the new crater rim

Table 4. Summary of selected observers of Ol Doinyo Lengai from April-early July 2008 (continued from *BGVN* 33:02). Observation Key: CV= climbed volcano; A=aerial observations/photos from crater overflight; F = flank observation. Most of list courtesy of F. Belton's Ol Doinyo Lengai website.

Recent observations. Table 4 lists recent observations from April through early July 2008.

On 2 April 2008, Chris Daborn of Tropical Veterinary Services Ltd reported that the color of ash plumes changed from "salty" white to a more inert black, and eruptions were much smaller, barely rising above the mountain. Heavy rains made movement in the area difficult, washing away ash.

Ben Wilhelmi flew over on 7 and 8 April 2008 just prior to an eruption on the 7th and following the start of an eruption on the 8th. The flanks showed newly formed erosion gullies in the recently deposited ash (figure 19). Pilots Wilhelmi and Michael Dalton-Smith observed little activity during early April, although visibility was hampered by atmospheric clouds on several occasions; aerial photos showed no activity on 11 April.

Figure 19. Aerial photographs of Ol Doinyo Lengai crater on (a, top) 7 April and (b, bottom) 8 April 2008. Photos courtesy Ben Wilhelmi.

On 14-16 May 2008, Chris Weber and Marc Szeglat visited. Weber noted that only minor ash eruptions were reported by local Masaai after the eruptions on 8 and 17 April 2008. Some of the evacuated Masaai had returned to their settlements, but part of the livestock had not returned by the middle of May. The fall-out of pyroclastics was still visible around the volcano. Due to a heavy rain season, vegetation damage was not as severe as it could have been. Up to an altitude of ~ 1,000 m the vegetation (mostly 'Elephant grass', normal grass, and some Akazia trees) was undamaged except for the W side, where severe damage occurred as far as 10 km from the summit. Some lahars had occurred on the N and NE sides. The former trekking route was not recommended because of rockfalls and poor conditions. Weber and Szeglat used a very steep route on the SE side (named "simba route"). From ~ 1,000 m altitude ash layers were clearly visible on the ground, but new grass had grown since the eruption. Above ~ 1,500 m on the SE flank all vegetation was covered by pyroclastic material. From an altitude of ~ 2,500 m, additional impacts of volcanic bombs were visible. In the inactive S crater, at their campsite, all vegetation was destroyed, and volcanic bomb impacts from the explosive events on April 2008 were quite impressive.

The active N crater had a new morphology (figure 20). The N-S diameter of the crater was 300 m and it was 283 m E-W. The crater floor was at ~ 2,740 m elevation, ~ 130 m deep below the W crater rim. Two vents, designated as c1 and c2, were present inside the crater (figure 20). Both vents were strongly degassing. On 15 May 2008, fine powdered ash was ejected until midday. It was not possible to determine which vent was responsible for this. After descent, Weber and Szeglat visited an abandoned Masaai boma (hut) a few kilometers W of the summit where ashfall had forced a family to flee.

On 8 June Wilhelmi saw a small eruption during a flyover. Photos made by Wilhelmi during overflights on 3, 10, and 12 June showed no activity. However, an ash-poor plume was seen by Fred Belton on 12 June.

On 17 June 2008 a group of Masaai from Engare Sero climbed via the W route through the Pearly Gates, which has been closed for several months. Fred Belton and Paul Hloben climbed on 18 June with a Masaai guide, Peter, and two other Tanzanians Paul Mongi and Mweena Hosa, following the route of the group from the previous day, which was covered by thick ash deposits. The route is subject to danger should there be a significant eruption. Belton's group spent about an hour on the rim of the active cone.

The new active cone covered the former crater floor entirely except for a region just N of the summit. The W, N, and E sides of the former crater were ~ 30 m higher than before and enclosed a deep pit crater with a couple of small vents. To the S, the rim of the new cone rested on the crater floor. To the E and W the new cone merged with and cov-

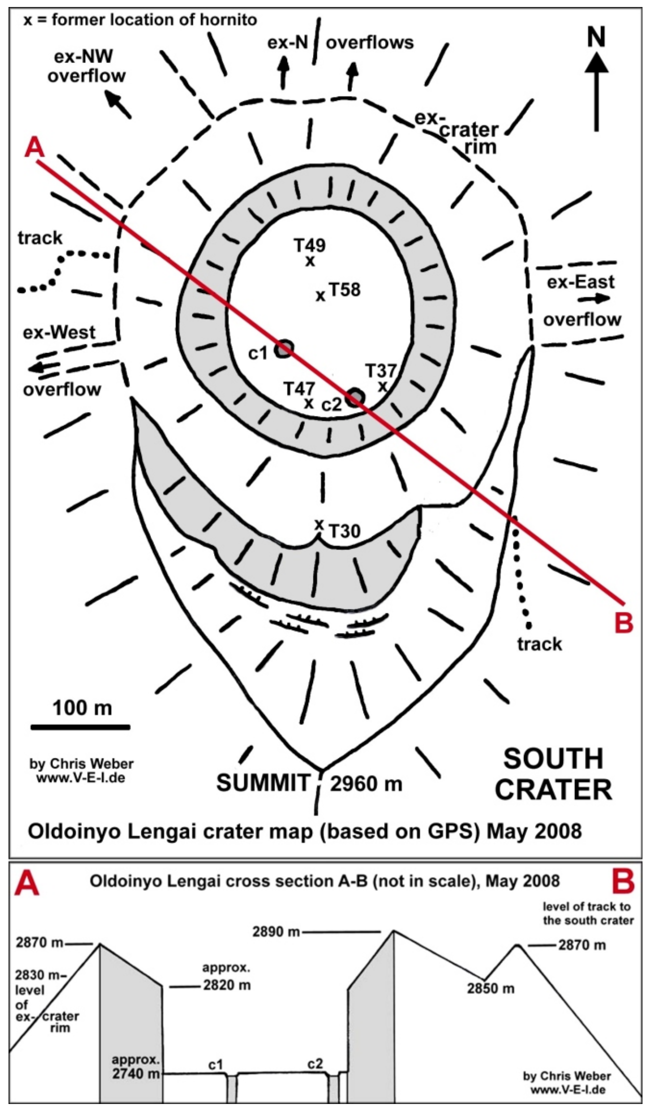

Figure 20. (a) Sketch map of Lengai, May 2008, and (b) cross section AB. Two vents were located as c1 and c2 inside the crater; older hornito locations are marked as T*xx* on the map (see hornitos on sketch map of Lengai as of 23 August 2007 in *BGVN* 32:11). Courtesy of Chris Weber.

ered up the old rim at the points where it intersects the arc formed by the summit ridge. Thus, there was a section of the former crater floor which was bounded to the N by the new cone's S rim and to the E, S, and W by the original curving summit ridge.

From approximately 0920-1020 the pit crater frequently emitted an ash-poor plume from the SW part of its floor, and there was light ashfall on the rim. Loud rumbling was continuous and occasional sounds of gas jetting and rockfalls were heard amid other noises. Occasionally there was a sloshing/hissing noise resembling the sound of 'lava at depth' often heard in the past, but there was no evidence of lava in the crater. The summit and S crater were not visited due to atmospheric clouds around the summit.

On 18 June, Ben Wilhelmi photographed the climbers with Belton during a flyover (figure 21). No activity was seen the next day, but on 30 June Wilhelmi saw gray plumes emerging. A small crater rim collapse was seen on the S part of the crater wall on 1 July 2008.

Satellite thermal anomalies. Table 5 lists MODIS/MODVOLC thermal anomalies measured between November 2007 through July 2008; MODVOLC is the algorithm for identifying thermal anomalies used by the HIGP Thermal Alerts System Group. On 17 April 2008, as noted in table 4, MODIS data analyzed by Matthieu Kervyn's algorithm MODLEN (sensitive to lower temperature anomalies than MODVOLC) indicated a significant hotspot, showing that activity, although intermittent, continued.

Date	Time (UTC)	Pixels	Satellite
17 Nov 2007	2000	2	Terra
31 Nov 2007	2310	1	Aqua
30 Dec 2007	0815	1	Terra
08 Jan 2008	2030	2	Terra
17 Jan 2008	2025	2	Terra
17 Feb 2008	2240	3	Aqua
22 Feb 2008	2300	1	Aqua
28 Feb 2008	1135	1	Aqua
29 Feb 2008	2305	1	Aqua
07 Mar 2008	2310	1	Aqua
10 Mar 2008	2045	4	Terra
03 Apr 2008	1955	1	Terra

Table 5. MODVOLC thermal anomalies measured by MODIS satellite at Ol Doinyo Lengai from November 2007 through July 2008. Courtesy of the MODIS Thermal Alerts System Group at the Hawai'i Institute of Geophysics and Planetology (HIGP).

Geologic Summary. The symmetrical Ol Doinyo Lengai stratovolcano is the only volcano known to have erupted carbonatite tephras and lavas in historical time. The prominent volcano, known to the Maasai as "The Mountain of God," rises abruptly above the broad plain south of Lake Natron in the Gregory Rift Valley. The cone-building stage of the volcano ended about 15,000 years ago and was followed by periodic ejection of natrocarbonatitic and nephelinite tephra during the Holocene. Historical eruptions have consisted of smaller tephra eruptions and emission of numerous natrocarbonatitic lava flows on the floor of the summit crater and occasionally down the upper flanks. The depth and morphology of the northern crater have changed dramatically during the course of historical eruptions, ranging from steep crater walls about 200 m deep in the mid-20th century to shallow platforms mostly filling the crater. Long-term lava effusion in the summit crater beginning in 1983 had by the turn of the century mostly filled the northern crater; by late 1998 lava had begun overflowing the crater rim.

Figure 21. View of the crater rim on 18 June 2008 showing four climbers at left center just below the rim. Photo courtesy of Ben Wilhelmi.

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