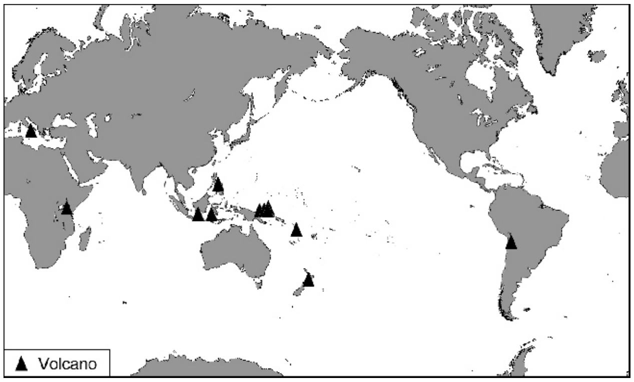
Bulletin of the Global Volcanism Network



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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).

Anatahan

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

Regular plume emissions seen in satellite imagery and by aviators during March-May 2006 (*BGVN* 31:05) apparently ended in June, with the last reported activity being a pilot report of an ash cloud on 26 June that reached 3 km altitude. A report issued by the U.S. Geological Survey (USGS) on 7 December noted that the Alert Level was being lowered to Green and that seismic activity at Anatahan was very low during late November and early December, although diffuse steam-and-gas plumes were occasionally visible on recent satellite images or by aviators.

According to the USGS, seismometers recorded tremor starting on 24 February (UTC) that continued at high levels through 17 March. During that time, recorded tremor occasionally increased to much higher values. In addition, OMI satellite spectrometer data showed occasionally high amounts of sulfur dioxide over Anatahan. Tremor levels increased significantly starting at 1625 on 9 March (UTC) and continued for over 40 hours. As of 13 March the tremor bursts were infrequent, and some were high amplitude. In addition, a distinct gas plume was visible in Moderate Resolution Imaging Spectroradiometer (MODIS) imagery, suggesting increased emissions. On that day the Alert Level was raised to Advisory.

The MODIS flying onboard the Aqua satellite captured a view of the plume on 18 March 2007 as emissions continued. In the image, the volcanic plume headed SE, then changed direction slightly and trended towards for the islands of Saipan and Tinian. The same day MODIS acquired this image, the U.S. Air Force Weather Agency reported an odor of sulfur, which would also suggest the presence of vog (volcanic smog) on Guam, ~200 km SW of Saipan. USGS and Emergency Management Office air quality instruments on Saipan recorded a maximum 5-minute average of 959 ppb sulfur dioxide and 99 ppb hydrogen sulfide on 18 March.

As of 24 March, the USGS was reporting that tremor levels after 17 March had remained low at pre-24 February levels. The plume visible in MODIS imagery had also remained weak but distinct since 18 March. On 24 March the Alert Level was lowered to Normal, with an aviation color code of Green. No confirmed ash eruptions had occurred after 3 September 2005.

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: *Juan Takai Camacho* and *Ramon Chong*, Emergency Management Office of the Commonwealth of the Northern Mariana Islands (EMO-CNMI), PO Box 100007, Saipan, MP 96950, USA (URL: http://www.cnmiemo.gov.mp/; Email: jtcamacho@cnmiemo.gov.mp, rcchong@cnmiemo.gov.mp); *Frank Trusdell*, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025-3591, USA (URL http://hvo.wr.usgs.gov/cnmi/update.html; Email: rwhite@usgs.gov, trusdell@usgs.gov); *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/NaturalHazards/); *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/).

Canlaon

Central Philippines
10.412°N, 123.132°E; summit elev. 2,435 m
All times are local (= UTC + 8 hours)

After a year of quiet following ash ejections from Canlaon in May 2005 (*BGVN* 30:06), the Philippine Institute of Volcanology and Seismology (PHIVOLCS) reported that a new period of activity began on 3 June 2006. In total, twenty-three ash ejections occurred between 3 June and 25 July 2006. These outbursts were all water-driven in nature, characterized by emission of ash and steam that rose up to 2 km above the active crater. The prevailing winds dispersed ash in all directions. The seismic network, however, did not detect significant seismic activity before or after the ash emissions, supporting the idea that the explosions were very near-surface hydrothermal events.

Four explosive episodes that occurred over the days 3, 10, and 12 June ejected mainly steam with some ash, and affected only the summit crater and upper SW slopes. The event at 1430 on 3 June sent dirty white to grayish steam 800 m above the summit. The activity was observed until 1445 when thick clouds covered the summit. Another emission started at 2316 on 10 June and lasted until 0030 the next morning. The plume was estimated to attain heights of 700-1,000 m before drifting SW. After the ash emission, moderate to wispy steam plumes escaped, to maximum heights of 600 m above the summit. Another steam-and-ash episode during 0515-0535 on 12 June caused a plume to rise about 600 m before drifting SW. After the ash emission, generally weak to moderate steaming to a height of ~ 400 m returned. Plumes rose 600-1,000 m and drifted SW; ashfall was confined to the upper slopes. This new period of low-level unrest prompted PHIVOLCS to raise the hazard status to Alert Level 1 on 12 June, suspending all visits to within 4 km of the summit.

Three small steam-and-ash emissions without recorded seismicity occurred again between the afternoon of 13 June and the morning of the 14th. The grayish steam clouds rose ~ 900 m above the active crater and drifted NE and NW. Only traces of ash were observed over the N upper slope. An explosion from 0845 to 0924 on 14 June produced an ash and steam cloud, which rose up to 1.5 km above the summit and drifted N, affecting mainly the upper slopes. Voluminous grayish steam plumes were then seen rising up to 1.5 km above the summit crater after 1640 through the next morning. The seismic network detected only two low-frequency volcanic earthquakes. Kanlaon City proper experienced light ashfall starting at 1630 on 15 June after voluminous dirty white steam was observed rising 1.5-2 km above the summit crater a few hours earlier (from 1346 to 1520). As of 1800, ashfall was still wafting through the city.

The character of this episode changed on the afternoon of 19 June when two episodes of steam-and-ash emission sent clouds 600 m above the crater that drifted SW. Weak to moderate steaming was observed after the second explosion and during the morning observation on the 20th. The initial explosion was recorded by the Cabagnaan station's seismograph as low-frequency tremor with a duration of 13 minutes. One minute of tremor was recorded at the time of the second explosion. No precursor seismicity was detected. Traces of ashfall and sulfurous odors were reported at Barangay Cabagnaan proper in La Castellana. During the 24 hours before 0730 on 20 June, the seismic network detected two cases of low-frequency tremor and three small low-frequency volcanic earthquakes.

An additional six short steam-and-ash emissions took place during 21-25 June. The explosions produced grayish columns that rose 800-1,500 m above the crater and drifted NW, SW, and SSW. Volcanic seismicity was not associated with these events except for a single harmonic tremor before the emission on 25 June. Light ashfall was reported at Upper Cabagnaan in La Castellana. Weak to moderate steaming was observed after the explosions.

Steam-and-ash emissions were not reported again until the afternoon of 2 July. The grayish steam clouds then rose to heights of up to 1,000 m above the active crater and generally drifted NW. Another episode on the morning of 3 July produced a column to a height of 500 m above the crater. The seismograph at Cabagnaan recorded ten volcanic earthquakes while the seismograph at Sto. Bama near Guintubdan in La Carlota City recorded eight local seismic events during the 24 hour observation period that included these emissions.

An explosion-type earthquake with a 10 min, 25 sec duration was recorded at 0426 on 23 July, but cloud cover prevented observations. Traces of ash fell up to about 9 km ENE from the crater, affecting Barangays Pula, Malaiba, and Lumapao. When clouds cleared during 0630-0800 on 25 July, ash-laden steam clouds were seen rising up to 300 m above the crater drifting ENE and SE. Light ashfall was experienced at Gabok, Malaiba, and Lumapao of Kanlaon City, about 9 km from the crater. This emission was not reflected on the seismic record as only two small volcanic earthquakes were detected during the preceding 24 hours. Dirty white steam was observed on the morning of the 26th rising to a maximum of 100 m above the crater.

Explosions ceased after 25 July, and other activity, such as weak steaming and minor seismicity, showed a general trend towards quiescence. After three months with no further explosive emissions, on 2 November 2006 PHIVOLCS lowered the hazard status from Alert Level 1 to Alert Level 0, meaning the volcano has returned to normal conditions.

Geologic Summary. Canlaon volcano (also spelled Kanlaon), the most active of the central Philippines, forms the highest point on the island of Negros. The massive 2,435-m-high stratovolcano is dotted with fissure-controlled pyroclastic cones and craters, many of which are filled by lakes. The summit of Canlaon contains a broad elongated northern caldera with a crater lake and a smaller, but higher, historically active crater to the S. The largest debris avalanche known in the Philippines traveled 33 km to the SW from Canlaon. Historical eruptions, recorded since 1866, have typically consisted of phreatic explosions of small-to-moderate size that produce minor ashfalls near the volcano.

Information Contacts: *Philippine Institute of Volcanology and Seismology (PHIVOLCS)*, Department of Science and Technology, PHIVOLCS Building, C.P. Garcia Avenue, Univ. of the Philippines Campus, Diliman, Quezon City, Philippines (URL: http://www.phivolcs.dost.gov.ph/).

Merapi

Java, Indonesia
7.542°S, 110.442°E; summit elev. 2,968 m
All times are local (= UTC + 7 hours)

Merapi, one of the most dangerous volcanoes in the world owing to its perched lava dome and location in populous central Java, underwent vigorous dome growth during early to mid-2006, and its increasingly unstable summit dome released numerous pyroclastic flows and incandescent avalanches. Thousands of residents evacuated and the volcano became prominent in international news. The longest pyroclastic flows of mid-2006 took place on 8 and 14 June, with respective run-out distances from the summit area of ~ 5 and 7 km. Merapi's summit lies 32 km N of the large city of Yogyakarta.

This report contains summary notes on activity during 7 March to 1 July 2006. These notes were assembled and reported by scientists from the Merapi Volcano Observatory and the Center of Volcanology and Geological Hazard Mitigation (CVGHM), formerly the Volcanological Survey of Indonesia, and augments material presented previously (*BGVN* 31:05 and 31:06).

The USGS provided a satellite image with labels showing key drainages and features near the summit (figure 1). The dome's instability leads to pyroclastic flows and various kinds of rockfalls and other mass wasting episodes down the labeled drainages. During the 7 March to 1 July reporting interval, pyroclastic flows followed the headwaters of the Gendol , Krasak, Boyong, and Sat rivers, which trend to the SE, SW, SSW, and W, respectively.

Tectonic earthquake on 27 May 2006. The tectonics of Java are dominated by the subduction of the Australia plate to the NNE beneath the Sunda plate with a relative velocity of ~ 6 cm/year. The Australia plate dips NNE from the Java trench, attaining depths of 100-200 km beneath the island of Java, and depths of 600 km to the N of the island. The earthquake of 27 May 2006 occurred at shallow depth in the overriding Sunda plate, well above the dipping Australia plate.

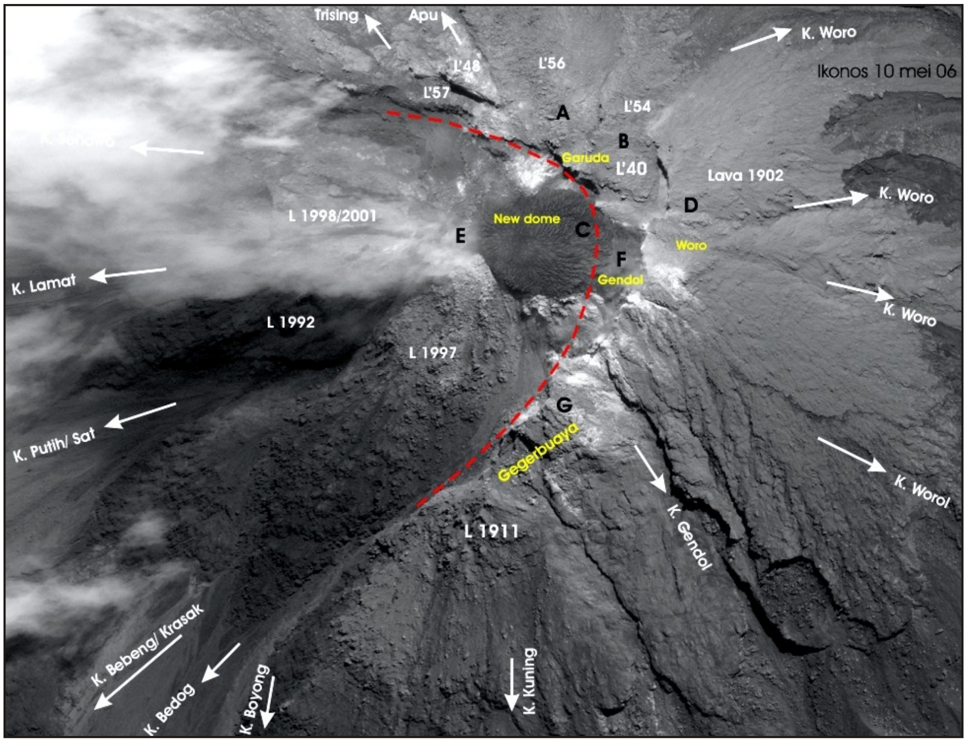

Figure 1. An annotated Ikonos satellite image of Merapi taken 10 May 2006. Image resolution is 2 m; N is to the top, and the scale is such that the entire distance N-S on the image is approximately 1 km. The labeled arrows indicate key rivers into which upslope avalanche shoots drain. Multiple drainage names are separated by a slash, and many western headwaters descend into the Woro river. The "K." stands for Kali, Indonesian for stream. Lava domes and viscous flows ("L") are labeled with the year of extrusion. The Gegerbuaya ridge was formed by 1911 lavas. Garuda, Woro, and Gendol identify headwaters. Letters reference locations used by scientists to facilitate communication. The Kaliurang Observatory lies ~ 4 km to the SE of the summit. The labeled image was a collaborative effort provided here courtesy of John Pallister, USGS. Image copyright 2006, GeoEye.

The pace of volcanism and the intensity of the regional crisis increased after 27 May 2006. At 0553 that day, a destructive M_w 6.3 earthquake occurred leaving damage across central Java's southern coastal and inland areas (figure 2). The earthquake occurred at 10 km focal depth. The epicenter (at 7.962°S, 110.458°E) was 20 km SSE of Yogyakarta (population, 511,000; 6 million in the larger metro area). Some initial estimates put the earthquake at M_R 5.9; this was later revised and even the newer (above-stated) seismic parameters are preliminary.

A US Geological Survey (USGS) summary stated that the earthquake caused 5,749 deaths, 38,568 injuries, and led to as many as 600,000 people displaced in the Bantul-Yogyakarta area. The shaking left more than 127,000 houses destroyed and an additional 451,000 houses damaged in the area, with the total loss estimated at ~3.1 billion US dollars. Modified Mercalli intensities were as follows: at Bantul and Klaten, IX; at Sleman and Yogyakarta, VIII; at Surakarta, V; at Salatiga and Blitar, IV; and at Surabaya, II. The earthquake was felt in much of Java and at Denpasar, Bali. The website of the US Geological Survey's Earthquake Hazards Program features a large number of photos (captioned in English) depicting various aspects of the earthquake.

Events during 7 March-1 July 2006. Tables 1 and 2 summarize some of the details during the reporting interval. Merapi's activity had increased to include volcanic earthquakes and deformation of the summit area a year earlier (in July 2005). Although the number of daily lava avalanches and pyroclastic flows had increased almost a week earlier, a tectonic earthquake, M_R 6.3 (Richter scale magnitude), at 0555 (local time, WIB) on 27 May was followed by another significant increase in those events for another week (tables 1 and 2). Pyroclastic flows and lava avalanches between 10 May and 30 June were rare in the W-flank Sat drainage (31 May, 2 June, and 10 June), and did not descend into the Boyong drainage (SSW) after 4 June (table 2). The Krasak river drainage (SW) had material entering it on an almost daily basis after 27 May, except for a brief time during 14-19 June, with maximum run-out distances of 4 km. The Gendol drainage (SE) also experienced daily pyroclastic flows and lava avalanches starting on 28 May. Most of these flows to the SE did not extend more than 5 km, but on 14 June a pyroclastic flow descended 7 km.

Because of the vigor of activity, the Alert Level rose in several steps as follows: 19 March (Green to Yellow), 12 April (Yellow to Orange), and 13 May (Orange to Red). The step to Red (which is the highest alert level, and sometimes also referred to as Level 4) followed clear deformation at the

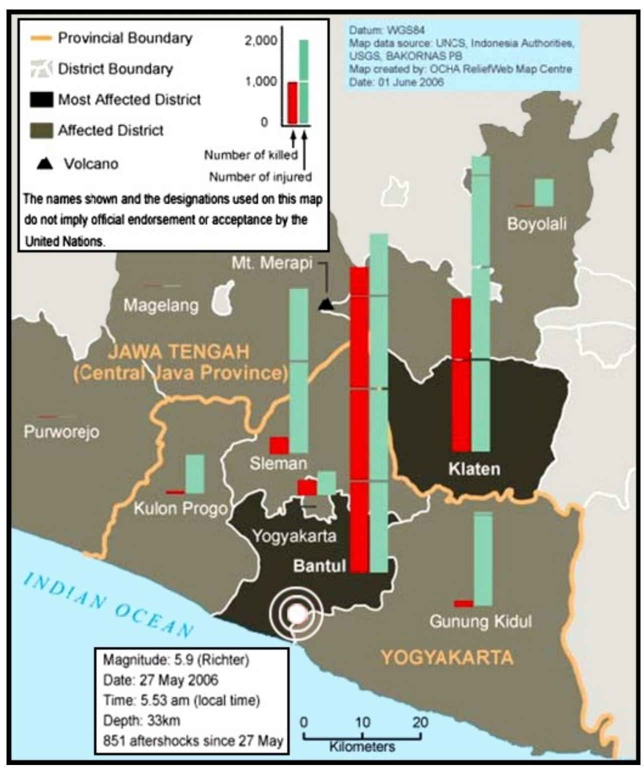

Figure 2. Epicenter of the 27 May 2006 earthquake in Central Java, including impact on regions around Merapi. The histograms show numbers of people killed (on left bar) and injured (right bar). As mentioned in text, some of the seismic parameters stated were later revised. Modified from a UN OCHA ReliefWeb Map Centre (1 June 2006) map in a 2006 United Nations report (see References).

Date (2006)	Plume seen to (meters above summit)	Lava avalanche signals	Multiphase earthquakes	Pyroclastic flow signals	Tectonic earthquakes
07-12 Mar	—	—	198	—	—
13-19 Mar	—	—	239	—	—
21 Apr	—	13	162	—	1
22 Apr	—	12	95	—	—
23 Apr	—	5	60	—	1
24 Apr	—	21	178	—	1
25 Apr	200	6	25	—	—
26-27 Apr			Missing		
28 Apr	—	20	126	—	—
29 Apr- 5 May			Missing		
06 May	—	82	95	—	—
07 May	—	59	104	—	—
08 May			Missing		
10 May	—	133	153	—	—
11 May	600	88	115	—	—
12-21 May			Missing		
22 May	—	309	56	25	—
23 May	700	243	60	31	—
24-26 May			Missing		
27 May *	100	279	—	54	138
28 May	1600	237	43	159	95
29 May	500	332	18	88	57
30 May	800	337	19	56	40
31 May	800	276	36	127	24
01 Jun	1300	315	35	144	13
02 Jun	650	338	25	163	24
03 Jun	800	488	79	107	16
04 Jun	900	397	54	118	25
05 Jun	400	300	9	157	17
06 Jun	300	212	10	78	14
07 Jun	275	256	12	66	8
08 Jun	300	210	28	67	10
09 Jun			Missing		
10 Jun	900	337	37	34	4
11 Jun	800	299	20	20	10
12 Jun	350	264	31	22	8
13 Jun	1200	273	88	28	5
14 Jun	500	371	29	61	2
15 Jun	900	260	100	27	6
16-18 Jun			Missing		
19 Jun	600	272	88	21	7
20 Jun	1250	312	136	38	4
21 Jun	Obscured	256	65	15	4
22 Jun	1200	319	39	4	5
23 Jun **	600	78	5	4	5
24 Jun	1500	338	48	21	6
25 Jun	800	321	32	18	17
26 Jun	800	372	27	17	11
27 Jun	1000	251	16	23	11
28 Jun	1000	308	16	19	1
29 Jun	700	290	11	15	12
30 Jun	500	74	0	9	3
01 Jul **	350	250	4	13	4

* Earthquake, M_R 6.3 (Richter scale magnitude) recorded at 0555 (local time, WIB)
** Incomplete data only 0000-0600 (local time)

Table 1. A compilation of seismic events at Merapi during 7 March to 1 July 2006. In creating this table *Bulletin* editors merged the category "landslides" with the category "lava avalanches". Similarly, the category "hot cloud reports" was interpreted to be equivalent to "pyroclastic flow" and those were also merged. Those mergers were driven by sudden shifts in terminology found in CVGHM reports. All data courtesy of CVGHM.

dome during elevated seismicity. On 28 April, a new lava dome emerged. By 20 May, pyroclastic flows several kilometers long were regularly seen passing down several key drainages (table 2). Figure 3 shows a 15 May pyroclastic flow (seen two days after the alert status rose to red).

Volcano enthusiasts and photographers Martin Rietze and Tom Pfeiffer viewed Merapi on the morning of 27 May, during the destructive earthquake, from a high-elevation parking area ~ 4 km S of the summit. Prior to the earthquake, Rietze took several spectacular photos of incandescent avalanches pouring down avalanche shoots (figure 4 A-B). During the earthquake, he described horizontal swinging motion and dull rumbling sounds lasting perhaps 20 seconds. Dust rose from the volcano. Plants rubbing together also produced a rustling noise. Cries and engine noises in the background came from distant residents responding to the earthquake. At ~1-minute intervals, Merapi emitted about six pyroclastic flows and a substantial ash cloud grew overhead, reaching several kilometers in altitude above them. The photo in figure 4 C depicts the scene on Merapi around that time (which Rietze lists as 0555 on 27 May). His companion, Tom Pfeiffer, also took photos just after the large earthquake (eg., figure 4 D).

Date	Gendal (km)	Krasak (km)	Boyong (km)	Sat (km)
10 May	0.2	1.5	—	—
20 May	3.0	3.0	3.0	—
22 May	—	3.5	—	—
27 May	—	3.8 (2.0)	(2.0)	—
28 May	3.0 (1.0)	(2.5)	(2.5)	—
29 May	1.0 (1.0)	3.5 (2.0)	(2.0)	—
30 May	2.0 (1.0)	3.5 (2.00	(2.0)	—
31 May	2.0 (1.5)	3.5 (2.5)	3.5 (2.5)	(2.5)
01 Jun	1.5 (1.5)	2.0 (3.0)	2.0 (3.0)	—
02 Jun	1.0 (1.0)	3.0	3.0	(1.0)
03 Jun	4.0 (1.0)	2.0 (1.0)	2.0 (2.0)	—
04 Jun	4.0 (1.0)	1.5 (2.0)	1.5 (2.0)	—
05 Jun	3.0 (1.0)	1.5 (2.0)	—	—
06 Jun	2.0 (1.0)	(2.0)	—	—
07 Jun	3.0 (1.0)	1.5 (2.0)	—	—
08 Jun	5.0 (1.0)	4.0 (2.0)	—	—
09 Jun	4.0	—	—	—
10 Jun	3.5 (1.0)	(2.0)	—	(3.0)
11 Jun	4.0	(3.0)	—	—
12 Jun	1.5	(3.0)	—	—
13 Jun	3.0 (1.0)	(2.0)	—	—
14 Jun	7.0	—	—	—
15 Jun	4.5	—	—	—
16-18 Jun		No data reported		
19 Jun	3.0 (1.0)	—	—	—
20 Jun	3.5 (1.0)	(2.0)	—	—
21-22 Jun		Obscured by weather		
23 Jun	(1.0)	(2.0)	—	—
24 Jun	4.0 (1.0)	2.5 (2.5)	—	—
25 Jun	3.0 (1.0)	(3.0)	—	—
26 Jun	4.5 (1.0)	4.0 (3.0)	—	—
28 Jun	3.0 (1.0)	(2.5)	—	—
29 Jun	2.0 (1.0)	(2.5)	—	—
30 Jun	3.0 (1.0)	(2.0)	—	—

Table 2. Record of run out distances (km) of pyroclastic flows and lava avalanches (the latter, in parentheses) toward river drainages on Merapi from 10 May to 30 June 2006. Courtesy of CVGHM.

During early June the activity level of Merapi remained at red and on 4 June, the increase in volume of the new lava dome had caused the southern part of the crater wall called Gegerbuaya (1910 lavas) to collapse. Prior to its collapse, Gegerbuaya had functioned as a barrier to prevent pyroclastic flows moving southward from entering the Gendol River, which they did later in June.

On 8 June, multiple pyroclastic flows reached 4 km from the Krasak and Boyong Rivers and up to 4.5 km down the Gendol River. On 9 June, ash drifted W and NW and accumulated as ashfall ~ 1.5 mm thick. Pyroclastic flows traveled as far as 4 km toward the Gendol River. Figures 5 and 6 show pyroclastic flows on 7 and 10 June.

In the period after the hazard level was raised to red, the lava dome grew and by 22 May its volume was ~ 2.3 million cubic meters. The M 6.3 earthquake in S-Central Java on 27 May triggered additional activity at Merapi. The dome's growth rate increased from the previous rate of around 100,000 cubic meters/day, leading to a lava dome volume on 8 June 2006 of ~4.3 million cubic meters. That lava dome stood 116 m above the nominal summit elevation of Merapi's peak (Garuda peak).

Dome collapse created the longest pyroclastic flow of the reporting interval, which took place on 14 June 2006. That pyroclastic flow attained a run-out distance of 7.0 km (table 2, figures 7 and 8, and previously reported in *BGVN* 31:05).

At least in part owing to loss of topographic relief at the Gegerbuaya ridge along the S crater wall (figure 1), the 14 June pyroclastic flow took a different path. It crossed the former barrier and descended the Gendol drainage. As previously noted (*BGVN* 31:05), the 14 June pyroclastic flow took two lives when the underground bunker where the victims sought refuge was buried by the pyroclastic flow.

The bunker overridden on 14 June resides in Kaliadem village (~ 5 km SE of the summit). News stories showed pictures of the rescue attempt with initial digging commencing using picks and shovels, with the excavation by soldiers wearing dust masks and standing on boards or wooden platforms, presumably to reduce the heat flow from the fresh deposit. The article also noted that the soldiers wore heat-retardant clothes. A report from the *Taipei Times* of 16 June 2006 and credited to the Associated Press said that "The fierce heat melted the troops' shovels and the tires on a mechanical digger brought in to plow through more than 2 m of volcanic debris covering the bunker, built for protection from volcanic eruption . . .." Later news reports noted that authorities unearthed the bunker, which lay beneath more than 2 m of steaming pyroclastic flow deposit. The two bodies had suffered burns and the facility's door was ajar. A BBC report showed deeper portions of the hole being excavated by a large backhoe. They also noted that upon deeper excavation a probe into the deposit with a hand-held digital thermometer apparently indicated temperatures reached ~ 400°C. Several grim photographs circulated in the press showing the excavated entrance of the bunker and a team in the process of removing the victim's bodies. No report has been found discussing the exact reason for the bunker's failure, although several comments in the press suggested it was not designed to withstand burial by a pyroclastic flow.

Figure 3. A photo taken on 15 May 2006 (0555 local time) of a pyroclastic flow traveling down the W flank of Merapi (the Krasak headwaters). Photo taken by Dari from the Kaliurang Observatory. Courtesy of CVGHM.

Figure 5. A pyroclastic flow at Merapi at 08:54:37 on 7 June 2006 showing a pyroclastic flow traveling down Merapi's upslope region in a generally SE direction. Photo credit to BPPTK (The Research and Technology Development Agency for Volcanology, Yogyakarta). Provided courtesy of CVGHM.

Prior to that, on 13 June, the alert status dropped to orange, but it rose back to red again the next day after the pyroclastic flow and increases in multi-phased earthquakes. Activity remained stable but high through June 29 but began to decrease after 30 June. During July the intensity and frequency of pyroclastic flows and rock falls decreased. On 10 July, authorities reduced the alert status to orange on all but the S slopes. By the end of July 2006, pyroclastic flows had ceased.

Merapi's long-term dome growth continued at low to modest levels during the rest of 2006 and early 2007. The Darwin Volcanic Ash Advisory Center noted a plume to 6.1 km altitude drifting NE on 19 March 2007. These later incidents will be discussed in more detail in a forthcoming issue of the *Bulletin*.

MODIS data. The Hawai'i Institute of Geophysics and Planetology MODIS Thermal Alert System web site lacked any thermal alerts for over a year preceding May 2006. Thermal alerts over Merapi began 14 May 2006 and extended through early September 2006 on nearly a daily basis. The alerts continued intermittently into 2007.

Geologic Summary. Merapi, one of Indonesia's most active volcanoes, lies in one of the world's most densely populated areas and dominates the landscape immediately N of the major city of Yogyakarta. Merapi is the youngest and southernmost of a volcanic chain extending NNW to Ungaran volcano. Growth of Old Merapi volcano beginning during the Pleistocene ended with major edifice collapse perhaps about 2,000 years ago, leaving a large

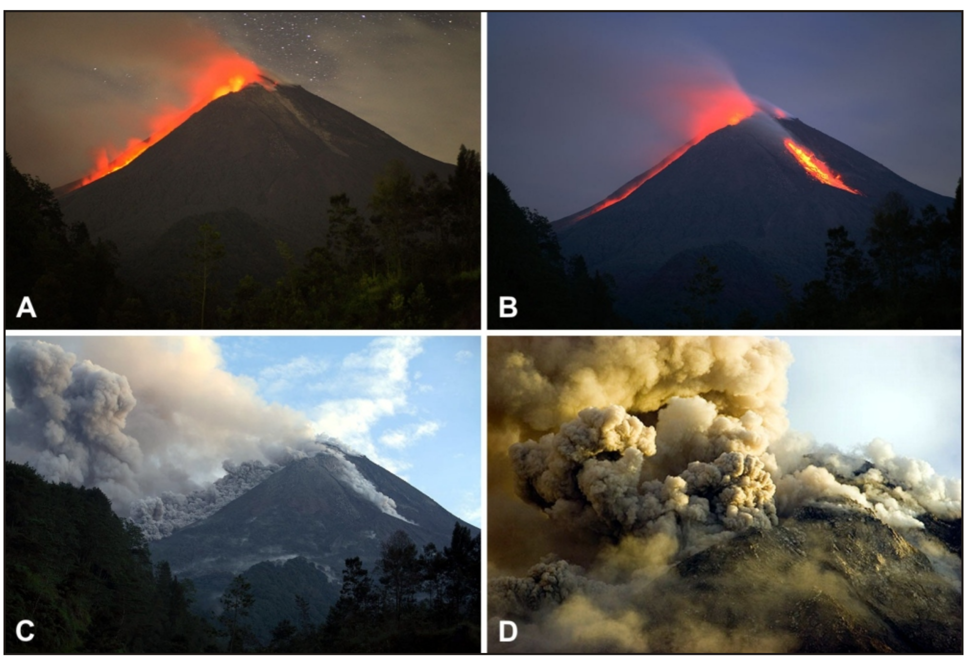

Figure 4 (A and B) Pre-dawn shots of incandescent material traveling down S-flank avalanche shoot(s) at Merapi on 27 May 2006 (prior to the M ~ 6 earthquake). (C) A photo of Merapi's response at 0555 on 27 May during or just after the M ~ 6 earthquake, with several pyroclastic flows clearly visible. (D) A second photo of the scene on Merapi during or just after the earthquake. This photo captured the chaotic scene at the summit and upper slopes, including a complex array of billowing ash clouds seemingly from multiple sources, and suspended dust hanging over many parts of the volcano (particularly distinguishable along the photo's lower central and right-hand areas). Copyrighted photos; those labeled A-C, used with permission of Martin Rietze; the one labeled D, with permission of Tom Pfeiffer.

arcuate scarp cutting the eroded older Batulawang volcano. Subsequently growth of the steep-sided Young Merapi edifice, its upper part unvegetated due to frequent eruptive activity, began SW of the earlier collapse scarp. Pyroclastic flows and lahars accompanying growth and collapse of the steep-sided active summit lava dome have devastated cultivated lands on the volcano's western-to-southern flanks and caused many fatalities during historical time. The volcano is the object of extensive monitoring efforts by the Merapi Volcano Observatory.

Figure 6. A Merapi pyroclastic flow in its early stages as seen at 08:50:53 on 10 June 2006. Photo credit to BPPTK; provided courtesy of CVGHM.

Figure 7. Deserted houses and dislodged lumber amid ash and volcanic rocks from Merapi (left-background) as seen in the village of Kaliadem (E of Kinahrejo near Bebeng, on the SE flank ~ 5 km from the summit) shortly after the 14 June 2006 pyroclastic flows passed through the settlement. Courtesy of Agence France Presse (photo by Tarko Sudiarno).

Figure 8. Night photo of Merapi (unknown date) showing incandescence on the slopes and, in the foreground, the large pyroclastic flow deposited on 14 June 2006. This photo is taken from nearly the same spot as the photos of 27 May (figure 4, above). Copyrighted photo used with permission of Tom Pfeiffer.

Reference: United Nations, 2006, Indonesia Earthquake 2006 Response Plan: United Nations, OCHA Situation Report No. 5, Issued 31 May 2006, GUDE EQ-2006-000064-IDN, 42 p.

Information Contacts: *Center of Volcanology and Geological Hazard Mitigation (CVGHM)*, Jalan Diponegoro 57, Bandung 40122, Indonesia (URL: http://portal.vsi.esdm.go.id/joomla/); *United Nations-Office for the Coordination of Humanitarian Affairs (OCHA)*, United Nations, New York, NY 10017, USA; *National Earthquake Information Center*, US Geological Survey, PO Box 25046, Denver Federal Center MS967, Denver, CO 80225, USA (URL: http://earthquake.usgs.gov/); *Darwin Volcanic Ash Advisory Centre (VAAC)*, Bureau of Meteorology, Northern Territory Regional Office, PO Box 40050, Casuarina, Northern Territory 0811, Australia (URL: http://www.bom.gov.au/info/vaac/advisories/); *John Pallister*, Volcano Disaster Assistance Program, USGS Cascades Volcano Observatory, 1300 SE Cardinal Court, Suite 100, Vancouver, WA 98683-9589, USA (URL: http://volcanoes.usgs.gov/); *Tom Pfeiffer* and *Martin Rietze*, Volcano Discovery (URL: http://www.decadevolcano.net/; http://www.tboeckel.de/EFSF/); *Tarko Sudiarno*, Agence France Presse (AFP) (http://www.afp.com/english/home/); *Taipei Times* (http://www.taipeitimes.com/); *Associated Press* (http://www.ap.org/); *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/).

Ijen

Java, Indonesia
8.058°S, 114.242°E; summit elev. 2,799 m

Scientists from Simon Fraser and McGill universities conducted preliminary geophysical and geochemical field studies at Ijen (figure 9) between 13 and 26 August 2006. During this period, volcanic activity was low and restricted to persistent degassing of the solfatara in the SE part of the crater.

Measurements of temperature and pH were made every morning during 14-19 August at four locations: the Banyupuhit River, ~ 5 km from the Banyupuhit River source, the acid lake in the summit crater, and the E shore of the crater lake. Temperatures of the Banyupuhit River were 16-20°C, always above atmospheric temperature by ~ 1-3°C; the pH was ~ 0.4. Lake temperatures varied between 31 and 43°C and the pH was -0.02. The color of the crater lake was generally homogeneous, although large black to brown linear patches, probably sulfur deposits from the solfatara, were observed on the turquoise-green surface. These ephemeral patches were of variable size (e.g.

Figure 9. Photograph of the acid crater lake and solfatara (bottom left) in the active crater at Ijen, August 2006. View is from the E crater rim. Courtesy of G. Mauri.

Figure 10. Close-up view of the solfatara at Ijen with fumarole temperature of more than 220°C. Note pipes for extracting sulfur gases. Courtesy of G. Mauri.

several ten's of meters long and a few meters wide) and moved across the lake during the course of the day, but were not always evident throughout the day. The area near the E shore appeared lighter than the rest of the lake, probably due to a spring at the bottom of the inner E slope.

Pipes driven into the fumaroles are used to extract gases for sulfur mining (figure 10). Temperatures measured 50 cm down into four of those pipes ranged from 224 to 248°C. These measurements almost certainly represent minimum estimates of the true temperatures due to heat loss along the length of the extraction pipes. After the gases had exited less than 50 cm from the pipes, temperatures had dropped below 120°C, the melting point of native sulfur.

A survey of sulfur dioxide (SO_2) fluxes made by a portable spectrometer (FLYSPEC) on 21 and 23 August along the SE rim of the crater consisted of seven and twelve walking traverses through the plume, respectively. The gas plume produced directly from the active solfatara near the lake surface rose buoyantly before flowing over the crater rim. During the first survey (conducted over a 2-hour period), the concentration-pathlength of the gas in the plume fluctuated between 1,000 and 2,500 ppm-m. The wind speed (measured by handheld anemometer at plume height) during this time averaged 6.1 m/s and the resultant SO_2 flux was therefore calculated to average 412 metric tons per day (t/d) with a standard deviation of 154 t/d. On 23 August, gas concentrations were somewhat lower, ranging between 500 and 2,000 ppm-m. The average wind speed during the survey period (2 hours) was 3.9 m/s and the resultant SO_2 flux averaged 254 t/d, with a standard deviation of 117 t/d. Based on this very limited survey, the flux of SO_2 was estimated to be 330 t/d.

Gravity surveys (Bouguer and dynamic) were conducted in the active crater and seven gravity stations were selected for future dynamic gravity monitoring. A digital elevation map was prepared (using digital photogrammetric mapping methods) to provide the spatial framework required for interpretation of the geophysical surveys.

The scientists also applied the self-potential (SP) method, also know as spontaneous potential, that measures electrical potentials developed in the Earth by electrochemical action between minerals and solutions with which they are in contact. SP mapping of the active summit crater showed two main hydrologic structures (figure 11). The first is a hydrogeologic zone on the E and NE rim characterized by a negative SP anomaly with a minimum at -100 mV (millivolts), an inverse SP/elevation gradient of -1.6 mV/m, and length of 1,500 m. This almost certainly represents inflow of meteoric water and groundwater.

The second structure is the main hydrothermal system located S, W, and N of the crater as well as in the southern inner slope of the crater, places where the surface expressions are solfataras. The SP maxima range between 48 and 60 mV and are located on the slope of the river below a dam on the outer W slope (+52 mV), on the N rim (+48 mV) and in the S part of the solfatara (+ 59 mV). Processing of the SP data along the crater profile by continuous wavelet transform (Mauri and others, 2006) shows that the hydrothermal fluid cells are near the surface (less than 200 m below the topographic surface) suggesting that the hydrothermal system is under high pressure with significant heat flux, as shown by the solfatara.

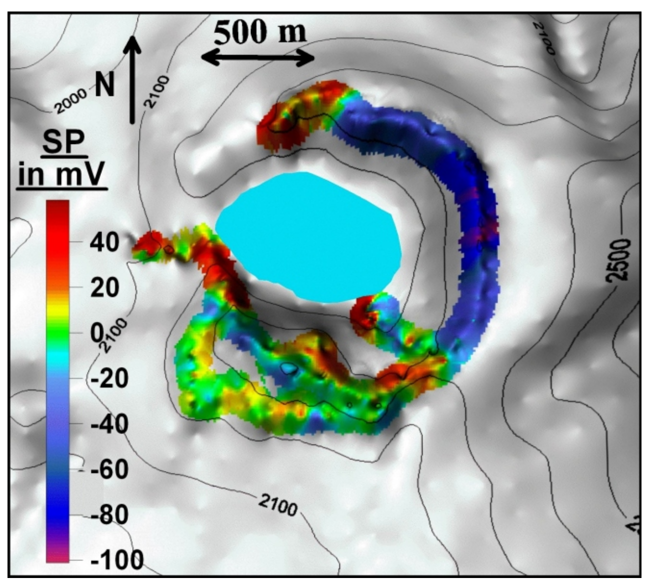

Figure 11. Self-potential survey results shown on a topographic map of the active crater of Ijen, August 2006. All the SP data were referenced at the Banyupuhit River and at a spring on the inner E slope of the crater. Contour line intervals are 100 m. Courtesy of G. Williams-Jones.

Geologic Summary. The Ijen volcano complex at the eastern end of Java consists of a group of small stratovolcanoes constructed within the large 20-km-wide Ijen (Kendeng) caldera. The N caldera wall forms a prominent arcuate ridge, but elsewhere the caldera rim is buried by post-caldera volcanoes, including Gunung Merapi stratovolcano, which forms the 2,799 m high point of the Ijen complex. Immediately W of Gunung Merapi is the renowned historically active Kawah Ijen volcano, which contains a nearly 1-km-wide, turquoise-colored, acid crater lake. Picturesque Kawah Ijen is the world's largest highly acidic lake and is the site of a labor-intensive sulfur mining operation in which sulfur-laden baskets are hand-carried from the crater floor. Many other post-caldera cones and craters are located within the caldera or along its rim. The largest concentration of post-caldera cones forms an E-W-trending zone across the southern side of the caldera. Coffee plantations cover much of the Ijen caldera floor, and tourists are drawn to its waterfalls, hot springs, and dramatic volcanic scenery.

Reference: Mauri, G., Saracco, G., and Labazuy, P., 2006, Volcanic activity of the Piton de la Fournaise volcano characterized by temporal analysis of hydrothermal fluid movement, 1992 to 2005: AGU, Eos Trans, v. 87, no. 52, Fall Meet. Suppl., Abstract V51A-1653.

Information Contacts: *Guillaume Mauri* and *Glyn Williams-Jones*, Department of Earth Sciences, Simon Fraser University, Burnaby, BC V5A 1S6, Canada (URL: http://www.sfu.ca/earth-sciences/, Email: gmauri@sfu.ca); Willy (A.E.) Williams-Jones, Department of Earth and Planetary Sciences, McGill University, Montreal, Quebec, Canada 9URL: http://www.eps.mcgill.ca/); *Deddy Mulyadi*, Centre of Volcanology and Geological Hazard Mitigation (CVGHM), Diponegoro 57, Bandung, Jawa Barat 40122, Indonesia (URL: http://portal.vsi.esdm.go.id/joomla/).

Langila

New Britain, Papua New Guinea
5.525°S, 148.42°E; summit elev. 1,330 m

Moderate activity occurred at Langila between January and March 2006 (*BGVN* 31:05), with eruptive activity accompanied by a continuous ashfall, rumbling, and weak emissions of lava fragments. Since March 2006, activity has continued at Crater 2.

According to the Darwin Volcanic Ash Advisory Center (VAAC), eruptions at Crater 2 occurred in August 2006 and from October 2006 through March 2007, with explosions of incandescent lava fragments, roaring noises at regular intervals, and continuous emissions of gray-to-brown ash plumes. Plumes generally reached 2.3-3.3 km altitude, although on 31 October a small ash plume rose to an altitude of 4.6 km. Ash plumes were occasionally visible on satellite imagery. During October and through the first part of January 2007, plumes generally drifted N, NW, W, WNW, and NE; between the end of January and March, plumes drifted SE and SW.

Thermal anomalies detected by MODIS instruments on the Terra and Aqua satellites were absent after 2 January 2006 until 21 July 2006. The same system (the HIGP Thermal Alerts System) identified anomalies again on 24 and 31 October, 12 and 21 November, 16 and 27 December 2006, 6 January, 8 March, and 18 March 2007.

Geologic Summary. Langila, one of the most active volcanoes of New Britain, consists of a group of four small overlapping composite basaltic-andesitic cones on the lower eastern flank of the extinct Talawe volcano. Talawe is the highest volcano in the Cape Gloucester area of NW New Britain. A rectangular, 2.5-km-long crater is breached widely to the SE; Langila volcano was constructed NE of the breached crater of Talawe. An extensive lava field reaches the coast on the N and NE sides of Langila. Frequent mild-to-moderate explosive eruptions, sometimes accompanied by lava flows, have been recorded since the 19th century from three active craters at the summit of Langila. The youngest and smallest crater (no. 3 crater) was formed in 1960 and has a diameter of 150 m.

Information Contacts: *Rabaul Volcano Observatory (RVO)*, PO Box 386, Rabaul, Papua New Guinea; *Darwin Volcanic Ash Advisory Centre (VAAC)*, Bureau of Meteorology, Northern Territory Regional Office, PO Box 40050, Casuarina, Northern Territory 0811, Australia (URL: http://www.bom.gov.au/info/vaac/); *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/).

Ulawun

New Britain, SW Pacific
5.05°S, 151.33°E; summit elev. 2,334 m

A previous report (*BGVN* 31:02) described small earthquakes on 1-2 March 2006, accompanied by "gray-blue emissions." Subsequent ongoing eruptions continued at Ulawun through 18 January 2007, generating almost daily aviation reports describing plumes blowing W to NW and of generally modest height (table 3). The tallest plume of the reporting interval rose to 4.6 km altitude.

No MODIS thermal alerts were identified between March 2006 and January 2007 on the Hawai'i Institute of Geophysics and Planetology MODIS Thermal Alert System web site. The lack of thermal anomalies may indicate explosive eruptions, and not lava emissions. However, such activity has occurred at the summit in the past. One such episode, in November 1985, generated Strombolian activity and pyroclastic flows (figure 12).

Four Volcanic Ash Advisory Centers (VAAC): Tokyo, Washington, Darwin, and Wellington, have an interest in this volcano, because plumes may enter their areas of responsibility (figure 13). The VAACs came into existence to keep aviators informed of volcanic hazards. A key player in their development was the International Civil Aviation Organization (ICAO), a United Nations Related Agency that is the recognized international authority regarding a large number of aviation isses. Nine VAAC were created, in Anchorage (Alaska), Buenos Aires (Argentina), Darwin (Australia), London (England), Montreal (Canada), Tokyo (Japan), Toulouse (France), Washington (United States), and Wellington (New Zealand). These centers are tasked with monitoring volcanic ash plumes and providing Volcanic Ash Advisories (VAA) whenever those plumes enter

Figure 12. Photograph of Ulawun taken from a helicopter on 25 November 1985. The view from the NE shows emission of large clots of molten lava into the air above the vent and pyroclastic flows (right). The other large stratovolcano in the background is 2,248-m-tall Bamus. Photographs were taken and provided by James Mori, Disaster Prevention Research Institute, Kyoto University.

their assigned airspace. The VAACs are often integrated with aviation weather centers; many have developed back-up sites. For example, the Washington VAAC is backed-up by the US Air Force Weather Agency; the Tokyo by Japan Meteorological Association Headquarters, and Darwin by the National Meteorological & Oceanographic Centre.

Geologic Summary. The symmetrical basaltic-to-andesitic Ulawun stratovolcano is the highest volcano of the Bismarck arc, and one of Papua New Guinea's most frequently active. Ulawun volcano, also known as the North Son, rises above the N coast of the island of New Britain across a low saddle NE of Bamus volcano, the South Son. The upper 1000 m of the 2334-m-high Ulawun volcano is unvegetated. A prominent E-W-trending escarpment on the S may be the result of large-scale slumping. Satellitic cones occupy the NW and eastern flanks. A steep-walled valley cuts the NW side of Ulawun volcano, and a flank lava-flow complex lies to the S of this valley. Historical eruptions date back to the beginning of the 18th century. Twentieth-century eruptions were mildly explosive until 1967, but after 1970 several larger eruptions produced lava flows and basaltic pyroclastic flows, greatly modifying the summit crater.

Information Contacts: *Rabaul Volcano Observatory* (RVO), P. O. Box 386, Rabaul, Papua New Guinea (Email: hguria@global.net.pg); *Darwin Volcanic Ash Advisory Centre* (VAAC), Commonwealth Bureau of Meteorology, Northern Territory Regional Office, PO Box 40050, Casuarina, NT 0811, Australia (URL: http://www.bom.gov.au/info/vaac/; Email: darwin.vaac@bom.gov.au); *US Air Force Weather Agency (AFWA)*, Satellite Applications Branch, Offutt AFB, NE 68113-4039, USA (Email:charles.holliday@afwa.af.mil); *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/); *James Mori*, Disaster Prevention Research Institute, Kyoto University, Uji, Kyoto 611-0011, Japan (http://eqh.dpri.kyoto-u.ac.jp/~ mori/).

Date	Comments
22-28 Mar 2006	Ash visible at an altitude of ~ 3 km (pilot report).
09 Apr 2006	Small low-level plume extending W.
14 May 2006	An ash plume of unknown height.
25 May 2006	Thin steam-and-ash plume.
31 May 2006	A thin steam-and-ash plume reached an altitude of below 3 km.
15 Aug 2006	Ash-and-steam plume to an altitude of ~ 3.7 km.
25 Aug 2006	Steam-and-ash plumes reached altitudes of 3.7 km and drifted NW.
27 Aug 2006	Steam-and-ash plumes reached altitudes of 3.7 km and drifted W.
28 Aug 2006	Steam-and-ash plumes reached altitudes of 3.7 km and drifted SW.
30 Aug 2006	Ash-and-steam plumes drifting SW.
02 Sep 2006	Ash-and-steam plumes drifting S visible on satellite imagery.
12 Nov 2006	Diffuse plume to altitude of 4.6 km drifted NW.
16-18 Nov 2006	Diffuse plumes drifting N and NW. Ash-and-steam plume visible on 18 November.
22 Nov 2006	Diffuse plume.
28 Nov 2006	Ash-and-steam plume.
29 Nov 2006	Diffuse ash-and-steam plume. The altitudes and drift directions were not reported.
04 Dec 2006	Ash plume. Altitudes and drift directions not reported.
09 Dec 2006	Diffuse plumes reaching altitudes of 4 km.
11 Dec 2006	Plumes reached unreported altitudes.
21 Dec 2006	Ash plumes drifting ENE.
22 Dec 2006	Ash plumes drifting NW.
25 Dec 2006	Ash plumes drifting SW.
04 Jan 2007	Diffuse steam-and-ash plumes drifting SW.
18 Jan 2007	Pilot report noted an ash plume to an altitude of 2.4 km drifting SW.

Table 3. A summary of key events at Ulawun observed during the reporting interval 22 March 2006-18 January 2007. Reported plumes did not attain an altitude of over 4 km except on 12 November, when they reached an altitude of 4.6 km. Information based primarily on satellite data and pilot reports from the Darwin VAAC and in a few cases, the US Air Force Weather Agency (AFWA).

Figure 13. Map of Indonesia and Papua New Guinea showing selected volcanoes, including Ulawun on New Britain (right center), with areas of responsibility for local VAACs. Courtesy of Darwin VAAC.

Rabaul

New Britain, SW Pacific
4.271°S, 152.203°E; summit elev. 688 m
All times are local (= UTC + 10 hours)

As previously reported, the Rabaul Volcano Observatory noted a large, sustained Vulcanian eruption at Rabaul on 7 October 2006. Since that initial event at the Tavurvur cone, activity has varied in intensity (*BGVN* 31:10). During 13 December 2006 through the end of March 2007, generally mild eruptive activity continued, often with loud roaring noises and in some cases with ash plumes rising 1.5 to 3.7 km above Tavurvur's summit.

During December 2006, there was only low level seismicity, including high-frequency earthquakes and mild eruptive activity. During 24-29 December, ash clouds rose 1-3.7 km above the summit before being blown variably to the NE and SW. On 25, 27, and 28 December, fine ash fell downwind, including in Rabaul Town, and occasional roaring noises were heard. Seismic activity continued at low levels. No high-frequency earthquakes were recorded. Low seismicity continued during most of January.

During 4-10 January 2007 plumes occasionally bearing ash rose 0.9-3.3 km above the cone and drifted E and NE. Vapor emissions accompanied by pale gray ash clouds occurred on 13, 16, and 24 January. The emissions rose 0.4-2.5 km above Tavurvur's summit and blew E, NE, and N. During 24-25 January there were nine low-frequency earthquakes recorded. Ground deformation measurements showed no significant movement apart from a slight deflation of about 1 cm during the last few days of January. From 29 January onwards, seismicity increased to a moderate level. Three high-frequency earthquakes were recorded, one on 27 January, and two on 30 January, all originating NE of the caldera. Low-frequency earthquakes began 24 January. A total of 16 events were recorded during 24-28 January, and a further 50-60 small events 29-31 January.

Two small explosions occurred at 0448 and 0548 on 27 January and a large explosion occurred at 0130 on 31 January. The latter explosion showered the cone's flanks. The accompanying ash clouds rose a couple of hundred meters straight above the summit. Fine ashfall occurred at Rabaul Town and surrounding areas.

Mild eruptive activity continued during early February with associated seismicity at very low levels. The small low-frequency earthquakes had declined in number by about half. Ground deformation data indicated a noticeable deflation of the caldera. Mild eruptive activity continued intermittently during the latter half of February, associated with low seismicity. Ash fell on surrounding villages on 20 February. On 16, 19, and 21 February, low-frequency earthquakes and white vapor emissions containing very low ash content rose as high as 3 km above Tavurvur's summit. The emissions were not accompanied by high-frequency signals or significant ground deformation.

Moderate explosions occurred on 21, 26, and 27 February. A larger explosion, at 1150 on 28 February, showered the cone's flanks with lava fragments. Thick ash clouds rose 2 km above the summit and blew NE.

Between 3 and 4 March, multiple explosions occurred; the biggest on 3, 4, and 8 March. The explosion's shockwaves rattled houses in Rabaul Town and surrounding villages. Thick ash and lava fragments showered the flanks of the cone. Other emissions consisted of white gray ash clouds that drifted E and SE. On 4 and 6 March ash plumes rose as high as 2.7 km above the summit. A weak glow was visible only during forceful emissions.

During 6 to 21 March, ash plumes intermittently rose as high as 3.7 km. From 16 to 25 March, multiple explosions again produced shockwaves felt in Rabaul Town, and ash fell in surrounding villages. Incandescent material was seen rolling down the cone's flanks. During the period 27-30 March only low level vapor emissions rising to 400 m above the cone were visible. Seismic activity continued to remain at a very low level, with just three or four short (< 30 second) low-frequency events. There were no high-frequency events.

Geologic Summary. The low-lying Rabaul caldera on the tip of the Gazelle Peninsula at the NE end of New Britain forms a broad sheltered harbor utilized by what was the island's largest city prior to a major eruption in 1994. The outer flanks of the 688-m-high asymmetrical pyroclastic shield volcano are formed by thick pyroclastic-flow deposits. The 8 x 14 km caldera is widely breached on the E, where its floor is flooded by Blanche Bay and was formed about 1,400 years ago. An earlier caldera-forming eruption about 7,100 years ago is now considered to have originated from Tavui caldera, offshore to the N. Three small stratovolcanoes lie outside the northern and NE caldera rims of Rabaul. Post-caldera eruptions built basaltic-to-dacitic pyroclastic cones on the caldera floor near the NE and western caldera walls. Several of these, including Vulcan cone, which was formed during a large eruption in 1878, have produced major explosive activity during historical time. A powerful explosive eruption in 1994 occurred simultaneously from Vulcan and Tavurvur volcanoes and forced the temporary abandonment of Rabaul Town.

Information Contacts: *Steve Saunders* and *Herman Patia*, Rabaul Volcanological Observatory (RVO), Department of Mining, Private Mail Bag, Port Moresby Post Office, National Capitol District, Papua, New Guinea (Email: hguria@global.net.pg); *Andrew Tupper*, Darwin Volcanic Ash Advisory Centre (VAAC), Bureau of Meteorology, Darwin, Australia (Email: A.Tupper@bom.gov.au).

Lopevi

Vanuatu, SW Pacific
16.507°S, 168.346°E; summit elev. 1,413 m
All times are local (= UTC + 11 hours)

Volcanic activity from Lopevi has continued intermittently since November 1998 (*BGVN* 24:02). Though there are no permanent residents on the island, which is known as Vanei Vollohulu in the local language, the nearby islands of Epi (~ 17 km SW) and Paama (~ 10 km WNW) are heavily populated. Ambrym, another active volcanic island 18 km NNW, is also at risk of ashfall from Lopevi. Ash plumes during active periods are often reported by aviators, and thermal anomalies are frequently detected by the MODIS instrument on the Terra and Aqua satellites. Ash plumes and lava flows have most recently been reported in January, May, and July 2006.

Activity during 2006. Vertical plumes were observed by aviators reaching altitudes of 2.1-2.4 km on the morning of 24 January, and ~ 2.7 km the next morning. Further advisories issued by the Wellington VAAC reported that "smoke" plumes with a "steady rate of growth" rose to ~ 2.1 km on the morning of 26 January and drifted S. Lava flowing down the S flank was also reported on the 26th.

Based on information from a pilot report, the Wellington VAAC reported that on 7 May 2006 a small ash plume was visible below an altitude of ~ 3 km and an active lava flow was observed. On 10 May, a slow moving plume reached 3 km altitude. The next day a plume rose to 4.6 km and trended SE. During 12-13 May, the plume heights lessened to 3 km as the eruption vigor reportedly decreased. News media also reported heavy ashfall on Ambrym and Paama from an eruption on 15 May. An official spokesperson for Vanuatu's National Disaster Management Office reported no new ashfall during 17-22 May.

A situation report from the UN Office for the Coordination of Humanitarian Affairs (OCHA) noted that the May eruptive episode caused heavy ashfall on Paama and SE Ambrym, affecting water supplies and crops. The total population of Paama is 1,572, comprised of 23 villages and 511 households. On the island of Paama, the two main cash crops of vanilla and pepper were damaged badly. On both islands, staple foods such as wild yams, kumala, taros, bananas, and coconut trees were either damaged or destroyed. Residents experienced health problems caused by the consumption of contaminated food and water as well as the inhalation of ash. Head pain, skin infections, diarrhea, vomiting and respiratory difficulties were reported.

The Wellington VAAC received pilot reports of an eruption plume on 5 July that reached an unknown altitude. Another pilot report indicated that the eruption may have started on 27 June. The eruption continued over the next few days, with dark ash plumes reaching altitudes of 3.7 km and drifting E and SE. No plumes were reported after the morning of 10 July.

MODIS thermal anomalies during 2005-2006. Thermal anomalies were detected by MODIS during 26-31 March 2005, though no corresponding explosive activity was reported. No hot spots were identified at Lopevi again until 27 October 2005, after which anomalies were present on most days through 26 January 2006; ash plumes were not reported until the end of this period, 24-26 January.

Later in 2006, thermal anomalies were detected by MODIS on most days during 25-28 April, 2-16 May, 25-28 May, 26 June-9 July, and 18 July-1 August 2006. The largest number of alert pixels (24) during this time occurred at 2225 on 2 May. These data indicated two significant episodes of activity that included both explosive activity and probably lava emission during 25 April-28 May and 26 June-1 August. Two periods of plumes observations discussed previously, during 7-15 May and 27 June-10 July, fall within these longer episodes defined by the thermal data. No MODIS thermal anomalies were detected between 2 August 2006 and mid-March 2007.

Geologic Summary. The small 7-km-wide conical island of Lopevi is one of Vanuatu's most active volcanoes. A small summit crater containing a cinder cone is breached to the NW and tops an older cone that is rimmed by the remnant of a larger crater. The basaltic-to-andesitic volcano has been active during historical time at both summit and flank vents, primarily along a NW-SE-trending fissure that cuts across the island, producing moderate explosive eruptions and lava flows that reached the coast. Historical eruptions at the 1,413-m-high volcano date back to the mid-19th century. The island was evacuated following eruptions in 1939 and 1960. The latter eruption, from a NW-flank fissure vent, produced a pyroclastic flow that swept to the sea and a lava flow that formed a new peninsula on the western coast.

Information Contacts: *Wellington Volcanic Ash Advisory Centre (VAAC)*, Meteorological Service of New Zealand Ltd (MetService), PO Box 722, Wellington, New Zealand (URL: http://www.metservice.com/vaac/, http://www.ssd.noaa.gov/VAAC/OTH/NZ/messages.html); *MODVOLC Alerts Team*, Hawai'i Institute of Geophysics and Planetology (HIGP), SOEST, University of Hawaii and Manoa, 168 East-West Road, Post 602, Honolulu, HI 96822, USA (URL: http://modis.higp.hawaii.edu/); *Department of Geology, Mines, and Water Resources*, PMB 01, Port-Vila, Vanuatu (Email: observatoire@vanuatu.com.vu; URL: http://www.mpl.ird.fr/suds-en-ligne/fr/volcan/vanu_eng/lopevi1.htm); *Port Vila Presse*, PO Box 637, Port Vila, Efate, Vanuatu (URL: http://www.news.vu/en/); *ReliefWeb*, Office for the Coordination of Humanitarian Affairs, United Nations, New York, NY 10017, USA (URL: http://www.reliefweb.int/).

Ruapehu

New Zealand
39.28°S, 175.57°E; summit elev. 2,797 m
All times are local (= UTC +12 hours)

A moderate volcanic earthquake struck Ruapehu at 2230 on 4 October 2006. The M 2.8 event falsely triggered the lahar warning system. A visit to the crater lake on 7 October revealed evidence that a small hydrothermal eruption had occurred. Wave action reached up to 4-5 m above the lake surface around the basin, but was insufficient to overflow the tephra dam where it might have formed a lahar on the outer slopes. Since the last measurement (date not specified) the lake's temperature rose ~ 8°C, and the water level increased ~ 1 m. Both of these effects were expected. Seismic activity remained at typical background levels on 7 October 2006.

At about 1300 on 18 March 2007, Crater Lake partly emptied and its runoff traveled rapidly downstream as a powerful lahar. A subsequent issue will discuss that dramatic event and its impact.

Since the last report in February 2004 (*BGVN* 29:02), from May 2003 to October 2006, there were eight alerts issued by the Institute of Geological & Nuclear Sciences (IGNS, table 4), indicating appreciable changes in both the level of the lake and its temperature; these alerts can be compared with the temperature data (table 5).

Volcanic tremor was recorded during July 2005 and continued at varying levels. Although tremor is not unusual at Ruapehu, this was the strongest recorded since November 2004. Prominent steam plumes rose above Ruapehu on the morning of 13 September 2005. The crater lake temperature had recently risen from 23°C in August 2005 (table 5) to 39°C in early September 2005. By 12 October 2005 it had fallen to 30°C, indicating the end of the heating cycle.

Alert Date	Alert Comments
26 May 2003	Steam plumes, volcanic tremor, Crater Lake temperatures increase
15 Nov 2004	Volcanic tremor, Crater Lake temperature increase
22 Aug 2005	Crater Lake temperature increase
13 Sep 2005	Steam plumes
18 Oct 2005	Crater Lake temperature decrease
01 Nov 2005	Crater Lake temperature increase
05 Oct 2006	Moderate (M 2.8) volcanic earthquake
07 Oct 2006	Minor hydrothermal eruptions

Table 4. Institute of Geological & Nuclear Sciences (IGNS) alerts posted for Ruapehu volcano, May 2003 to October 2006. Compiled from IGNS reports.

Thereafter, another cycle of lake heating took place in middle to late October 2005. During the period when the lake was at its hottest, steam plumes appeared on several days, but no eruptive activity was observed. Seismic activity continued at about normal levels except for a slight increase in the occurrence of volcanic earthquakes over the previous two weeks.

Lahar hazard. The last report on Ruapehu (*BGVN* 29:02) reviewed the government of New Zealand's efforts to lessen potential damage and loss of life from the possible collapse of the ash dam surrounding the lake that sits directly within the crater. An illustrative model of the most likely potential lahar was presented in the previous *Bulletin* (*BGVN* 29:02). Figure 14 provides more details on the regional geography.

According to IGNS and related government websites, the most likely lahar's path starts from a 7-m-thick tephra dam sitting above bedrock along the low point in Ruapehu's crater rim. This path descends along the Whangaehu valley, a drainage that initially travels radially down the cone to the E. Where the Whangaehu reaches beyond ~ 10 km from the rim (figure 14), the channel curves sharply S and then SW, ultimately crossing Ruapehu's S side. In contrast, just upstream of the above-mentioned bend, the intersecting Tongariro river flows N. At that connection between the two drainages (a divide), engineers added a 300-m-long embankment (a levee or bund), to keep substantial material from entering the Tongariro drainage. Engineers also added one or more chutes to direct some of the Whangaehu river S and away from the critical junction. Protecting the Tongariro river from sudden influx of water and debris protects infrastructure along and downstream of that river. For example, the Tongariro river enters Lake Taupo, a 30 x 40 km caldera lake. Lake Taupo drains to the N along the Waikato river and dams along that river generate hydroelectric power.

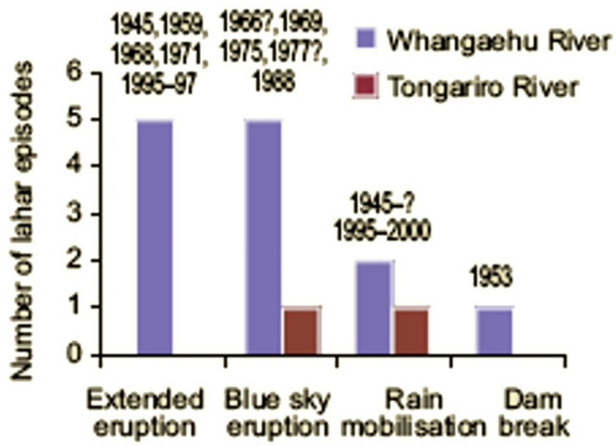

Figure 15. Lahar episodes occurring at Ruapehu since 1945, as grouped into four categories. The categories are those associated with an extended eruption, a sudden (blue-sky) eruption, rain mobilization, and dam break or failure. From Harry J. R. Keys (date unknown), Department of Conservation (see Reference, below).

According to the Institute of Geological & Nuclear Sciences (IGNS), about 60 lahars have swept down the mountain's southern side in the past 150 years. Lahars are not limited to the Whangaehu valley as eruptive and mass wasting processes can result in sudden influx of water and debris in other drainages as well. Lahar episodes since 1945 appear on figure 15.

Figure 16 contains plots of the crater lake's surface elevation during the past several years. The plot is part of a poster available on the Department of Conservation website. The poster also notes the approximate volume of

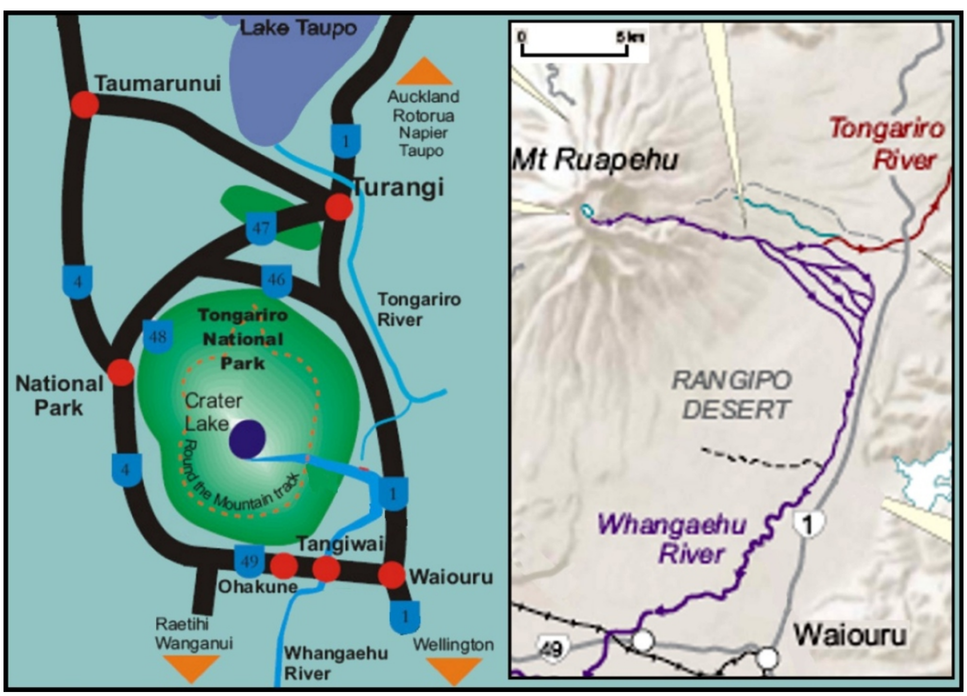

Figure 14. Composite maps of the Ruapehu area modified from part of a lahar hazards poster titled "How will the Lahar Affect Me?" The schematic map (at left) shows that the Tongariro river trends N, crosses State Highway 1 two times, and eventually enters Lake Taupo. The shaded relief map (right) of Ruapehu and adjacent flanks along its E-sector. Note the multiple chutes created to divert flood waters and lahars toward the S on the Whangaehu river. These chutes are intended to protect the Tongariro river's headwaters. Courtesy of the NZ Department of Conservation.

the crater lake, 10^7 m^3. The tephra dam allows lake water to seep through it, considerably complicating estimates of the late-stage-filling rates, and any predicted date of overflow or related failure. Derek Cheng wrote an 8 January 2007 New Zealand Herald news piece stating that the lake then stood ~ 2.7 m below the dam's top. According to Chang's news story, the tephra dam allowed lake water to seep through it at a rate of ~ 10 L per second.

Crater Lake observations. Ruapehu's Crater Lake had warmed following periods of volcanic tremor, with heating cycles getting to temperatures ranging from about 15 to 40°C (eg., 39°C during February 2004 and ~36°C during late October 2006; table 5). The IGNS website notes that Ruapehu's heating cycles typically occur every 9-12 months and normally last 1-3 months.

An innovative approach to covering the current lahar hazard status can be found at the Department of Conservation website. As of early February 2007 the reports were "updated every 1-2 weeks depending on weather conditions and [field] site visits."

Date (2003-2006)	Temperature (°C)
Jan 2003	42
05 Mar 2003	30
15 May 2003	42
15 Mar 2004	35
Aug 2004	16
13 Nov 2004	19
Feb 2005	39 (peak for heating cycle)
04 Aug 2005	23
21 Aug 2005	32
03 Sep 2005	39
24 Sep 2005	34
12 Oct 2005	30
24 and 27 Oct 2005	35-36
(Unstated date during the October 2005 to 5 October 2006 time span)	15
05 Oct 2006	23 (after earthquake)

Table 5. Lake temperature data at Ruapehu during 2003-2006. Gaps in the data over 2 months are indicated by blank rows. Some months have multiple sets of readings. Data were rounded to two significant figures. Compiled from IGNS reports.

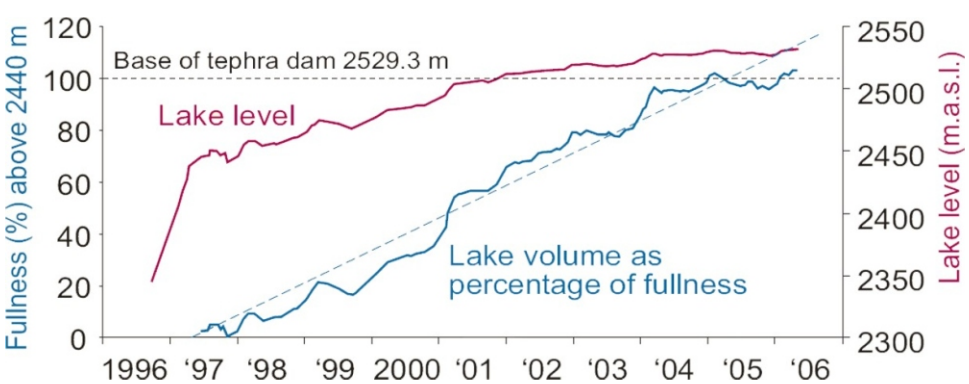

Figure 16. A plot of the surface elevation with time (1996 to mid-2006) of Ruapehu's crater lake. Absolute lake elevations in meters above sea-level apply to the curve labeled "Lake level" and correspond to the y-axis scale at the right. Indices of lake fullness (percent above or below the elevation 2,440 m) apply to the curve describing "Lake volume as percent of fullness." This curve corresponds to the y-axis at left (i.e., 0 % full = 2,440 m a.s.l.; 100% full = 2,529.3 m a.s.l.). The dotted horizontal line indicates the elevation of the base of the tephra dam that lies over the rim's low point. This plot came directly from an informative poster on the lahar available online at the Department of Conservation website (Keys, (date unknown), in reference list below).

Reference: Keys, H.J.R., (date unknown), Lahars from Mount Ruapehu—mitigation and management; NZ Dept. of Conservation website (a poster conveyed as a PDF file; creation/publication date unknown) (URL: http://www.doc.govt.nz/templates/summary.aspx?id=42442).

Geologic Summary. Ruapehu, one of New Zealand's most active volcanoes, is a complex stratovolcano constructed during at least 4 cone-building episodes dating back to about 200,000 years ago. The 110 cu km dominantly andesitic volcanic massif is elongated in a NNE-SSW direction and is surrounded by another 100 cu km ring plain of volcaniclastic debris, including the Murimoto debris-avalanche deposit on the NW flank. A series of subplinian eruptions took place at Ruapehu between about 22,600 and 10,000 years ago, but pyroclastic flows have been infrequent at Ruapehu. A single historically active vent, Crater Lake, is located in the broad summit region, but at least five other vents on the summit and flank have been active during the Holocene. Frequent mild-to-moderate explosive eruptions have occurred in historical time from the Crater Lake vent, and tephra characteristics suggest that the crater lake may have formed as early as 3000 years ago. Lahars produced by phreatic eruptions from the summit crater lake are a hazard to a ski area on the upper flanks and to lower river valleys.

Information Contacts: *Institute of Geological & Nuclear Sciences* (IGNS), Private Bag 2000, Wairakei, New Zealand (URL: http://www.gns/cri.nz/; http://data.geonet.org.nz/geonews/index.html) and *New Zealand Department of Conservation*, Private Bag, Turangi, New Zealand (URL: http://www.doc.govt.nz/).

Lastarria

Northern Chile
25.17°S, 68.50°W; summit elev. 5,697 m

The rarely visited Lastarria has not erupted in historical time, but has displayed strong fumarolic activity (figure 17) for at least 67 years. This is the first *Bulletin* report ever issued on this volcano; it presents new images of the steaming edifice. On 2 February 2007, a group of scientists from the Servicio Nacional de Geología y Minería (SERNAGEOMIN) and the Corporación Nacional Forestal (CONAF) observed the fumarolic activity from a distance. The scientists were on a field trip to count flamingos and other Andean birds at Ramsar sites. The Ramsar Convention on Wetlands (http://www.ramsar.org/), named after a city in Iran, is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. The group noted steam plumes blowing NE at mid-day from ~ 47 km SW. Fumarolic gases were again seen, from ~ 35 km WSW, slowly moving down the W slope of the cone (figure 18). Steam plumes were seen intermittently throughout the afternoon.

Jose Antonio Naranjo, who has worked at Lastarria since 1983, is very familiar with its spectacular fumarolic activity. He confirmed that the observations of February 2007 reflect Lastarria's normal intense fumarolic emissions. Such activity has continued since at least 1940, when observed by Danko Slozilo. Naranjo noted that in 2007 he saw the same fumarole locations as those he observed in 1983 and in October 2002 (figure 19). The temperatures of these fumaroles were unchanged between 1983 and 2002.

References: Naranjo, J.A., 1985, Sulphur flows at Lastarria volcano in the North Chilean Andes: Nature, v. 313, no. 6005, p. 778-780.

Naranjo, J.A., 1986, Geology and evolution of the Lastarria volcanic complex, north Chilean Andes: Unpublished M Phil. Thesis, The Open University, England, 157 p.

Naranjo, J.A., and Francis, P., 1987, High velocity debris avalanche at Lastarria volcano in the north Chilean Andes: Bull. Volcanol., v. 49, p. 509-514.

Naranjo, J.A., 1988, Coladas de azufre de los volcanes Lastarria y Bayo en el norte de Chile: reologia, genesis e importancia en geologia planetaria: Revista Geologica de Chile, v. 15, no. 1, p. 3-12.

Naranjo, J.A., 1992, Chemistry and petrological evolution of Lastarria volcanic complex in the north Chilean Andes: Geol. Magazine, v. 129, p. 723-740.

Geologic Summary. The NNW-trending edifice of 5,697-m-high Lastarria volcano along the Chile-Argentina border contains five nested summit craters. The youngest feature is a lava dome that overlaps the northern crater rim. The large andesitic-dacitic Negriales lava field on the western flanks was erupted from a single SW-flank vent. A large debris-avalanche deposit is found on the SE flank. Recent pyroclastic-flow deposits form an extensive apron below the northern flanks of the volcano. Although no historical eruptions have been recorded, the youthful morphology of deposits suggest that Lastarria has been active during historical time. Persistent fumarolic activity occurs at the summit and NW flank, and sulfur flows have been produced by melting of extensive sulfur deposits in the summit region.

Information Contacts: *Héctor Cepeda* and *Margaret Mercado*, Servicio Nacional de Geología y Minería (SERNAGEOMIN), Chile (Email: mapuchito@yahoo.com,

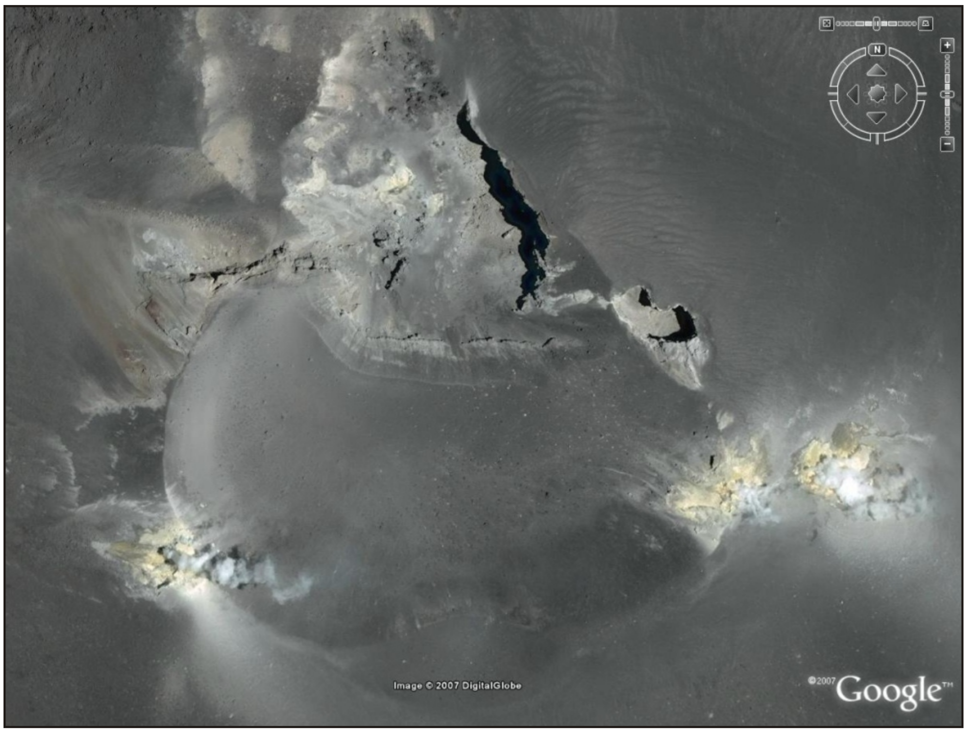

Figure 17. Lastarria imaged by satellite on an unknown date. Fumaroles can be seen on the SW and SE crater rims. Crater width (E-W) is ~600 m. Courtesy of Google Earth and DigitalGlobe.

Figure 18. Photograph showing Lastarria from ~35 km WSW, 2 February 2007. Fumarolic gases can be seen rising above the cone and moving down the W flank. Courtesy of Héctor Cepeda.

Figure 19. Photograph of the Lastarria cone showing the lava dome overlapping the N crater rim and fumaroles along the rim, October 2002. View is from the N. Courtesy of Jose Antonio Naranjo.

margaretmw@yahoo.com); *Jorge Carabantes*, *Cristian Rivera*, *Eric Díaz,* and *Juan Soto*, Corporación Nacional Forestal (CONAF), Chile (Email: jcaraban@conaf.cl, cristian.rivera@conaf.cl, ericdiaz@conaf.cl, jsotov@conaf.cl); *Jose Antonio Naranjo*, Volcano Hazards Programme, Servicio Nacional de Geologia y Mineria, Chile (Email: jnaranjo@sernageomin.cl).

Ol Doinyo Lengai

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

The previous *Bulletin* report (*BGVN* 31:03) discussed an unusually vigorous eruption during late March and early April 2006. This report revisits the March 2006 eruption and continues to the beginning of 2007, thanks in large part to the reports of many observers posted by Frederick Belton on his website.

March-April 2006 eruption. The March 2006 eruption was initially characterized in the *Arusha Times* as being more massive than the one in 1966. However, Celia Nyamweru noted that subsequent information indicated that the 2006-2007 event was smaller than the 1966-1967 event. During the March-April 2006 event, the volcano was reported to have emitted "red-hot rivers of molten rock and scalding fumes." Ibrahim Ole Sakay, a resident of Ngaresero (~1.3 km from the volcano) reported that the eruption began on the night of 24 March 2006, continuing the following day, and marked by "rumbling and spitting lava for more than a week."

Several news sources, including CNN, reported that on 30 March 2006 the eruption led to the evacuation of up to 3,000 people from several villages, some quite distant from the volcano. As of 5 April, there was a great deal of contradictory information about this eruption. Belton noted that news media and people distant from the volcano reported explosions, but that people living and working nearby reported a "smoke column" followed by a very large lava flow down the W flank, but no explosions or ash. All evidence now indicates that there was no explosive activity and that this was only a very large eruption of lava.

Visitor observations. Belton posted reports from a number of persons who observed the volcano before and shortly after the March 2006 eruption. One observer, Christoph Weber, drew a new map of the crater in February 2006 (figure 20). Belton visited the volcano in August 2006 and provided (figure 21) an update to Weber's February map as well as a photo of the recent changes (figure 22). The following text and table 6 were taken from observations by visitors, as reported by Belton on his website.

When Rick and Heidi Rosen flew over on 13 March 2006, there appeared to be no activity and many lava flows had turned white. Several flows still contained dark areas, their surface color indicating that they were then only a few days old. Narrow flows extended in all directions from the central cone mound, and a small flow originating on the upper part of T49B extended across the NW crater rim overflow and a short distance down that flank. Lava also appeared to have reached the E crater rim overflow. Most of the flows appeared to have been subject to the same amount of weathering, except for the flow down the NW flank, which looked more recent.

After a 1 April 2006 climb, Matt Jones reported that there was a fairly large lava flow down the W flank. Residents in nearby Ngaresero village and the Ngorongoro District Commissioner said that activity started on 27 March 2006. At the summit in the dark, Jones noted no glowing from lava emissions. The new eruption left a big hole to the left of the climbing path to the crater that emitted a plume of steam. On the following day, abundant steam came from the hornitos and from fissures all around the rim. Two central hornito's had been blown open relatively recently.

According to people interviewed by Amos Bupunga, who visited later, lava had flowed out on 29 (30?) March 2006 and extended to ~ 2 km from a Maasai family village (boma) at Ol Doinyo Lengai's foot. Bupunga heard that residents did not vacate their village. In the crater, lava of unstated ages covered almost all of the NW to SE regions of the crater to a depth of 2 m. At its outlet over the crater's W rim, one or more lava flows was 2.5 m deep and 3 m wide.

On 4 April 2006, Michael Dalton-Smith flew over and observed a very large lava flow that traveled over 1 km down the mountain and into a gorge. He reported that a bush pilot observed a 30 March eruption consisting of a fountain and lava flow, without an ash cloud. Local pilots also noted that on 4 April the eruption stopped. No steam was seen, nor any evidence that the large lava flow was still hot or moving.

On 5 April, Dalton-Smith drove to the foot of the volcano and saw a huge lava fountain coming from one of the summit hornitos. The fountain stopped before he could photograph it, but from the previous overall structure of the hornitos, it appeared that a new one had been building. All hornitos emitted black plumes, and there appeared to be a lake at the summit about the size of the large hornito.

Amos Bupunga visited the crater on 7 or 8 April 2006, and, in addition to the above-mentioned information he gathered relevant to 29 or 30 March, he saw that the fresh lava coming to the surface remained inside the new lava lake.

Table 7 summarizes annual measurements from 2000 to 2006 of widths of lava flows leaving the crater at various rim overflows. The number and size of the overflows have generally grown, although the width of the NW overflow has remained 135 m since 2002.

Aerial photos made on 1 April by Dean Polley showed that there had been a huge collapse of the upper parts of hornitos T56B and T58B, which merged together and probably contained a lava lake (figure 23); as noted earlier, photos by Rick Rosen showed that the collapse had not occurred by 13 March 2006.

Polley's 1 April photos show that at the SE base of T58C (just behind the collapse pit) there appeared to be a new vent with prominent lava channels leading away to the SE. Lava from this vent seemingly filled up the low lying areas in the S crater, spilled across the W overflow and down the flank. A similar eruption probably occurred again on 3 April. It was likely that a large amount of the lava was flowing through buried tubes, typical during an eruption of long duration.

From 6-11 May 2006, Jean Perrin and four others from Reunion Island visited ol Doinyo Lengai and reported an absence of active lava flows but small gaseous emissions at some hornitos and plausible rare explosions (which may

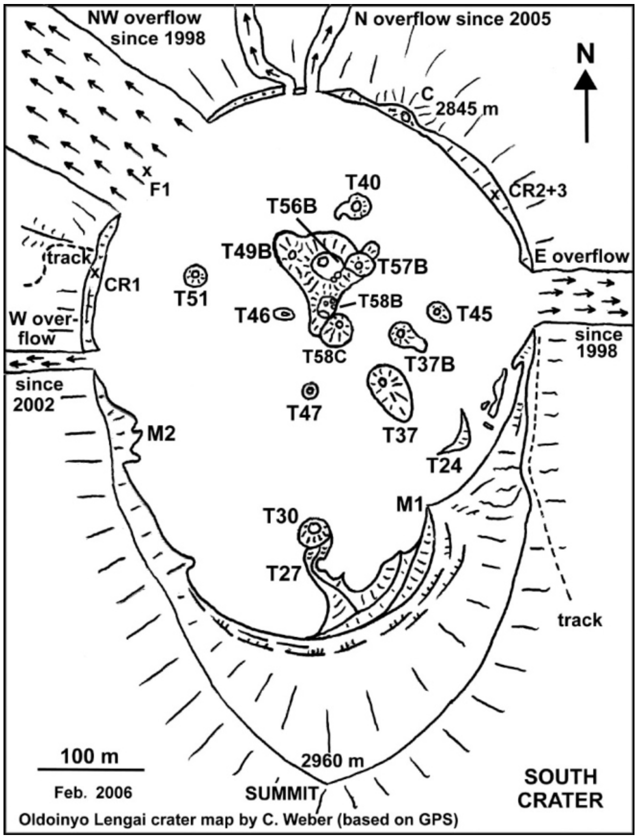

Figure 20. Sketch map showing features in Ol Doinyo Lengai's active crater as of February 2006 (i.e., before the March-April 2006 eruption). Courtesy of Christoph Weber.

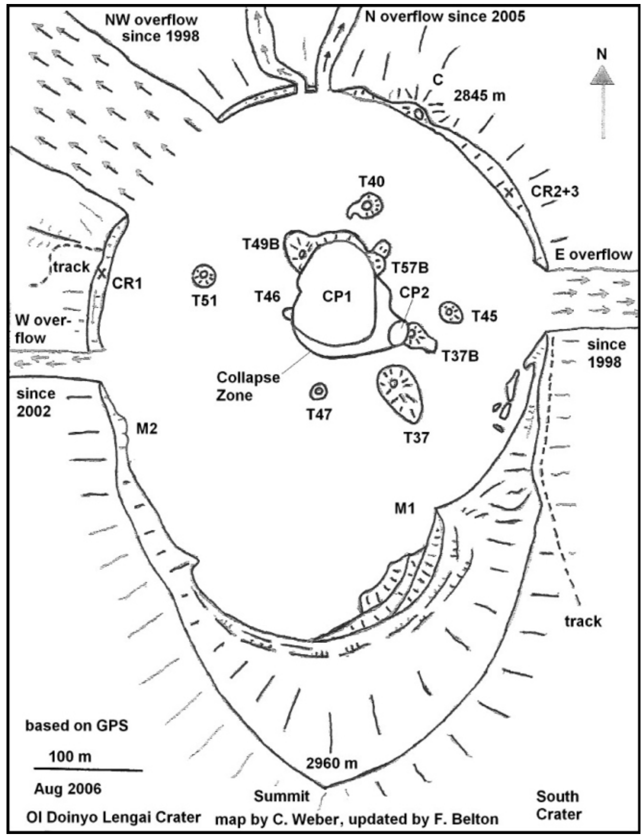

Figure 21. Sketch map showing features in Ol Doinyo Lengai's active crater as of August 2006 (i.e., after the March-April 2006 eruption). Courtesy of Frederick Belton, based on update of the map by Christoph Weber.

have also been the sound of rocks collapsing). Due to the very large collapse mentioned above, hornitos T56B, T58B, T58C, and T57B no longer existed. No lava lake activity was seen or heard in the collapsed area. The crater floor was covered with a thick ash layer and looked considerably different than before.

On 12-13 May 2006, Tobias Fischer reported seeing no activity, but the crater was filled with old lava much higher than what was seen the previous year. A very large collapsed cone with sharp rugged edges was noticed in the T58B area. Sulfur dioxide (SO_2) flux was measured using a differential optical absorption spectrometer (mini-DOAS), but the fluxes measured were low, the same as in 2005. Sampled lava were later analyzed and their carbonatite compositions were identical to 2005 lavas. Some possible carbonatite tephra was also sampled. Coming from deep inside the volcano there were discrete rumblings lasting for several seconds and up to 10 seconds; these repeated up to 15 times per hour.

Matthieu Kervyn reported that during his visit to the volcano, 21-28 May 2006, he noted no eruptive activity at all except for fumaroles from cracks in the rim and from most of the hornitos (especially in the afternoons). The collapse pit in the middle was enlarging through rim collapse. Visual inspection showed that the collapse pit might soon cause instability of the very high T49B cone. Maasai guides were also expecting T49B to collapse soon. There were some tremors felt several times per hour within the N crater, as if rocks were collapsing beneath the crater.

During 13-15 July 2006, Steve Beresford, Michelle Carey, and Mark and Rene Tait visited the active crater. Activity at that time was limited to abundant fumarolic degassing from the crater rim and central hornitos. They noted a recent (several days old) major lava flow in the SE part of the N crater, its path emanating from the S end of the lava lake at the crater dominating the central N crater. The pre-March 2006 morphology of the N crater had been the scene of a prominent central hornito cluster (figure 20). During 13-15 July the group found much of that cluster destroyed, with the dominant feature on 13 July being a wide

Figure 22. Photo of Ol Doinyo Lengai's active crater as seen 7 August 2006, looking N from the S rim. To elucidate recent changes in the crater, see maps in figures 20 and 21 [and earlier maps and photos from *BGVN* 31:03 (March 2006), 30:10 (October 2005), and 30:04 (April 2005)]. The tall cone is T49B. Slightly to its front and to the right, note the large collapse zone that grew in the spot where cones T56B, T58B, and T58C once stood. The dark lava on the right (E side of crater) was believed to have erupted around 20 June 2006 from T37B. The dark lava to the lower left probably dates from early April 2006. Although it appears dark and fresh here, it had already been highly weathered and easily crumbled into powder if touched. Courtesy of Frederick Belton.

(120 x 120 m) crater hosting a recently active lava lake. The hosting crater's S margin was very unstable and periodic collapse of the crater walls was common over the two days of observation. The crater's N margin was marked by a steep collapse scarp in the T49B hornito. Talus breccia from this scarp partially infilled the N part of the lava lake. Numerous scarp collapses (associated with abundant seismic activity) highlighted the ephemeral nature of the current crater/lava lake outline. Marks around the lava lake recorded former high-stands of lava during recent months. SE- and S-draining tubes were present, both testifying to the lateral draining of lava.

The above group saw the S tubes that emanated from the central lava lake appeared to connect to the T37B hornito. The majority of the lava flow of the March-April eruption appeared to have come from this hornito. The reduction in lava lake level and southerly flow direction suggested that the lava lake dramatically drained to the S and may have provided the lava that escaped in the T37B eruption. Pyroclastics surrounding T37B suggested that early mild Strombolian/Hawaiian style activity preceded or accompanied effusion, as was typical of recent N crater volcanism. The lava flow itself was dominantly slabby to spiny pahoehoe with many aa and frothy pahoehoe breakouts along the E margin. This flow appeared similar to an inflated slabby pahoehoe flow field. Very small toothpaste pahoehoe flows emanated from the slabby pahoehoe flow front.

August 2006 map and its interpretation. During 4-8 August 2006, Fred Belton and Peter and Jennifer Elliston camped on the volcano. The visitors found degassing cones and fumaroles; no lava erupted. Occasional rockfalls occurred in the collapse zone.

To explain the August map and field relationships (figure 21), Belton and the visitors provided the following synopsis of the most recent activity and collateral observations. Some of the following revisits observations already discussed, but other points are new to this report and convey the significance of this stage where substantial lava flows descend out of the summit crater.

Date	Reporting Visitor(s)	Brief Observation(s):(CV= climbed volcano; A=aerial photos from crater overflight; F = flank observation)
04 Jan-06 Jan 2006	Bernard Donth	- (CV) 1100 hours, 4 Jan: lava from hornito T49B; spatter and little flows in all directions with eruption every 30 min; 1 larger flow reached NW Overflow.
		- 1500 hours, 4 Jan: activity decreased; no more flows during rest of stay.
10 Jan 2006	Christian Mann and family	- (CV) no activity except some degassing from hornito T47.
		- during previous weeks lava filled large open vent of T56B and flowed from there to possibly other locations onto NE part of crater floor.
02 Feb-07 Feb 2006	Christoph Weber with film team	- (CV) (see BGVN 31:03)
13 Feb 2006	Christoph Weber	- (A) new lava flows from T58B and T56B vents
		- crater rim overflow widths unchanged since Aug 2005
25 Feb-26 Feb 2006	Chris DeVries with Mcgill Univ. students	- (CV) (see BGVN 31:03)
11 Mar 2006	Cristine Mentzel	- (A) numerous small lava flows extending in all directions in the crater from the central cone cluster
13 Mar 2006	Rick & Heidi Rosen	- (A)
14 Mar 2006	Serge & Sandrine Magnier	- (A) fresh lava on crater floor
		- photos of lava show thin, fine textured aa flows, very black, originating from unidentifiable source in central cone cluster
29 Mar 2006	Locals reporting to Amos Bupunga	- (F) lava flowed within 2 km of village, but no one vacated
01 Apr 2006	Dean Polley	- (A) photos of crater documenting partial collapse of T56B and T58B and possible existence of a lava lake there
01 Apr 2006	Matt Jones	- (CV)
04 Apr 2006	Michael Dalton-Smith	- (A)
05 Apr 2006	Michael Dalton-Smith	- (F)
07 or 08 Apr 2006	Amos Bupunga	- (CV) lava still being emitted only within the new lake
06 May-11 May 2006	Jean Perrin	- (CV) absence of lava lake activity; a thick ash layer was seen in the crater
12 May-13 May 2006	Tobias Fischer	- (CV)
21 May-28 May 2006	Matthieu Kervyn	- (CV)
13 Jul-15 Jul 2006	Steve Beresford, Michelle Carey, Mark and Rene Tait	- (CV)
31 Jul-05 Aug 2006	Daniela Szczepanski, Andreas Ramsler, Norbert Fischer	- (CV) no activity other than smoking cones and rockfalls in the collapse zone
04 Aug-08 Aug 2006	Fred Belton, Peter & Jennifer Elliston	- (CV)
20 Aug 2006	Ram Weinberger, Majura Songo	- (CV) no significant changes in crater since 8 Aug
22 Aug 2006	Helene Frume	- (CV) no eruptive activity and no visible change since 20 Aug
22 Sep 2006	Magda Kozbial	- (CV) no activity since the previous reported visit on 20 and 22 Aug; only noticeable change since early Aug was some additional collapse of CP1 on its W edge, which appeared to have destroyed all but a tiny remnant of T46
		- smoke arose from the cracks in the ground near the crater (CP1) behind the biggest cone, mostly at the location of T46, and smell of sulfur quite strong
31 Jan-02 Feb 2007	Tom Pfeiffer	- (CV)

Table 6. Summary of visitors to Ol Doinyo Lengai and their brief observation from January 2006 to February 2007 (see figures 20 and 21 for crater features). Detailed observations prior to March 2006 were reported in *BGVN* 31:03; most of the later observations were detailed in the text. Courtesy of Frederick Belton.

Prior to their arrival, lava had flowed from T37B and CP2 and spread over the SE part of the crater floor. Thermal anomaly satellite sensing data from MODIS, analyzed by Matthieu Kervyn, indicated that the eruption probably occurred on 20 June (UTC). An Aster image from June 29 shows new dark lava in the SE part of the crater. During the eruption, lava lakes existed in CP1 and CP2 and lava flowed from CP2 and T37B and covered most of the crater floor lying between T45, T37B, T37, and the crater rim. Lava also flowed across the E overflow and down the flank. The flow was composed of at least two distinct, differently weathered lavas that may have occurred within days or hours of one another. The first eruption phase produced a fine-textured aa no more than 40 cm thick and was the more extensive of the two flows, covering a large area of the crater floor and crossing the E rim overflow. The second phase produced a less extensive but much thicker flow, nearly 2 m deep in places, that stopped before reaching the crater rim or the E overflow. It consisted of broken, ropy pahoehoe slabs. Lava from this eruption and possibly from prior activity completely covered cone T24, which was no longer visible. The collapse of the E half of T46 has revealed an interior cave containing long thin stalactites.

Since March 2006, ~ 8,000 m^2 of the central crater floor had collapsed. Photographs by several observers indicated that the collapse began just prior to or during the eruption of late March through early April 2006 and continued as an ongoing process. The current collapse zone consisted of two collapse pits, designated CP1 and CP2 in figure 21, plus a fractured area between the two pits and S of CP1 where large sections of terrain had broken away from the crater floor proper and subsided by 1-3 m. The displaced sections had tilted at various angles and were separated from one another and the crater floor by 1- to 2-m-wide fissures. The fissures contain numerous large boulders composed of lavas that were altered by weathering and then lithified.

Cones T58C, T56B, and T58B had collapsed into CP1 and were completely gone. Further enlargement of CP1 claimed the SW half of T57B, the SE base of T49B, and the E half of T46. The SW half of T37B had collapsed into CP2. Tall cone T49B, visible from the Rift Valley floor, appeared likely to collapse in the near future. Failure of its SE base resulted in a talus slope that spilled out onto the floor of CP1. CP1 and CP2 were each ~ 10 m deep with respect to the lowest point on their rims. CP2's floor and E side were talus-covered, but CP1 had a bi-level floor of slabby pahoehoe lava, the surface of a frozen lava lake. A wide lava channel exited CP2 to the SE, near the base of T37B, indicating that it contained a lava lake, which had overflowed onto the crater floor during the March-April eruption. From the lowest point of CP2, a tunnel sloped upward to CP1, connecting the pits. The floor of the tunnel was covered by talus from its unstable walls and roof.

Figure 23. Aerial photo of Ol Doinyo Lengai, taken 1 April 2006, viewing the central crater looking toward the S. The very recent collapse of hornitos T56B and T58B, which appear to have merged together, is evidenced by the depressions sharp edges. Courtesy of Dean Polley.

A prominent open lava channel, with a smaller channel diverging from it, led SSE from CP1 past T37 and then wound W and NW to the W overflow, recording the route of the lava that flowed from T58C to Ol Doinyo Lengai's base during the exceptionally strong discharges of roughly 25 March-5 April 2006. Near CP1 the channel's path had thermally eroded to a depth of ~ 3 m, and remained nearly closed at the top. An overhanging ledge contained stalactites. The channel became indistinct in the S part of the crater, but regained prominence near the W overflow, where in places it attained a width of ~ 5 m and depth of ~ 2.5 m. A large chasm just below the W overflow carved by thermal erosion extended ~ 20 m down the flank, with a depth of 5 m and a width of ~ 12 m. Its sides appeared unstable and prone to collapse. Immediately downslope of the chasm, the lava entered an existing gully and could not be easily seen again until the slope moderated near the base of the volcano, at which place the lava chilled only a few meters from the climbing track. From there its path continued into an aa field at its terminus, ~3 km from the summit.

The terminus of the flow lies within 1 km of a Masai boma on the flank, the only habitation evacuated as a result of the eruption. The lava channel near the climbing track was ~ 3 m high and at one point formed a tumulus ~ 5 m in height (*tumulus*, an elliptical, domed structure formed on the surface of a pahoehoe flow on flat or gentle slopes, created when the upward pressure of slow-moving molten lava within a flow swells or pushes the overlying crust upward). A video of this segment of the lava flow (made during the eruption viewed from the escarp-

Date	NW Overflow	E Overflow	W Overflow	N Overflow
Jul 2000	60 m	38 m	—	—
23 Jul 2001	106 m	38 m	—	—
05 Aug 2002	135 m	39 m	12 m	—
02 Aug 2003	135 m	44 m	17 m	—
16 Jul 2004	135 m	47 m	17 m	—
07 Aug 2005	135 m	72 m	20 m	1 m at three locations
07 Aug 2006	135 m	73 m	23 m	1 m at three locations

Table 7. Annual crater rim overflow measurements taken during 2000 to 2006. Stated values are the width of the crater outflow area at the crater rim. Courtesy of Frederick Belton.

ment to the W) showed a rapid, turbulent flow with blobs of lava becoming airborne. The lava near the base of Ol Doinyo Lengai had a dark gray-black coloration and appeared less weathered than might be expected based on its age of 4 months.

Lava flows from the same eruption also covered much of the S part of the crater floor to a depth of at least 2 m. Based on the indistinctness of the main lava channel in the S part of the crater, it appeared likely that the low areas of the S part of the crater were filled by lava prior to spilling over the W crater rim overflow and down the flank. Hornitos T27 and T30, formed in 1993, were completely covered by this flow.

Satellite IR data for 2006 (MODIS and MODLEN). Remote thermal monitoring by satellite using an algorithm called MODLEN was analyzed by Matthieu Kervyn. The analysis suggested an increase in volcanism around 11-13 March 2006. MODLEN is the name of a semi-automated algorithm using MODIS night-time imagery to record thermal activity and detect abnormally high-intensity eruptive events. It is built upon MODVOLC, an algorithm developed by the University of Hawaii, which provides a fully-automated global-coverage hot-spot-detection system. MODLEN was specifically tailored to Ol Doinyo Lengai's low-temperature and small scale eruptive activity (Kervyn and others, 2006a and 2006b).

Table 8 shows the MODIS/MODVOLC thermal anomalies for the year 2006. MODIS thermal alerts on 25, 27, and 29 March 2006 indicated a small but intense area of activity, possibly in the form of a large lava lake. A thermal alert at about 2255 on 29 March was consistent with eye-witness reports and air photos by Polley (mentioned above). A thermal alert for a large area of the flank on 3 April probably indicated a second lava flow to the base of the volcano.

Date	Time (UTC)	Number of pixels	Satellite
23 Mar 2006	2325	1	Aqua
25 Mar 2006	2020	5	Terra
25 Mar 2006	2315	2	Aqua
27 Mar 2006	2005	1	Terra
27 Mar 2006	2300	2	Aqua
29 Mar 2006	1955	1	Terra
03 Apr 2006	0750	2	Terra
03 Apr 2006	2010	3	Terra
03 Apr 2006	2310	6	Aqua
04 Apr 2006	1130	1	Aqua
20 Jun 2006	2025	1	Terra
20 Jun 2006	2320	1	Aqua

Table 8. MODIS thermal anomalies detected at Ol Doinyo Lengai during 2006. Courtesy of Hawai'i Institute of Geophysics and Planetology.

Kervyn reported that the MODIS algorithm indicated a strong thermal anomaly in the crater on 20 June 2006 (table 8). He interpreted this anomaly as likely thermal signatures from new lava in the SE part of the crater and the lava lakes that later observers reported. No thermal alerts were detected through the remainder of 2006.

Early 2007 observations. Tom Pfeiffer reported that during a visit from 31 January-2 February 2007, no lava erupted from the summit vents. According to local Masai guides, the form of the central area of the crater with the large collapse pit near the tall hornito T49b appeared unchanged since the summer of 2006. From an open vent in the NE corner at the bottom of the pit at the base of the hornito, continuous sounds of loud sloshing suggested mobile lava in some caverns just beneath that area, an assumption confirmed by the glow of lava visible at night from a second, smaller vent located about 30 m S of the large vent in the base of the collapse pit. One guide confirmed he had seen spattering of lava from this vent some two weeks earlier. In addition to the loud sound of moving lava underground, a constant, deep rumbling could be heard from the ground, resembling the sounds of very distant thundering. It was strongest in the NW area of the crater between the collapse pit and the fissure vents of the March 2006 lava flow.

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 S 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.

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Information Contacts: *Frederick Belton*, Developmental Studies Department, PO Box 16, Middle Tennessee State University, Murfreesboro, TN 37132, USA (URL: http://www.mtsu.edu/%7Efbelton/; http://www.oldoinyolengai.org; Email: oldoinyolengai@hotmail.com); *Christoph Weber*, Volcano Expeditions International, Muehlweg 11, 74199 Untergruppenbach, Germany (URL: http://www.v-e-i.de/, Email: mail@v-e-i.de); *Celia Nyamweru*, Department of Anthropology, St. Lawrence University, Canton, NY 13617, USA (Email: cnyamweru@stlawu.edu; URL: http://it.stlawu.edu/~cnya//lenweb4b.htm); *Matthieu Kervyn*, University of Ghent, Geology Department, Ghent, Belgium (URL: http://users.ugent.be/~mkervynd/lengai.htm; Email: Matthieu.KervynDeMeerendre@ugent.be); *Arusha Times*, Arusha, Tanzania (URL: http://www.arushatimes.co.tz/); *Tom Pfeiffer*, Volcano Discovery (URL: http://www.volcanodiscovery.com/); *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/).

Etna

Italy
37.734°N, 15.004°E; summit elev. 3,350 m
All times are local (= UTC + 1 hour)

The 10-day-long eruption of Etna's Southeast Crater (SEC) in mid-July 2006 (*BGVN* 31:08 and 31:10) was considered by scientists at the Istituto Nazionale di Geofisica e Vulcanologia (INGV) to represent a distinct phase of 2006 activity for Etna. They identified a very different phase when eruptive activity shifted to SEC's summit vent between 31 August and early 15 September 2006. The latter activity led to lava overflows and repeated collapse on SEC's E side. The seven eruptive activity episodes previously described (*BGVN* 31:10) have since been renumbered slightly, with Episode 1 taking place between 31 August and 16 September.

The following report was compiled from recent reports by Boris Behncke and Sonia Calvari, based on daily observations by numerous staff members of the INGV Catania (INGV-CT). This issue overlaps with our previous *Bulletins* and then goes on through the end of 2006.

Overview of the 31 August to 14 December eruption. Figure 24 indicates key vents and lava flows during the period 4 September-7 December 2006. It excludes lavas emitted during the short but intense final episode (Episode 20, 11-14 December 2006), but they did not significantly extend beyond flow margins shown here. The longest lava flows of the reporting interval reached ~ 4.7 km SE from their source vent (figure 24).

Table 9 summarizes the 20 episodes of recent eruptive activity, as currently identified by the INGV staff. Note, however, that episode numbers have changed since discussed in *BGVN* 31:10. One earlier episode has been added (31 August-15 September). Former Episodes 1-7 as listed in *BGVN* 31:10 based on earlier INGV reports, have been renumbered to Episodes 2-8. Subsequent episodes (9 through 20) are the main subject of this report.

Episode 9. Although there were no real paroxysms of Strombolian activity or lava fountaining at the SEC during 26 October-4 November, clear pulses of activity occurred at the effusive vents at 2,800 and 3,050 m elevation, accompanied by ash emission or weak Strombolian explosions at the SEC. These events defined Episode 8, on 27 October, and Episode 29, which took place during 29-30 October. The clear pattern of distinct paroxysms from the SEC finally returned on 5 November and lasted through late that month, before the activity became again more continuous early in December.

Episode 10. Following one week of intermittent ash emissions and weak Strombolian activity on late 4 November, a new strong eruptive episode started at the SEC summit vent at 2004 on 5 November and continued with some fluctuations and intermittent ash emissions for the next 9.5 hours. Light ashfalls occurred over populated areas to the SE. At about 2147 on 5 November, the effusion rate increased at a vent at 3,050 m elevation at the S base of the central summit cone (C on figure 24) which had been continuously active since 27 October. A new lobe of lava traveled S of the summit cone complex across a flat area known as the Cratere del Piano.

An apparent increase in the effusion rate was also noted at the effusive fissure at 2,800 m elevation on the ESE flank (B on figure 24), with active lava lobes extending downslope. Lava effusion from the 3,050-m vent ended during the morning of 6 November, and for the following 48 hours, lava emission continued only at the 2,800-m vent.

Episode 11. Ash emissions from the summit of the SEC occurred on 8 November 2006, followed by vigorous Strombolian activity that continued until about 2200. Around 1600, lava started to flow from a new vent located in the saddle between the SEC cone and the adjacent main summit cone, at an elevation of ~ 3,180 m (D on figure 24). The lava reached the SW base of the SEC cone in a few minutes, where it bifurcated into several short lobes, the largest and westernmost lobe stopping at the E margin of the lava flow field from the 3,050-m vent. Lava from the 3,180-m vent had ceased flowing by about 1845, whereas spattering and lava effusion continued at the 3,050-m vent for some time. Spattering ended at that vent around 1930, but lava continued to flow for another 24 hours.

Episode 12. At 2100 on 10 November 2006, tremor amplitude rapidly increased. Bad weather hampered visual observations until 11 November, when it became evident that this episode was quite similar to its predecessor, with lava emission occurring from both the 3,050-m and 3,180-m vents. Strombolian activ-

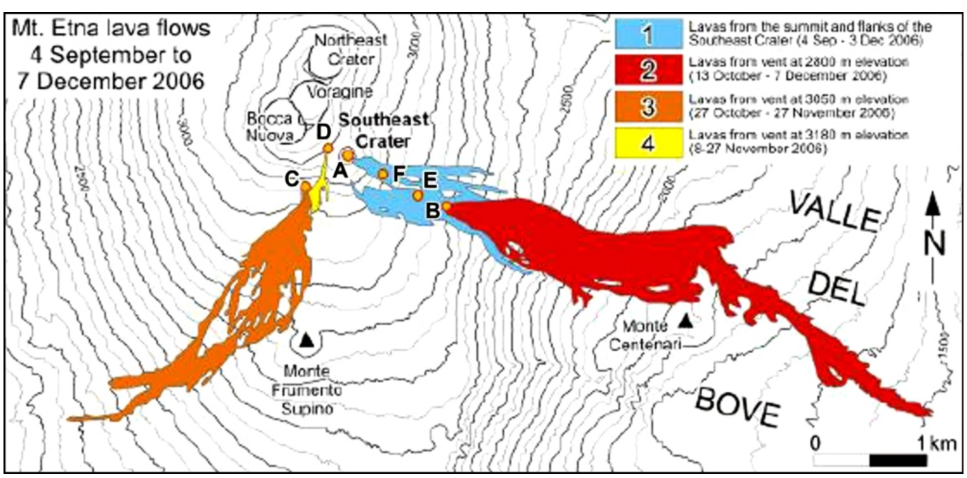

Figure 24. Map Etna showing lava flows and their corresponding periods of activity: (1) lavas from the summit and flanks of the SEC, 4 September-3 December 2006; (2) lavas from the 2,800-m vent, 13 October-7 December 2006; (3) lavas from the 3,050-m vent, 27 October-27 November 2006; and (4) lavas from 3,180-m vent, 8-27 November 2006. The capital letters indicate the most persistent eruption sources: (A) SEC summit; (B) 2,800–m vent; (C) 3,050-m vent; (D) 3,180-m vent; (E) 3,100-m vent (active between 30 November and 3 December 2006); and (F) the foundation crater of the 23 October 2006 activity (which developed a pit that was also active between 24 November and 7 December 2006). Courtesy of INGV-CT; Behncke, Branca, Neri, and Norini (2006).

Episode (former number)	Duration date (Time–morning = a. m., afternoon = p.m.) Year = 2006	Comments on onset of episode
1 (new)	31 Aug-15 Sep	eruptive activity shifted to SEC's summit vent (see BGVN 31:10)
2 (1)	22 Sep (p.m.)-27 Sep(a.m.)	mild Strombolian explosions for first 2 days
3 (2)	3 Oct (p.m.)-6 Oct (a.m.)	started with Strombolian explosions from SEC summit, increasing in vigor during the following hours
4 (3)	10 Oct (late p.m.)-11 Oct (late p.m.)	vigorous Strombolian activity and lava descending SE flank of SEC cone
5 (4)	20 Oct (0500-late)	rapid increase in tremor amplitude, vigorous Strombolian activity in the central SEC summit and isolated large explosions from a vent near the E rim
6 (5)	23 Oct (0600-?)	vigorous Strombolian activity and pulsating lava fountained from two vents at the summit of the SEC
7 (6)	25 Oct (late p.m.)-26 Oct (late p.m.)	marked increase in tremor amplitude and ash emissions from the summit of the SEC, which produced only weak Strombolian activity
8 (7)	27 Oct (p.m.)	increase in tremor amplitude and ash emissions from the SEC (see text for 26 Oct-4 Nov)
9	29-30 Oct	pulse of activity
10	5 Nov (2004)-6 Nov (a.m.)	strong eruptive episode started at SEC summit vent and continued with some fluctuations and intermittent ash emissions
11	8 Nov (until 2200)	ash emissions from summit of SEC, followed by vigorous Strombolian activity
12	10 Nov (2100)-11 Nov (1100)	tremor amplitude rapidly increased, bad weather hampered visual observations
13	16 Nov (0500-late p.m.)	lava issued from the 3,180-m vent, sharp increase in tremor amplitude, vigorous ash emissions at the SEC summit, these gradually replaced by intense Strombolian bursts
14	19 Nov (0400)-20 Nov (a.m.)	Strombolian activity at SEC occurred from 2 vents at the summit, lava flowed through the 16-November trench
15	21 Nov (1200)-23 Nov (0000)	inclement weather, a black ash plume rose to 1.5 km above the summit
16	24 Nov (0219-1530)	ash emissions mixed with Strombolian explosions at the SEC
17	27 Nov (0410-pm)	SEC monitoring camera recorded thermal anomaly and an ash plume
18	31 Nov (1600)-3 Dec(a.m.)	rising lava fountains followed 2 hours later by the '23 October pit' emitting dense ash and Strombolian explosions
19	6 Dec	increased tremor implied weak Strombolian activity and ash emission at SEC
20	11 Dec (0330)-14 Dec (p.m.)	Strombolian explosions and voluminous lava flows from 2,800-m vent, ash from '23 October pit'

Table 9. List of eruptive episodes (#1-20) at Etna as reported by INGV-CT for the interval 31 August-December 2006. "Former #" refers to the episode numbers stated in *BGVN* 31:10 but here revised. Courtesy of INGV-CT.

ity from the SEC summit ceased at 1100 on 11 November. Lava emission from the 3,050-m vent continued until the following night, and the associated lava flow field grew mainly on its W side, with flow fronts descending to ~ 2,800 m. For the next five days, lava emission continued unabated from the 2,800-m-vent, whereas the SEC and all other vents remained inactive.

Episode 13. Following a sharp increase in tremor amplitude at 0500 on 16 November, vigorous ash emissions started at the SEC summit at 0507 and were gradually replaced by intense Strombolian bursts, marking the onset of this eruptive episode.

Very early during the episode, lava issued from the 3,180-m vent, forming a lobe ~ 100 m long before activity at this vent ceased.

Lava effusion from the summit started at 0615 on 16 November and triggered a series of rockfalls down the SE flank of the SEC cone, before the lava descended on the same flank. At 0626, brownish ash was emitted from a spot next to the effusive vent, and major rockfalls and avalanches started shortly thereafter. These originated at the S rim of what remained of the 2004/2005 collapse pit on the E flank of the SEC (see BGVN 30:01 and 30:12). Plumes rising from the descending avalanches contained both brownish ash and white steam. Avalanching was most intense between 0631 and 0640, after which the new lava flow rapidly descended the lower SE flank of the cone and began to extend beyond its base toward the area of the 2,800-m vent. At the same time, strong emissions of black ash marked the opening of another explosive vent next to the summit, and a third explosive vent became active in the same area. For the next several hours, the vents continued to eject ash and occasionally bombs, and to produce vigorous Strombolian activity.

At 0700 on 16 November emissions of white vapor occurred from the SE flank of the SEC cone; a few minutes later large rock avalanches started to descend that flank. Simultaneously a fissure began to open near the summit to downslope on the SSE flank, triggering local rockfalls and dust avalanches. This fissure initially propagated ~ 100 m downslope, then it temporarily stopped; but at 0720, it propagated another 150 m downslope. During the following 15 minutes, another fissure perpendicular to the earlier one cut SE across the flank, generating more rockfalls and dust avalanches. The resulting fissure system had the form of an inverted Y delimiting a block that was actively pushed outward by magma intruding into the cone's flank.

Lava began to issue from the lower end of the W branch of the fissure system at about 0810 on 16 November. At approximately the same time, the 3,050-m vent started to emit lava. By this time, the upper portion of the fissure cutting the SSE flank of the SEC cone had significantly enlarged and became a deep trench. Dense volumes of steam were emitted from this trench at 0831 and were followed a few minutes later by another series of rockfalls and avalanches. Direct observation from ~ 700 m showed that the most energetic of these avalanches resulted from the collapse of low fountains of gas and tephra at the lower end of the large trench. The avalanches and rockfalls lasted about 15 minutes, then a voluminous surge of lava issued from the lower end of the opening trench.

Over the next few hours this sequence of events (vapor emission–rockfalls and avalanches–lava emission) was repeated several times as the trench widened and propagated further downslope. During the few moments when steam and dust clouds cleared and the interior of the trench became visible, a cascade of very fluid lava was seen in the center of the trench. Apparently, the lava issued from a source high in the head wall of the trench, and at times spurted from the vent like a firehose.

At 1100 on 16 November, white steam plumes, rockfalls, and dust avalanches appeared high on the SE flank of the SEC cone, in the area where the summit lava flow was emitted. These phenomena marked a major collapse of the E wall of the trench, which eventually cut into the descending summit lava flow, diverting it into the trench. The original flow, which had descended immediately S of the 2,800-m vent down to ~ 2,600 m elevation, rapidly stopped, although lava continued to drain from the main flow channel and accumulated in a thickening lobe at the cone's base.

At about 1425 on 16 November, several vertical jets of black tephra shot upward from an area at ~ 150 m distance from the cone's base. These emissions were very distinct in color from the brownish dust clouds, which at the same time descended from the trench. The activity at the new site appeared to migrate rapidly both toward the SEC as dark plumes began to rise closer to the cone, while a ground-hugging plume of white vapor shot in the opposite direction. A few ten's of seconds later, very dense clouds of dark brown material began to appear at the base of the surging white cloud and formed a distinct flow that rapidly overtook the front of the white cloud while speeding toward SE. At the slope break along the W rim of the Valle del Bove (~ 2,800 m elevation), both clouds disappeared from view in weather clouds, but at the site where the activity had originated, a huge plume of white vapor soared skyward. White vapor continued to rise from the area and from the path of the white and dark brown clouds for more than 15 minutes.

Another explosive emission of white steam and dark brown plumes occurred at about 1455. Like the 1425 event, it generated ground-hugging clouds of steam and dark brown material, the latter again traveling faster. During the following hours, activity at the SEC gradually decreased, with several spectacular cascades of lava descending through the trench on the cone's SSE side. Steam explosions and rock avalanches occurred at the lower termination of the trench at 1525. Strombolian activity ceased at 1500 on 16 November, but lava emission continued until about midnight. This lava does not seem to have extended far from the base of the SEC cone, since investigation during the following day failed to reveal any fresh lava on top of the debris deposits emplaced during the major explosive events at 1425 and 1455. A minor lava flow was also fed from a new short fissure ~ 80 m E of the 3,050-m vent. During the evening a small lobe of lava was emitted from the accumulation at the SEC cone's base.

Fieldwork and aerial surveys during the two days following 16 November revealed that the 1425 and 1455 explosions and related volcaniclastic density currents (figure 25) had left two main types of deposit. One was of lobate shape and extended a few hundred meters from the source of the explosions to the SE, covering a footpath established by mountain guides to allow tourists to approach the persistently active 2,800-m vent.

On the ground the deposit consisted of very fine grained reddish-brown ash made up almost exclusively of lithic fragments. To the N the deposit gradually thickened and larger clasts were found on its surface, some of which represented fresh magmatic material. Close to the 2,800-m vent, the deposit abruptly graded into a sort of debris flow rich in lithics but with up to 25% of fresh magmatic clasts. These latter showed a peculiar flattened-out morphology. Where this deposit overlay the tourist path near the 2,800-m vent it was 1.52 m thick. In one place the flow had surrounded a plastic-coated sign warning tourists to stay on the path. The plastic lacked evidence of strong heating, indicating that the flow was relatively cool at this point along its path.

Volcanic tremor amplitude began to increase during the late afternoon of 18 November and, during a helicopter

Figure 25. One of the peculiar density currents at Etna that occurred during Episode 13, 16 November 2006. The photo was taken from the N side of the large 2002-2003 cone complex, ~ 1.3 km S of the SEC. Seen in the photo are strong emissions of dark gray ash from two vents at the summit (a third caused intense Strombolian activity, but not in the moment shown in the photo). A huge gash carved out of the near right side of the cone emitted a lot of white vapor, with lava flowing from its lower end, and a ground-hugging brownish ash cloud spilling downslope on top of the flowing lava. Photo courtesy of INGV-CT.

flight at 1800, the 2,800-m vent showed vigorous spattering. Active lava from the vent traveled ~ 3 km to Monte Centenari. Bright incandescence was also noted within the 3,180-m vent during this overflight.

Episode 14. At 0400 on 19 November, Strombolian activity at the SEC occurred from 2 vents at the summit while lava flowed through the 16 November trench and divided into numerous braiding lobes on top of the debris deposited 3 days earlier. The longest lobe traveled along the prominent channel in the main debris flow, passing immediately to the S of the 2,800-m vent and extending to an elevation of ~ 2,600 m. This episode was much less violent than its predecessor and lacked the explosions, surges, and flows characteristic of that event. Strombolian activity continued until the late evening, while lava effusion ended early on 20 November. As during previous episodes, lava had also briefly issued from the 3,050-m and 3,180-m vents. In addition, a flow of a few meters in length started from another fissure that opened at ~ 3,200 m, on the saddle between Bocca Nuova and SEC. This upper flow merged with the flow coming out from the 3,180-m vent.

Episode 15. This eruptive episode at the SEC started at 1200 on 21 November 2006, but direct observations were thwarted by inclement weather through nightfall. At about 1500, a black ash plume was seen rising above the cloud cover to ~ 1.5 km above the summit. Light ashfalls occurred along the Ionian coast near Giarre and further N, while at Rifugio Citelli (~ 6 km NE of the SEC), ash deposition was nearly continuous.

After 1900, the cloud cover gradually opened, allowing direct views of the strong Strombolian explosions generating jets sometimes over 300 m high. Lava once more flowed through the 16 November trench on the cone's SSE flank toward the 2,800-m vent. Likewise, the 3,050-m and 3,180-m-vents reactivated, although the latter apparently ceased erupting early during the episode. Lava flowed from the trench until shortly after midnight on 22 November. Bad weather precluded observations until the evening, when all activity was again limited to the 2,800-m vent.

Episode 16. At 0219 on 24 November, there began ash emissions mixed with Strombolian explosions. These were recorded by the INGV-CT thermal camera in Nicolosi (~ 15 km S of the SEC) with a significant anomaly occurring at the SEC summit. Strombolian activity at 0320 was accompanied by voluminous ash emission, which formed a plume that rose ~ 2 km above the summit before being blown to SE.

Two particularly powerful explosions occurred at 0452 and 0455. The latter was followed by lava extruding from a vent presumably located within the 16-November trench. At around 0535, lava began to issue from the 3,050-m vent, forming a small flow on the W side of the lava flow field emplaced since 26 October. A second minor flow issued from another vent located ~ 80 m SE of the 3,050-m vent. Vigorous ash emission from the summit of the SEC caused light ashfalls over populated areas between Zafferana and Acireale (figure 26).

A fracture opened at about 0817 at the SSE base of the SEC cone, producing a violent explosion and a rock avalanche that descended at a speed of several ten's of km/h toward the Valle del Bove, following the path of similar avalanches that had occurred on 16 November. Lava effusion continued from vents at the cone's base, where mild spattering was observed. Upslope from the effusive vent at 2,800 m elevation, a second fracture formed and commenced spattering and lava emission.

Figure 26. Dark ash plume rising from Etna's SEC during eruptive Episode 16 on the morning of 24 November, photographed from a helicopter provided by the Italian Department of Civil Defense (Dipartimento di Protezione Civile) during that day's particularly explosive episode. A small steam plume at left rises from the area of the 2,800-m vent. More diffuse gas emitted from active lava flows engulfs the photo's extreme left. Etna's other summit craters (Northeast Crater foremost, with Voragine and Bocca Nuova behind) are in the lower right corner of the image, showing normal degassing activity. View is approximately to the S. Courtesy of INGV-CT.

During the early afternoon a change in the wind direction drew the plume from its earlier SE-ward course toward Catania and adjacent areas, forcing the closure of the Fontanarossa International airport of Catania. The activity began to diminish, and by 1530 all explosive phenomena ceased. For several more hours lava continued to issue from two vents at the SEC cone's base.

Late in the afternoon of 24 November, weak sporadic Strombolian explosions occurred from a pit located on the E flank of the SEC cone, which had formed during the 23 October eruptive episode (hereafter, '23 October pit' identified as F on figure 24). On 25 November this vent produced pulsating ash emissions that continued intermittently for the next two days.

Episode 17. At around 0410 on 27 November, eruptive activity occurred at the SEC and the thermal monitoring camera at Nicolosi began to record a significant thermal anomaly at the crater and a W-drifting ash plume. Visual observations were hampered by inclement weather. Around 0730, the thermal camera at Nicolosi disclosed lava emission on the W side of the SEC cone, possibly from the vent at 3,180 m elevation in the saddle between the SEC and the Bocca Nuova. About 45 min later, lava emission became evident at the cone's SE base. No further visual observations were available after 0845, but the tremor amplitude remained high until the afternoon, when a sharp drop indicated the end of this eruptive episode.

Bad weather persisted until early on 29 November when observers saw ash emissions from the '23 October pit.' These emissions became more intense after 0545, and the tremor amplitude began to increase rapidly during the late morning. Intermittent, weak Strombolian activity from the '23 October pit' was visible after nightfall; this became notably stronger shortly after 0100 on 30 November and reached its highest intensity around 0130, after which there was a notable decrease. Ash emissions occurred from the same pit at dawn and again from 1240 onward, producing low ash plumes.

Episode 18. At around 1600 on 30 November 2006, lava fountains began to rise from the 2,800-m vent. Two hours later the '23 October pit' emitted a dense ash plume, and Strombolian explosions reached up to 150 m above the vent. At 2045, a fissure opened at ~ 3,100 m elevation, venting spatter several ten's of meters high and releasing a short lava flow towards the 2,800-m vent. After about 10 min the effusion rate at this new fissure diminished, but lava continued to escape at a decreasing rate for ~ 1 hour. The '23 October pit' remained vigorously active for the next 5 hours, producing incandescent jets and a dense tephra plume.

The new fissure at 3,100 m elevation revived around 0115 on 1 December, with vigorous spattering and a new surge of similarly directed lava. At the same time, the '23 October pit' emissions strongly increased. Like on the evening before, the new fissure at 3,100 m elevation remained active only for a short time; lava emission ceased by 0200 on 1 December.

The 2800-m vent produced the largest lava flows during the entire period of activity, in this episode extending lava flows to ~ 1,500 m elevation on the Valle del Bove floor, to a distance of ~ 4.7 km from their source.

Between 1-3 December, the '23 October pit' remained active with nearly continuous emissions of ash interspersed with Strombolian activity. This was accompanied by the 3,100-m fissure emitting low fountaining and lava; lava flows from that fissure were generally short and did not extend far beyond the 2,800-m vent. The last observed activity at the 3,100-m vent occurred during the morning of 3 December. Ash emissions from the '23 October pit' continued for another few days but became progressively weaker; likewise the lava emission at the 2,800-m vent diminished gradually.

Episode 19. Weak Strombolian activity and ash emission occurred at the SEC on the afternoon of 6 December, evidenced by increased tremor, but the amplitude dropped rapidly to very low levels implying that the SEC ceased erupting late on 6 December. Minor lava emissions continued from the 2,800-m vent. On the morning of 8 December, no eruptive activity was visible at any of the numerous vents of the previous weeks. Following several days of very low tremor amplitude, it began to increase again late on 10 December.

Episode 20. Eruptive activity resumed around 0330 on 11 December 2006 from the '23 October pit' on the SEC, with Strombolian explosions documented by INGV-CT's monitoring cameras. Simultaneously, lava emission started from the area of the 2,800-m vent, forming a flow that slowly descended toward the Valle del Bove. Bad weather hampered observations during the following days, but occasional clear views revealed ash emissions from the '23 October pit.' In addition, there were voluminous lava emissions from the 2,800-m vents, feeding a broad lava flow adjacent the N margin of the lava flowfield produced from the same vent between mid-October and early December. The 2,800-m vents generated vigorous Strombolian explosions from two vents that built up a pair of large hornitos, and lava emissions came from a third vent located on the lower E flank of the larger, more easterly of the hornitos. No activity occurred from any other of the numerous vents that had been active during the previous weeks at the summit and in the vicinity of the SEC. Late in the afternoon of 14 December, a sharp drop in tremor amplitude indicated that the end of this final eruptive episode was imminent, and field observations made on the following morning revealed the absence of eruptive activity.

INGV considered Etna's 2006 summit eruptions during 14 July-14 December and made a rough estimate of erupted lava volumes. The total volume produced during those 5 months amounted to ~ 15-20 x 10^6 m^3.

There was a single, relatively small ash emission from Bocca Nuova on 19 March 2007, discharged without an associated seismic signal. This was followed ten days later by a brief episode of violent lava fountaining and tephra emission from the SEC. Details on that and subsequent activity will be reported in a future *Bulletin*.

Geologic Summary. Mount Etna, towering above Catania, Sicily's second largest city, has one of the world's longest documented records of historical volcanism, dating back to 1500 BC. Historical lava flows of basaltic composition cover much of the surface of this massive volcano, whose edifice is the highest and most voluminous in Italy. The Mongibello stratovolcano, truncated by several small calderas, was constructed during the late Pleistocene and Holocene over an older shield volcano. The most prominent morphological feature of Etna is the Valle del Bove, a 5 x 10 km horseshoe-shaped caldera open to the E. Two styles of eruptive activity typically occur at Etna. Persistent explosive eruptions, sometimes with minor lava emissions, take place from one or more of the three prominent summit craters, the Central Crater, NE Crater, and SE Crater (the latter formed in 1978). Flank vents, typically with higher effusion rates, are less frequently active and originate from fissures that open progressively downward from near the summit (usually accompanied by strombolian eruptions at the upper end). Cinder cones are commonly constructed over the vents of lower-flank lava flows. Lava flows extend to the foot of the volcano on all sides and have reached the sea over a broad area on the SE flank.

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Information Contacts: *Sonia Calvari* and *Boris Behncke*, Istituto Nazionale di Geofisica e Vulcanologia-Catania (INGV-CT), Sezione di Catania, Piazza Roma 2, 95123 Catania, Italy (URL: http://www.ct.ingv.it/).