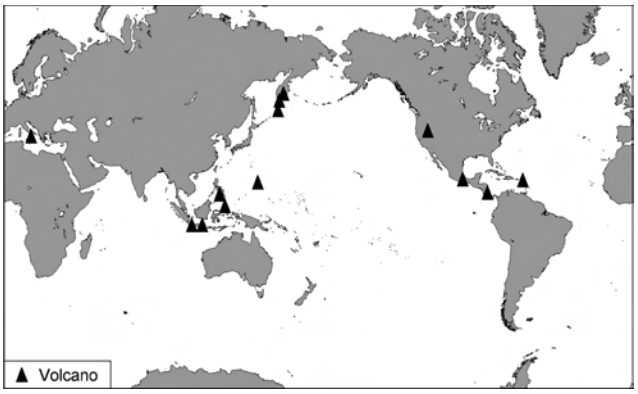
Bulletin of the Global Volcanism Network



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Anatahan

Mariana Islands, central Pacific Ocean
16.35ºN, 145.67ºE; summit elev. 788 m

Anatahan erupted on the evening of 10 May 2003 (*Bulletin* v. 28, no. 4). The volcano, which forms the uninhabited Anatahan Island in the Commonwealth of the Northern Mariana Islands (CNMI), had no recorded historical eruptions. This report provides observations from a 25 July 2003 report (updated 31 July 2003) by the University of Tokyo Earthquake Research Institute (ERI) documenting fieldwork by their team during 16-19 July 2003. During the inspection, the volcano was quiet, with only weak steaming at the active crater. Seismicity reported by the Commonwealth of the Northern Mariana Islands (CNMI) Emergency Management Office continued into early August.

Tephra deposits. The recent eruption left recognizable tephra deposits consisting mainly of pumice-bearing brown ash in a lower unit and fine gray ash in an upper unit (figure 1). Both the upper and lower units consist of many sublayers. At the village (NW end of the island) the total thickness of brown ash was 20 cm and gray ash was 3 cm.

At the SE part of the island tephra deposits were less than 3 cm thick. Although grass and trees did not show heat damage, plastic bottles had melted. The outer S slope of the active crater in the E caldera was thickly covered by gray ash. Many rills and gullies developed on these deposits due to the impermeable nature of the gray ash, which typically consisted of very fine particles. Occasionally the observers noted partly broken, stripped trees on the slopes, with a thick cover of gray tephra accumulated on the side facing the active crater. Tephra was ~ 20 cm thick near the crater rim and pumice-bearing tephra below was ~ 25 cm thick. The latter included blocks and fragments of pumice.

Inside the W caldera, tephra deposits reached a thickness of up to 1 m. Gray ash was deposited most thickly NW of the crater. Pumice-bearing tephra was thickest in the WSW direction from the crater. The latter is consistent with the drift direction of eruption plumes in the earliest stage shown by satellite images (*Bulletin* v. 28, no. 6). Although most of the trees had survived falling pumice early during the eruption, they were toppled by the strong lateral movement of gray ash during the phreatic phase.

Crater observations. The mid-July fieldwork included two days of helicopter inspection; observers saw only steaming at the active crater. That crater occupied the S part of the E crater, which lies inside the E caldera. The S wall of the active crater extended directly into the wall of the E crater. The new crater was ~ 300 m across and ~ 100 m deep, with the deepest part in the S containing a dried-out mud pool.

A mound-like but rugged-ridged lava dome protruded along the active crater's inner N periphery (figure 2). The surface of this recently erupted dome lay beneath a thick

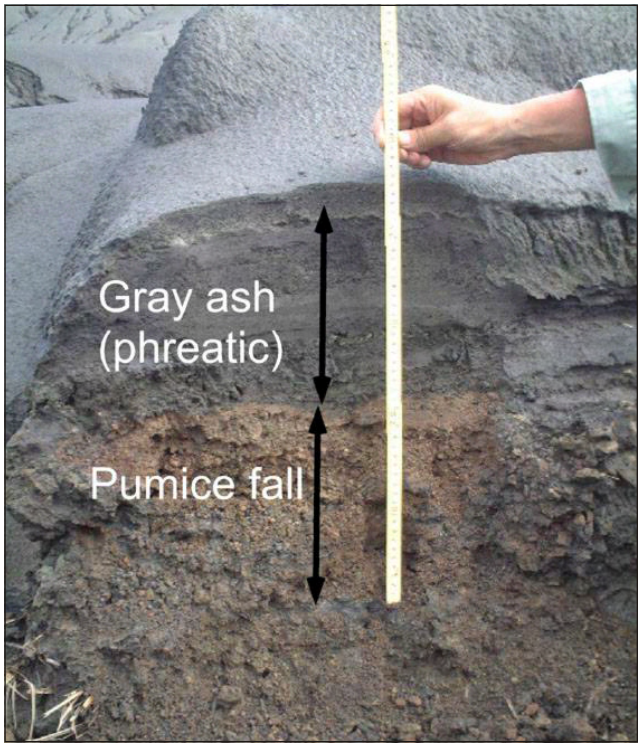

Figure 1. Section of tephra seen just S of Anatahan's active crater on 18 July showing deposits laid down in the eruptions that began in May 2003. The section contains a lower (brown) pumice-fall deposit (~ 25 cm thick) covered by multiple layers (~ 20 cm thick) of gray ash from phreatic eruptions. Courtesy of S. Nakada, University of Tokyo.

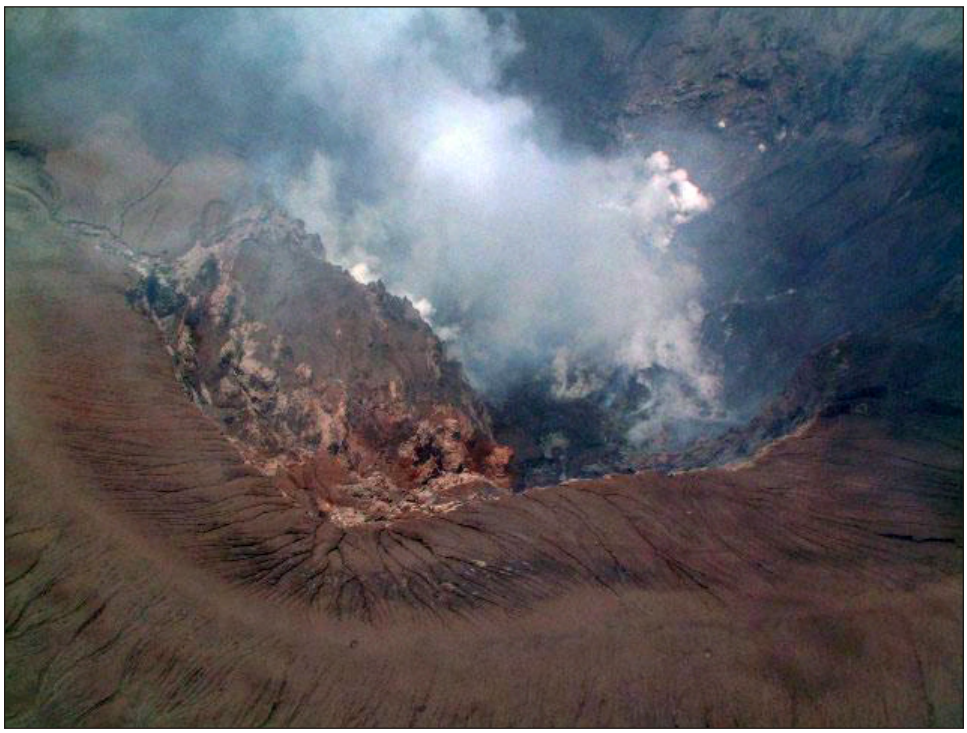

Figure 2. Aerial view showing the steaming crater at Anatahan from the NW on 19 July 2003. The lava dome (center left) lies inside the crater. A pyroclastic cone had developed on the N side, surrounding the crater. Courtesy of S. Nakada, University of Tokyo.

cover of gray ash associated with the phreatic eruption. Infrared camera images indicate that it remained at higher temperature than deposits outside the crater.

The dome may have been broken by explosive eruptions in mid-June when high seismic and visual activities were reported. Products of a reamed-out dome may have been broken into small clasts, widely dispersed, and buried by later deposits. On the other hand, neither bombs nor blocks were clearly visible on the floors of either the E crater (outside the pyroclastic cone) or in the E caldera. Thus, the absence of large blocks of lava dome around the active crater could suggest that the original dimensions of the lava dome may have been small and that the dome had undergone comparatively little sculpting by later explosions.

A low pyroclastic cone developed on the crater's N side (figure 2). The maximum thickness of newly deposited tephra exposed in a gully through this cone reached ~ 20 m.

Chemistry and degassing of magma. Pumice from this eruption was crystal-poor and light to dark brown in color. A pumice block with a light-brown crust and dark-brown vesicular core collected from the pumice-fall layer just S of the active crater was analyzed by x-ray fluorescence spectroscopy at ERI. The crust and core parts were separately analyzed; each contained 61 weight percent SiO_2.

Observers saw blue- to purple-colored gas escaping the active crater and smelled a strong rotten-egg near the S rim of the E caldera on 18 July. Instrumental concentration estimates measured 2-4 ppm SO_2 and 0.5 ppm H_2S. The SO_2 emission rate remained moderate to low throughout the inspection; the total SO_2 flux was probably less than several thousand tons a day, similar to that at Sakurajima, Japan.

Ongoing activity, July into early August. According to CNMI reports, volcanic tremor and other seismicity at Anatahan persisted through July and into August 2003 at a relatively low level. On 1 August the Anatahan seismic station registered a small swarm of a dozen or so long-period (LP) events of approximate magnitude 1; similar swarms occurred on 4 and 5 August. Several hundred small (LP) events occurred during 5-6 August. The number of small LP events was greater than that of previous days, but the overall energy release appears not to have increased significantly. No LP events were recorded on 7 August.

Background. The elongated, 9-km-long island of Anatahan in the central Mariana Islands consists of two coalescing volcanoes with a 2.3 x 5 km, E-W-trending summit depression formed by overlapping summit calderas. The larger western caldera is 2.3 x 3 km wide and extends eastward from the summit of the western volcano, the island's 788 m high point. Ponded lava flows overlain by pyroclastic deposits fill the caldera floor, whose SW side is cut by a fresh-looking smaller crater. The summit of the lower eastern cone is cut by a 2-km-wide caldera with a steep-walled inner crater whose floor is only 68 m above sea level. The sparseness of vegetation on the most recent lava flows on Anatahan indicates that the flows are of Holocene age.

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Gamalama

Halmahera, Indonesia
0.80°N, 127.325°E; summit elev. 1,715 m
All times are local (= UTC + 9 hours)

According to the Volcanological Survey of Indonesia (VSI), at 0300 on 31 July 2003, six type-A volcanic earthquakes were recorded. At 0600 the cloud issuing from the crater became thicker, but the gas pressure remained modest and similar to that normally seen. A series of explosive eruptions that began at 1434 sent a dark gray ash column 500-1,000 m high that drifted E toward Sultan Baabulah airport. A second explosion at 1625 produced a dark-gray ash column with strong gas pressure. The ash column rose 1-2 km above rim and drifted E carrying glowing material.

At 1627 a pyroclastic flow into Togorar valley on the NE flank traveled as much as 1 km but did not reach the village. A continuous blasting sound accompanied a series of ash emissions. Between 1704-1812, a dark gray ash column rose to 1,000-1,500 m, then during 1850-2200 a white-gray ash plume rose to 500 m. Several white gas plumes rose 10-150 m from 2209 through 0600 on 1 August. A steady glow was observed from 0200-0400.

After the initial outbursts, during 0000-1430 on 1 August, seismometers registered seven tectonic earthquakes, 16 shallow volcanic earthquakes, and two deep volcanic earthquakes. Continuous tremor also registered, with a maximum amplitude of 29-30 mm. Ashfall was 1-3 cm thick in the E part of the area, and some of the local population was evacuated.

According to local officials, Ternate (the regional capital, ~ 7 km E of Gamalama) was covered with thick ash. There were no reports of casualties or damage. The hazard status was set at level 3 starting at 1250 on 31 July and raised to the maximum, level 4, at 0000 the next day.

Background. Gamalama (Peak of Ternate) is a near-conical stratovolcano that forms the island of Ternate. Gamalama lies off Halmahera island's W coast, and is one of Indonesia's most active volcanoes. Ternate island served as a major regional center in the Portuguese and Dutch spice trade for several centuries, which contributed to written documentation of Gamalama's historical activity. Three cones, progressively younger to the N, form the summit of Gamalama. Several maars and other vents define a rift zone parallel to the Halmahera island arc, which cuts the volcano. Eruptions, recorded frequently since the 16th century, typically originated from the summit craters, although flank eruptions occurred in 1763, 1770, 1775, and 1962-63.

Ash explosions were previously reported in May 1993 through October 1994 (*Bulletin* v. 18, no. 7, and v. 19, nos. 5, 7, and 10). VSI reported that the last eruption occurred in 1996 from the main crater, followed by a pyroclastic flow to the E.

Information Contacts: *Dali Ahmad*, Volcanological Survey of Indonesia (VSI), Jalan Diponegoro No. 57, Bandung 40122, Indonesia (Email: dali@vsi.dpe.go.id; URL: http://www.vsi.dpe.go.id).

Karangetang (Api Siau)

Sangihe Islands, Indonesia
2.78°N, 125.48°E; summit elev. 1,784 m

Karangetang (previously reported on in *Bulletin* v. 28 no. 5) was the scene of volcanic and seismic unrest during early June 2003. The volcano produced ash plumes up to 400 m high and two lava avalanches.

In reports from the Volcanological Survey of Indonesia (VSI), activity for the week of 2-8 June 2003 was characterized by emissions of white-to-dark gray colored ash from the S crater, rising to 400 m. Observers at night noted a red glow up to 25 m over the crater. In the N crater, a white-colored gas emission rose to 150 m. During this week, a lava avalanche that occurred in the direction of the Batang river reached as far as 1000 m from the crater. There was a decrease in multiphase earthquakes compared to the previous week, but an increase in shallow volcanic earthquakes.

During the week of 9-15 June, white-colored gas emissions came from both the N and the S craters. Observers at night noted a continued red glow up to 25 m over the crater. Another lava avalanche occurred, this time traveling in the direction of the Beha river as far as 1000 m and toward the Batu Awang river as far as 250 m from the crater. There were increases in volcanic earthquakes and avalanche events.

The seismic record for 2-8 June suggested 11 deep volcanic earthquakes, 348 shallow volcanic earthquakes, 233 multiphase earthquakes, 46 emission earthquakes, 110 avalanches, and 26 tectonic earthquakes. The seismic record for 9-15 June noted 32 deep volcanic earthquakes, 438 shallow volcanic earthquakes, one explosion event, 228 multiphase earthquakes, 21 emission earthquakes, 447 avalanches, and 20 tectonic events. The volcano remained at alert level 2 (on a scale reaching a maximum of 4).

Background. Karangetang (Api Siau) volcano lies at the northern end of the island of Siau, N of Sulawesi. The 1784-m-high stratovolcano contains five summit craters arranged along a N-S line. Karangetang is one of Indonesia's most active volcanoes, with more than 40 eruptions recorded since 1675 and many additional small eruptions that were not documented in the historical record (Catalog of Active Volcanoes of the World). Twentieth-century eruptions have included frequent explosive activity sometimes accompanied by pyroclastic flows and lahars. Lava dome growth has occurred in the summit craters; collapse of lava flow fronts has also produced pyroclastic flows.

Information Contacts: *Dali Ahmad* and *Nia Haerani*, VSI (see Gamalama).

Awu

Sulawesi, Indonesia
3.67°N, 125.50°E; summit elev. 1,320 m

The last report for Awu described a visit to the crater lake on 11 May 1992 (*Bulletin* v. 17, no. 4). The Volcanological Survey of Indonesia (VSI) issued reports of activity at Awu during June-July 2000, November-December 2002, and more recently during January-early March 2003, all of which are summarized here.

During June 2000, VSI reported an increase in seismicity, especially deep volcanic earthquakes (table 1). Satellite-relayed monitoring (by ARGOS) showed an increase in seismic energy beginning on 18 May 2000; deformation data showed inflation of ~ 800 µrad since 23 May.

During 14-16 October 2002, tremor was recorded and was followed by a felt tectonic earthquake with an amplitude of I-II MMI on 10 October. Soon after the tremor activity decreased, volcanic earthquakes began to be recorded (table 1). VSI reported a significant increase in seismicity during mid-November 2002; volcanic earthquakes that normally occurred less than five times per day occurred 81 times on 15 November. Activity decreased to normal levels by late 2002. Visual observations of the summit did not reveal significant changes. Volcanic earthquakes continued during January-early March 2003 (table 1). Awu remained at Alert Level 2 (on a scale of 1-4).

Background. The massive Awu stratovolcano occupies the northern end of Great Sangihe Island, the largest of the Sangihe arc. Deep valleys that form passageways for lahars dissect the flanks of the 1,320-m-high volcano, which was constructed within a 4.5-km-wide caldera. Awu is one of Indonesia's deadliest volcanoes; powerful explosive eruptions in 1711, 1812, 1856, 1892, and 1966 produced devastating pyroclastic flows and lahars that caused more than 8,000 fatalities. Awu contains a summit crater lake that was 1 km wide and 172 m deep in 1922, but was largely ejected during the 1966 eruption.

Information Contact: *Dali Ahmad*, VSI (see Gamalama).

Date	Deep Volcanic (A-type)	Shallow Volcanic (B-type)	Tectonic
13 Jun-19 Jun 00	21	—	161
25 Jul-30 Jul 00	389	—	135
17 Oct 02	3	—	—
20 Oct 02	1	—	—
05 Nov 02	1	—	—
07 Nov 02	1	—	—
09 Nov-12 Nov 02	~ 2 per day	—	—
11 Nov 02	2	—	33
12 Nov 02	2	—	28
13 Nov 02	—	—	22
14 Nov 02	—	—	23
15 Nov 02	56	25	18
16 Nov 02	2	12	26
17 Nov 02	1	1	36
19 Nov-24 Nov 02	12	5	129
23 Dec-29 Dec 02	1	—	196
06 Jan-12 Jan 03	4	—	161
13 Jan-19 Jan 03	2	—	114
20 Jan-26 Jan 03	3	—	151
27 Jan-02 Feb 03	4	—	121
03 Feb-09 Feb 03	5	—	125
10 Feb-16 Feb 03	1	—	95
17 Feb-23 Feb 03	2	—	155

Table 1. Seismicity reported at Awu during 13 June 2000-2 March 2003. Courtesy VSI.

Leroboleng

Lesser Sunda Islands, Indonesia
8.358°S, 122.842°E; summit elev. 1,117 m
All times are local (= UTC + 9 hours)

The Darwin Volcanic Ash Advisory Center (VAAC) provided a series of pilot reports on Leroboleng. Confirmation from observers on the ground are pending.

At 1038 on 26 June 2003 aviators reportedly saw an ash plume rise to ~ 1.8 km altitude. An aircraft crew advised that the activity appeared to be increasing. Ash was not visible on satellite imagery. Another report stated that an ash plume was visible above Leroboleng at 1606 on 14 July at ~ 2.5 km altitude. Ash was not visible on satellite imagery and at that time VSI personnel could not observe the volcano. An alleged eruption on 29 July at 0900 lasted 10 minutes and sent an ash cloud to ~ 7.3 km altitude.

Background. Leroboleng volcano lies on NE Flores Island and has numerous synonyms and spelling variants (including Iliburak Lereboleng Leweno, Lewero, Leweroh, Lewono, Leworoh). The volcano sits at the eastern end of a 4.5-km-long, WSW-trending chain of three volcanoes straddling a narrow peninsula. Leroboleng's summit area contains 29 small, fissure-controlled craters, two of which impound lakes. Most of the craters formed along three N-trending fissures immediately E of Leroboleng's summit. A small lava dome occupies one of the craters. The largest crater, 250-m-wide Ili Gelimun, sits SSE of the summit. Explosive eruptions came from Burak crater in the years 1873, 1876, and (prior to this report) 1881.

Information Contacts: *Darwin Volcanic Ash Advisory Centre (VAAC)*, Bureau of Meteorology, Northern Territory Regional Office, PO Box 40050, Casuarina, NT 0811, Australia (URL: http://www.bom.gov.au/info/vaac/).

Semeru

eastern Java, Indonesia
8.108°S, 112.92°E; summit elev. 3,676 m

According to the Volcanological Survey of Indonesia (VSI), activity during 24 March-29 June 2003 was continually at a high level. Explosions produced white-gray ash plumes several times per week that rose 300-600 m over the summit. Pyroclastic flows on 27 March had a run-out distance of 3,750 m toward Besuk Bang. More pyroclastic-flow events on 14 and 18 April traveled toward Besuk Bang (3,500 m) and Besuk Kembar (2,500 m). On 11 May a pyroclastic flow entered Besuk Kembar and extended 1,500 m. Seismographs continually recorded earthquake activity (table 2). The hazard status remained at Level 2 (on a scale of 1-4) throughout the report period.

Background. Semeru, the highest volcano on Java, and one of its most active, lies at the southern end of a volcanic massif extending north to the Tengger caldera. The steep-sided volcano, also referred to as Mahameru (Great Mountain), rises abruptly to 3676 m above coastal plains to the south. Gunung Semeru was constructed south of the overlapping Ajek-ajek and Jambangan calderas. A line of lake-filled maars was constructed along a N-S trend cutting through the summit, and cinder cones and lava domes occupy the eastern and NE flanks. Summit topography is complicated by the shifting of craters from NW to SE. Frequent 19th and 20th century eruptions were dominated by small-to-moderate explosions from the summit crater, with occasional lava flows and larger explosive eruptions accompanied by pyroclastic flows that have reached the lower flanks of the volcano. Semeru has been in almost continuous eruption since 1967.

Information Contacts: *Dali Ahmad* and *Nia Haerani*, VSI (see Gamalama).

Date (2003)	Explosions	Avalanches	Tremor Events	Other	Tectonic Earthquakes
24 Mar-30 Mar	794	48	17	1 flood; 12 PF's	6
31 Mar-06 Apr	738	28	12	2 shallow; 2 PF	6
07 Apr-13 Apr	698	33	11	7 PF	6
14 Apr-20 Apr	697	70	20	12 PF	7
21 Apr-27 Apr	713	82	16	1 deep volc	9
28 Apr-04 May	651	36	31	1 deep volc	2
05 May-11 May	846	37	27	2 shallow volc; 1 PF	5
12 May-18 May	730	41	38	1 shallow volc	3
19 May-25 May	748	17	17	—	8
26 May-01 Jun	585	27	26	—	8
02 Jun-08 Jun	758	29	24	—	4
09 Jun-15 Jun	600	27	63	2 deep volc	13
16 Jun-22 Jun	711	20	13	1 shallow volc	8
23 Jun-29 Jun	838	33	—	—	4

Table 2. Seismicity at Semeru, 24 March-29 June 2003. Courtesy of VSI.

Dieng Volcano Complex

central Java, Indonesia
7.20°S, 109.92°E; summit elev. 2,565 m

According to the Volcanological Survey of Indonesia (VSI), on 20 July 2003 mud poured from Sileri crater. The crater contains a lake and boiling mud pots, and has been the site of small-to-moderate historical eruptions. The incident of 20 July occurred at night and sent mud as far as 25 m S of the crater rim. On 21 July, a temperature measurement of the crater recorded 74°C, no striking increase from earlier measurements.

On the morning of 24 July, another mud outpouring from the crater covered an area up to 50 m N and E of the crater rim. Activity then continued with small areas of mud bubbling and ejecta thrown 1 m high at the middle of the crater. Neither of the mud-outpouring events were recorded on the seismometer 1.1 km S of the crater. The volcano's hazard status was raised to level 2 on 22 July.

Background. The Dieng plateau in the highlands of central Java is renowned both for the variety of its volcanic scenery and as a sacred area housing Java's oldest Hindu

temples, dating back to the 9th century AD. The Dieng volcanic complex consists of two or more stratovolcanoes and more than 20 small craters and cones of Pleistocene-to-Holocene age spread over a 6 x 14 km area. Prahu stratovolcano was truncated by a large Pleistocene caldera, which was subsequently filled by a series of dissected to youthful cones, lava domes, and craters, many containing lakes. Lava flows cover much of the plateau, but have not occurred in historical time, when activity has been restricted to minor phreatic eruptions. Toxic volcanic gas emission has caused fatalities and is a hazard at several craters. The abundant thermal features that dot the plateau and high heat flow make Dieng a major geothermal prospect.

Information Contact: *Dali Ahmad*, VSI (see Gamalama).

Papandayan

Java, Indonesia
7.32°S, 107.73°E; summit elev. 2,665 m

On 11 November 2002, ash eruptions occurred at Papandayan (*Bulletin* v. 27, no. 11 and figure 3). Subsequently, seismic and eruptive activity waned, although gas emission continued (ending 4 May 2003). Lessening seismicity and volcanism in January 2003 resulted in a reduction of the hazard status from 3 to 2 (on a scale of 1 to 4, where 4 is the highest). Reduction in the activity continued through the beginning of May 2003 at which time the Volcanological Survey of Indonesia (VSI) terminated its weekly reporting on Papandayan.

During December 2002, white-gray ash plume was emitted continually from Baru crater and rose 150-400 m to the NE. As the activity level reduced (table 3) the typical height of the ash plume dropped from 150-400 m in December and early-January 2003 to 75-250 m by late-January.

Two explosions occurred at 0700 on 4 December and at 1758 on 8 December 2002, and another occurred at 1758 on 12 December. During the week of 2-8 December, shallow volcanic earthquakes decreased, while deep volcanic and tectonic earthquakes increased. During the subsequent week, shallow earthquakes increased, while deep earthquakes decreased (table 3). Insignificant lahars occurred at Cibeureum Gede and Ciparugpug rivers at 1600 on 13 December and at 1700 on 14 December. The movement of stepped landslides on the wall of Nangklak crater were recorded on the seismograph throughout most of December; the last landslide occurred at 1154 on 21 December. The hazard level was reduced to 2 by the week of 13-19 January 2003.

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

Information Contact: *Dali Ahmad*, VSI (see Gamalama).

Figure 3. Photograph of the new crater at Papandayan formed on 11 November 2002; by 8 December it was no longer active and was filled by water. The crater diameter is ~ 300 m. Courtesy of VSI.

Date	Deep	Shallow	Tectonic	Avalanches
02 Dec-08 Dec 2002	9	10	17	—
09 Dec-15 Dec 2002	1	25	—	—
16 Dec-22 Dec 2002	1	20	21	—
23 Dec-29 Dec 2002	3	16	12	—
30 Dec-05 Jan 2003	28	42	29	—
06 Jan-12 Jan 2003	11	21	33	7
13 Jan-19 Jan 2003	7	11	16	12
20 Jan-26 Jan 2003	14	30	29	—
27 Jan-02 Feb 2003	8	25	30	—
03 Feb-09 Feb 2003	3	18	12	1
10 Feb-16 Feb 2003	—	14	18	2
17 Feb-23 Feb 2003	3	24	17	3
24 Feb-02 Mar 2003	2	1	3	—
03 Mar-09 Mar 2003	—	1	—	7
10 Mar-16 Mar 2003	1	10	16	—
17 Mar-23 Mar 2003	2	8	24	—
24 Mar-30 Mar 2003	2	10	14	—
31 Mar-06 Apr 2003	3	15	33	—
07 Apr-13 Apr 2003	1	8	9	—
14 Apr-20 Apr 2003	2	12	16	—
21 Apr-27 Apr 2003	8	5	23	—
28 Apr-04 May 2003	2	7	3	—

Table 3. Weekly seismic events at Papandayan from 2 December 2002 to 4 May 2003. Courtesy of VSI.

Krakatau

Sunda Straits
6.102°S, 105.423°E; summit elev. 813 m

According to reports from the Volcanological Survey of Indonesia (VSI), no visual observations were made this month due to foggy weather. The volcano remained at alert level 2 for the month. They also noted that relatively few volcanic and tectonic earthquakes were recorded during the weeks of 2-8 and 9-15 June 2003. Specifically, the 2-8 June record consisted of 9 deep volcanic earthquakes, 19 shallow volcanic earthquakes, and 5 tectonic earthquakes; the record of 9-15 June consisted of 6 deep volcanic earthquakes, 17 shallow volcanic earthquakes, and 4 tectonic earthquakes.In the week of 16-22 June, a significant increase in shallow volcanic earthquakes was observed, although no tectonic earthquakes were recorded. The sesimic record for that week showed 11 deep volcanic earthquakes and 63 shallow volcanic earthquakes. Both volcanic and tectonic earthquakes were recorded for the week of 23-29 June, with 7 deep volcanic earthquakes, 61 shallow volcanic earthquakes, and 2 tectonic earthquakes detected.

Background. The renowned volcano Krakatau (frequently misstated as Krakatoa) lies in the Sunda Strait between Java and Sumatra. Collapse of the ancestral Krakatau edifice, perhaps in 416 AD, formed a 7-km-wide caldera. Remnants of this ancestral volcano are preserved in Verlaten and Lang Islands; subsequently Rakata, Danan and Perbuwatan volcanoes were formed, coalescing to create the pre-1883 Krakatau Island. Caldera collapse during the catastrophic 1883 eruption destroyed Danan and Perbuwatan volcanoes, and left only a remnant of Rakata volcano. This eruption, the 2nd largest in Indonesia during historical time, caused more than 36,000 fatalities, most as a result of devastating tsunamis that swept the adjacent coastlines of Sumatra and Java. Pyroclastic surges traveled 40 km across the Sunda Strait and reached the Sumatra coast. After a quiescence of less than a half century, the post-collapse cone of Anak Krakatau (Child of Krakatau) was constructed within the 1883 caldera at a point between the former cones of Danan and Perbuwatan. Anak Krakatau has been the site of frequent eruptions since 1927.

Information Contacts: *Dali Ahmad* and *Nia Haerani*, VSI (see Gamalama).

Canlaon

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

Ash ejections were reported at Canlaon (also spelled Kanlaon) on 10 and 11 July 2003. At 1735 on 10 July a column of ash-laden steam, described as a moderate to strong dirty white color, was seen rising from the volcano to a height of 1 km by observers in Kanlaon City. The cloud drifted to the NW, SW, and NE, with an area within a 4-km radius from the crater affected by ashfall. The explosion registered as a low-frequency volcanic earthquake. Prior to this activity, two low-frequency volcanic earthquakes and two low-frequency short-duration harmonic tremors were recorded by the seismograph at Kanlaon Volcano Station. The phreatic activity continued as of 2000 that night.

Two ash ejections were reported on 11 July, from 0620 to 0624 and 0658 to 0705. Dirty white steam rose up to 1.3 km above the crater and drifted to the SW. The seismic network recorded six low-frequency volcanic earthquakes and three low-frequency short-duration harmonic tremors.

The alert status remained at Level 1 and PHIVOLCS reiterated its warning to the public not to venture within the 4 km radius Permanent Danger Zone.

Background. 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 northern crater with a crater lake and a smaller, but higher, historically active crater to the south. The largest debris avalanche known in the Philippines traveled 33 km to the SW from Canlaon. Eruptions recorded since 1866 have typically consisted of phreatic explosions of small-to-moderate size producing minor ashfalls near the volcano.

Information Contact: *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/).

Stromboli

Aeolian Islands, Italy
38.79°N, 15.21°E; summit elev. 926 m

Effusion of lava from vents located at about 600 m elevation on the upper eastern corner of the Sciara del Fuoco decreased in early June and completely stopped between 21 and 22 July. The decreasing effusion rate caused shorter lava flows, which during July did not spread below 600 m elevation. The upper part of the lava flow field, formed since 15 February on the upper Sciara del Fuoco, reached an estimated thickness of more than 50 m as a result of the slower rate.

Since the 5 April eruption (*Bulletin* v. 28, no. 4), the summit craters of the volcano have been blocked by fallout debris obstructing the conduit. Small, occasional, and short-lived explosions of juvenile, hot material were observed at Crater 3 (the SW crater) on 17 April during a helicopter survey with a hand-held thermal camera, and at Crater 1 (the NE crater) on 3 May from the SAR fixed camera located at 400 m on the eastern rim of the Sciara del Fuoco.

Strombolian activity from Crater 1 (NE crater) became more frequent and intense in June, and almost continuous in July, with spatter often falling outside the crater. In July, Crater 3 (SW crater) activity consisted mainly of degassing and sporadic ash emissions, with Strombolian explosions becoming more common in the second half of July.

Erosion of the N flank of Crater 1 by landslides in the upper Sciara del Fuoco increased in July, with the 30 December 2002 landslide scar extending backward and upslope, cutting the flank of the cone 50 m below the crater rim.

Background. Spectacular incandescent nighttime explosions at Stromboli volcano have long attracted visitors

to the "Lighthouse of the Mediterranean." Stromboli, the NE-most of the Aeolian Islands, has lent its name to the frequent mild explosive activity that has characterized its eruptions throughout much of historical time. The small, 926-m-high island of Stromboli is the emergent summit of a volcano that grew in two main eruptive cycles, the last of which formed the western portion of the island. The Neostromboli eruptive period from about 13,000 to 5000 years ago was followed by formation of the modern Stromboli edifice. The active summit vents are located at the head of the Sciara del Fuoco, a prominent horseshoe-shaped scarp formed about 5000 years ago as a result of the most recent of a series of slope failures that extend to below sea level. The modern volcano has been constructed within this scarp, which funnels pyroclastic ejecta and lava flows to the NW. Essentially continuous mild strombolian explosions, sometimes accompanied by lava flows, have been recorded at Stromboli for more than a millennium.

Information Contact: *Sonia Calvari*, Istituto Nazionale di Geofisica e Vulcanologia, Piazza Roma 2, 95123 Catania, Italy (URL: http://www.ct.ingv.it/, Email: calvari@ct.ingv.it).

Chikurachki

Kuril Islands, Russia5
0.325°N, 155.458°E; summit elev. 1,816 m
All times are local (= UTC + 11 hours)

The eruption of the Chikurachki volcano that began on 18 April 2003 continued into mid-July. Ash explosions, possibly up to 4 km above the crater, diminished, and by 3 July only rose up to 2 km above the crater. The volcano is remote, being ~ 60 km from Severo-Kurilsk on Paramushir Island. It also lacks seismic instruments, and the Kamchatkan Volcanic Eruptions Response Team (KVERT) receives only occasional reports from Severo-Kurilsk.

According to a report from Leonid Kotenko of Severo-Kurilsk, ash explosions up to 500 m above the crater were observed from Shelekhov bay during 1930-2310 on 27 May. Ash plumes extended 70-80 km to the NE. At 0900 on 28 May, an ash plume rose 4 km above the crater and extended over 100 km to the NE. From 1030 on the same day, the plume heights decreased to 500 m above the crater. On 29 May, low-level ash plumes extended 15-20 km to the NE. In the afternoon of 29 May, an ash plume rose ~ 1.2 km above the crater, extended over Severo-Kurilsk, and ash fell on the town. Explosions occurred continually.MODIS (moderate resolution imaging spectroradiometer) Terra and Aqua Goddard images from 1105 and 1235 on 30 May, depicted a faint, small ash cloud trending to the E. Clouds obscured the volcano on the other days in later May.

Kotenko reported on 6 June that the eruption continued. On 8 June, an ash plume extended 25-30 km to the SSE. On 9-10 June, the plume did not rise more than 500 m above the volcano and extended SSE. Ash fell on the Podgorny settlement, located at a distance of ~ 20 km SSE of the volcano. The observers from Shelekhov bay had noted more strong explosions during the night than in the day-time.

In the AVHRR (advanced very-high resolution radiometer) image at 1308 on 6 June, a narrow weak ash plume was observed extending to the SE for about 100 km from the volcano. In MODIS Goddard Terra images at 1100 on 8 June and at 1145 on 9 June, a narrow plume was seen extending to the SE for ~ 100 km. In the AVHRR image at 1245 on 9 June, this plume was also seen, but no ash was detected. Clouds obscured the volcano on the other days.

According to observers from Shelekhov settlement, on 15-16 June an ash plume was observed constantly at the volcano summit. The plume did not rise upwards, but was bent down the flanks of the volcano by a strong wind. On 17 June, observers saw a short gas-steam plume bent by a gale-force wind. On 18 June, Kotenko reported that the eruption continued. On other days, clouds obscured the volcano and prevented observation. According to the last report from Severo-Kurilsk, on 17-25 June, when the weather was good, fishermen from Shelekhovo bay observed only gas-steam activity from the volcano.

By 3 July, KVERT reported that the eruption of Chikurachki had possibly finished. According to satellite data from the USA and Russia, no activity of the volcano was noted from 25 June through 11 July.

Background. Chikurachki, the highest volcano on Paramushir Island in the northern Kurils, is actually a relatively small cone constructed on a high Pleistocene volcanic edifice. Oxidized scoria deposits covering the upper part of the young cone give it a distinctive red color. Lava flows from 1,816-m-high Chikurachki reached the sea and form capes on the NW coast; several young lava flows also emerge from beneath the scoria blanket on the eastern flank. The Tatarinov group of six volcanic centers is located immediately to the south of Chikurachki. In contrast to the frequently active Chikurachki, the Tatarinov volcanoes are extensively modified by erosion and have a more complex structure. Tephrochronology gives evidence of only one eruption in historical time from Tatarinov, although its southern cone contains a sulfur-encrusted crater with fumaroles that were active along the margin of a crater lake until 1959.

Information Contacts: *Olga Girina*, Kamchatka Volcanic Eruptions Response Team (KVERT), a cooperative program of the Institute of Volcanic Geology and Geochemistry, Far East Division, Russian Academy of Sciences, Piip Ave. 9, Petropavlovsk-Kamchatskii 683006, Russia (Email: girina@kcs.iks.ru), the Kamchatka Experimental and Methodical Seismological Department (KEMSD), GS RAS (Russia), and the Alaska Volcano Observatory (USA); *Alaska Volcano Observatory (AVO)*, a cooperative program of the U.S. Geological Survey, 4200 University Drive, Anchorage, AK 99508-4667, USA (URL: http://www.avo.alaska.edu/; Email: tlmurray@usgs.gov), the Geophysical Institute, University of Alaska, P.O. Box 757320, Fairbanks, AK 99775-7320, USA (Email: eisch@dino.gi.alaska.edu), and the Alaska Division of Geological and Geophysical Surveys, 794 University Ave., Suite 200, Fairbanks, AK 99709, USA (Email: cnye@giseis.alaska.edu).

Karymsky

Kamchatka Peninsula, Russia
54.05°N, 159.43°E; summit elev. 1,536 m

Dark ash was observed on the NE, SE, and W flanks of the volcano on 30 May in a MODIS (moderate resolution imaging spectroradiometer) Terra image. Intermittent ex-

Date(s)	Thermal Anomaly (pixels)	Comments
3 June	2 (faint)	No ash plume observed
22-24 June	1-4	—
27 June	—	Short narrow plume to NE
28-30 June	1-4	—
4, 6-9 July	1-4	—
14-15 July	2-3	—
13, 16 July	2-5	No ash plumes observed
19 July	—	Ash plume to SW
25, 27-29 July	1-3	—

Table 4. Thermal anomalies at Karymsky from AVHHR (advanced very-high resolution radiometer) satellite images and visual observation during June and July 2003. Courtesy Kamchatkan Volcanic Eruptions Response Team (KVERT).

plosive eruptive activity at Karymsky occurred from early June into mid-August 2003, with seismic activity above background levels. Between 90 and 270 local shallow events occurred per day. The character of the seismicity indicated that ash-and-gas explosions to heights of 1,000-2,000 m above the volcano (2,500-3,500 m altitude) and gas blow-outs possibly occurred. On the morning of 17 July a strong, long duration (86 minutes), seismic event occurred that possibly resulted from a large pyroclastic flow or the onset of a new lava emission. Satellite data confirmed the continuing activity (table 4).

Background. Karymsky, the most active volcano of Kamchatka's eastern volcanic zone, is a symmetrical stratovolcano constructed within a 5-km-wide caldera that formed during the early Holocene. The caldera cuts the south side of the Pleistocene Dvor volcano and is located outside the north margin of the large mid-Pleistocene Polovinka caldera, which contains the smaller Akademia Nauk and Odnoboky calderas. Most seismicity preceding Karymsky eruptions has originated beneath Akademia Nauk caldera, which is located immediately S. The caldera enclosing Karymsky volcano formed about 7,600-7,700 radiocarbon years ago; construction of the Karymsky stratovolcano began about 2,000 years later. The latest eruptive period began about 500 years ago, following a 2,300-year quiescence. Much of the cone is mantled by lava flows less than 200 years old. Historical eruptions have been Vulcanian or Vulcanian-Strombolian with moderate explosive activity and occasional lava flows from the summit crater.

Information Contacts: *KVERT* and *AVO* (see Chikurachki).

Bezymianny

Kamchatka Peninsula, Russia
55.98°N, 160.59°E; summit elev. 2,882 m
All times are local (= UTC + 12 hours)

According to visual observation from the city of Klyuchi by Yu. Demyanchuk, a large explosive eruption of Bezymianny began at 2120 on 26 July 2003; a later report from KVERT (Kamchatkan Volcanic Eruptions Response Team) indicated that the eruption began at 2057. An ash plume rose up to 8-11 km and extended to the W, WNW, and SW. A large pyroclastic flow probably formed.

Prior to the eruption, a weak thermal anomaly was noted on satellite images from 6 July. Two shallow earthquakes of M 1.8 registered on 23 and 25 July.

Satellite data revealed plumes extending WNW at 2122 and 2300 on 26 July, to distances of 31 km and 86 km, respectively. Longer plumes were reported on 27 July to 192 km at 0305 and 217 km at 0445. At 1102 on 27 July, an 8-pixel thermal anomaly was observed with a temperature of 31ºC on a background of 10ºC. The ash cloud was ~ 250-300 km W of the vent. At 1258 that day a 5-pixel thermal anomaly was noted with a temperature of 50ºC on a background of 35ºC. The ash cloud was unchanged, and was also detected at 1325. At 1240 probable pyroclastic deposits were identified on the SE flank.

Satellite observations also noted that at 2058 on 27 July, a 10-pixel thermal anomaly yielded a temperature of 29ºC on a background of 9ºC. At 0246 on 28 July a 2-to 6-pixel thermal anomaly yielded a temperature of 33ºC on a background of 5ºC. At 2216 there was a 1-pixel thermal anomaly without accompanying ash. At 0246 and 0715 on 28 July, 2-to 6-pixel thermal anomalies were noted, with temperatures of 33º and 39ºC on a background of 5º and 16ºC, respectively. No ash was recorded for either event.

No seismicity was registered on 27-30 July, and no visual information was available because of meteorological clouds. Thermal anomalies of 1-to 3-pixels with a temperature of 16-25ºC on backgrounds from -3º to 5º C, were observed on 28-29 July, 31 July, and 1 August. No seismicity was registered from 31 July-3 August, in part because of the seismicity due to a large volcanic tremor at nearby Klyuchevskoy. According to visual data, gas-steam plumes extended ~ 15 km to the NW on 2 August. Clouds obscured the volcano on other days.

Background. Prior to its noted 1955-56 eruption, Bezymianny volcano had been considered extinct. The modern Bezymianny volcano, much smaller in size than its massive neighbors Kamen and Kliuchevskoi, was formed about 4700 years ago over a late-Pleistocene lava-dome complex and an ancestral volcano that was built between about 11,000-7000 years ago. Three periods of intensified activity have occurred during the past 3000 years. The latest period, which was preceded by a 1000-year quiescence, began with the dramatic 1955-56 eruption. This eruption, similar to that of Mount St. Helens in 1980, produced a large horseshoe-shaped crater that was formed by collapse of the summit and an associated lateral blast. Subsequent episodic but ongoing lava-dome growth, accompanied by intermittent explosive activity and pyroclastic flows, has largely filled the 1956 crater.

Information Contacts: *KVERT* and *AVO* (see Chikurachki).

Kliuchevskoi

Kamchatka Peninsula, Russia
56.06ºN, 160.64ºE; summit elev. 4,835 m
All times are local (= UTC + 12 hours [or 13 hours in March-June])

Eruptions continued at Kliuchevskoi during late 2002 through mid-2003, with typical plume heights estimated at several hundred meters and occasionally reaching ~ 2 km above the volcano (eg., early July and August 2003).

Date	Plume Details
30 Nov-2 Dec, 4 Dec	Gas-and-steam plumes rose 100-400 m above crater and extended 10 km SE, E, W, and N.
3 Dec	Gas-and-steam plumes rose ~ 1,300 m above crater and extended N and NE (NNE ~ 15 km from Russian satellite data).
5, 9, 12 Dec	Gas-and-steam plumes rose ~ 100 m above crater and extended 3-10 km E and SE.
10-11 Dec	Gas-and-steam plumes rose ~ 1,500 m above crater and extended N and NE.
13-16, 18 Dec	Gas-and-steam plumes rose ~ 100-800 m above crater and extended 5-10 km E and SE.
17, 19 Dec	Gas-and-steam plumes rose ~ 1,000-1,500 m above crater and extended 10 km E.
19, 21, 23 Dec	Gas-and-steam plumes rose ~ 1,000-2,000 m above crater and extended to E, S, and N.
24 Dec	0100 UTC. Gas-and-ash explosion rose ~ 4,000 m above crater and plume extended WSW
4 Jan 2003	2125 UTC. Gas-and-steam plume rose ~ 1,000 m above crater and extended 20 km NE.
5, 7, 9 Jan	Gas-and-steam plumes rose 10 m above crater.
8 Jan	Gas-and-steam plumes rose 1,000 m above crater.
11-13, 15 Jan	Gas-and-steam plumes rose 50-300 m above crater (very narrow plume extended 30-50 km NNE from US satellite data).
24, 27 Jan	Gas-and-steam plumes rose 1,000 m above crater and extended 10 km NE (24 Jan) and SE (27 Jan).
25-26, 28-29 Jan	Gas-and-steam plumes rose 100-300 m above crater.
1-3 Feb	Gas-and-steam plumes rose 100-300 m above crater (extended 30 km NNE from Russian satellite data).
4 Feb	Gas-and-steam plumes rose 1,300 m above crater and extended 10 km NE.
9 Feb	Gas-and-steam plumes rose 1,500 m above crater and extended 10 km N.
10 Feb	Narrow gas-and-steam plume extending 25 km N.
11, 13, 18-19 Feb	Gas-and-steam plumes rose 50 m above crater.
15-17 Feb	Gas-and-steam plumes rose 1,000 m above crater.
22-26 Feb	Gas-and-steam plumes rose 200 m above crater.
23 Feb	Gray sector (perhaps ash deposits) showed up on MODIS satellite data from Russia on the SE part of summit.
5 Mar	Gas-and-steam plumes rose 300 m above crater.
10-13 Mar	Gas-and-steam plumes rose 50 m above crater.
16 Mar	Gas-and-steam plumes extended 25-40 km W (from US and Russian satellite data).
18-19 Mar	Gas-and-steam plumes rose 700-1,500 m above crater (extended < 30 km W on 19 Mar, from US and Russian satellite data).
21-22 and 24-25 Mar	Gas-and-steam plumes rose up to 300-1,000 m above crater and and extended 5-30 km in all directions (extended 30 km NNW on 21 Mar and 100 km NNE on 24 Mar, from US and Russian satellite data).
22 Mar	Gas-and-steam explosions with ash-poor plumes that rose up to 200 m above the crater.
28-30 Mar, 2 Apr	Gas-and-steam plumes rose up to 50-300 m above crater and extended in all directions 5-20 km (10 km NW on 28 Mar, from US and Russian satellite data).
5 Apr	Gas-and-steam plumes rose up to 300 m above crater and extended 10 km E.
7 Apr	Weak fumarolic activity observed.
15-16 Apr	Series of ash plumes rose up to 300 m above crater and extended 10 km E

Table 5. Plumes visible at Kliuchevskoi during December 2002 through mid-April 2003. Courtesy KVERT.

Above-background seismicity prevailed during most or all the reporting interval.

The volcano (also spelled Klyuchevskoy) was last reported on in *Bulletin* vol. 28, no. 2, and vol. 27, no. 11, issues discussing events through 4 March 2003. This report relies heavily on tabled data to convey observations from as far back as 3 December 2002, providing some further details during the 3 December-4 March 2003 interval of overlap with the earlier reports. The source reports came from the Kamchatkan Volcanic Eruption Response Team (KVERT) and were communicated via the Alaska Volcano Observatory (AVO). Table 5 summarizes recent plume observations, while table 6 summarizes recent earthquake and intermittent spasmodic volcanic tremor, basically above-background seismicity affiliated with ongoing eruptive unrest.

Unrest continued during June 2003. Seismicity was above background and continuous spasmodic volcanic tremor tended to increase slowly and consistently. Earthquakes, both at 30 km and shallow depths, continued to register. The character of seismicity also indicated that weak gas-ash explosions possibly occurred. Table 7 summarizes thermal observations.

Background. Kliuchevskoi is Kamchatka's highest and most active volcano. Since its origin ~ 7,000 years ago, the symmetrical, basaltic stratovolcano has produced frequent moderate-volume explosive and effusive eruptions with no major periods of inactivity. More than 100 flank eruptions have occurred during the past 3,000 years. The morphology of its 700-m-wide summit crater has been frequently modified by historical eruptions, which have been recorded since the late-17th century. Historical eruptions have originated primarily from the summit crater, but have also included major explosive and effusive eruptions from flank craters. A large summit eruption occurred in January 1990.

Information Contacts: *KVERT* and *AVO* (see Chikurachki).

Shiveluch

Kamchatka Peninsula, Russia
56.653°N, 161.360°E; summit elev. 3,283 m

Eruptive activity continued during May-August 2003, including growth of a lava dome in the active crater. Seismic activity continued to remain above background levels, and shallow earthquakes at a depth of 5 km were recorded with magnitudes in the range of 1.8-2.8. Several short-lived explosive eruptions each week sent ash-gas plumes to

Date	Earthquakes per day (~30 km depth)	Intermittent tremor (in terms of geophone velocity)
28 Nov-1 Dec	8-13	~0.8 x 10^{-6} m/s.
2-4 Dec	24-33	~0.8 x 10^{-6} m/s.
5-12 Dec	12-24	~0.5-0.7 x 10^{-6} m/s.
13-19 Dec	6-12	0.5-0.7 x 10^{-6} m/s.
19-25 Dec	6-9	~0.6-0.7 x 10^{-6} m/s.
24 Dec	—	Gas-and-ash explosion at 0010 UTC.
3, 4 Jan 2003	9, 10	~0.5-0.7 x 10^{-6} m/s.
5-9 Jan	10-13. 1, M 1.75 earthquake	Increased from 0.55 x 10^{-6} m/s on 5-7 Jan to 0.7 x 10^{-6} m/s on 8 Jan.
10-12 Jan	12-18	0.4-0.75 x 10^{-6} m/s.
13-15 Jan	33-35	0.4-0.75 x 10^{-6} m/s.
16-23 Jan	—	0.4-0.6 x 10^{-6} m/s.
16-19 Jan	Increased from 44 to 90.	—
20-22 Jan	Gradually decreased 35 to 21.	—
24-31 Jan	10-22. 18, M 1.25 earthquakes	0.3-0.5 x 10^{-6} m/s.
1-6 Feb	16-39. 15, M 2.0-2.2 earthquakes	0.4-0.6 x 10^{-6} m/s.
1 Feb	—	1.26 x 10^{-6} m/s from 0311 to 2400 UTC.
6-12 Feb	17-30. 17, M 2.0-2.1 earthquakes	0.5-0.7 x 10^{-6} m/s.
13-20 Feb	14-81. 6, M 2.0-2.2 earthquakes	0.4-0.7 x 10^{-6} m/s (on 14 Feb, continuous tremor increased to 0.9 x 10^{-6} m/s).
20-27 Feb	10-14. 16, M 2.0-2.2 earthquakes	0.4-0.6 x 10^{-6} m/s (from 1140 UTC 26 Feb, continuous tremor increased to 0.95 x 10^{-6} m/s).
28 Feb-6 Mar	5-11. 3, M 2.0-2.2 earthquakes	0.5-0.8 x 10^{-6} m/s.
6-13 Mar	6-11. 12, M 2.0-2.2 earthquakes	0.5-0.8 x 10^{-6} m/s (6-9 Mar)
10-13 Mar	—	1.1-1.3 x 10^{-6} m/s.
13-20 Mar	7-9. 7, M 2.0-2.1 earthquakes	0.5-1.5 x 10^{-6} m/s.
14 Mar	—	1.5 x 10^{-6} m/s.
20-24 Mar	6-9	—
20-26 Mar	16, M 2.0-2.2 earthquakes (26 on 25 Mar; 41 on 26 Mar)	1.0-2.8 x 10^{-6} m/s.
28 Mar-3 Apr	24-63	0.7-1.4 x 10^{-6} m/s.
4-10 Apr	10-15. 14, M 2.0-2.2 earthquakes	1.5-3.7 x 10^{-6} m/s.
15 Apr	~70	Up to 4.0 x 10^{-6} m/s.

Table 6. Earthquakes and intermittent spasmodic volcanic tremor registered at Kliuchevskoi during December 2002 through mid-April 2003. Courtesy of KVERT.

heights of 2,500-5,000 m above the dome. Intermittent spasmodic volcanic tremor was registered. Satellite data on thermal anomalies are shown in table 8.

Background. The high, isolated massif of Shiveluch volcano (also spelled Sheveluch) rises above the lowlands NNE of the Kliuchevskaya volcano group. The 1,100 km³ Shiveluch is one of Kamchatka's largest and most active volcanic structures. At least 60 large eruptions of Shiveluch have occurred during the Holocene, making it the most vigorous andesitic volcano of the Kuril-Kamchatka arc. Widespread tephra layers from these eruptions have provided valuable time markers for dating volcanic events in Kamchatka. Frequent collapses of dome complexes, most recently in 1964, have produced debris avalanches whose deposits cover much of the floor of the breached caldera.

Information Contacts: *KVERT* and *AVO* (see Chikurachki).

Date(s) (2003)	Thermal Anomaly (in pixels)	Comments
2 June	—	Gas-and-steam plume rose 400 m above volcano.
3 June	3	—
6-7 June	—	Ash-poor plume extending S 30-80 km; explosions sent ash-gas plumes to 50-500 m above volcano.
9 June	—	Ash on NNE flank.
7-8 June	weak	—
13, 16, and 19 June	1-4	Four-pixel anomaly with max temp of 46ºC in a background of -1ºC; ash-poor plumes 50-500 m above volcano.
23 June	3	Possible ash deposits on SE flank; gas-and-steam plumes to 50-700 m above volcano.
28 June, 2 July	3	Ash-poor plumes to 100 m above volcano); separate and continuous ash plumes to 1,000 m above volcano; plumes extended to E.
4-6 July	1-2	Gas-and-steam with ash-poor plume extending 100 km to ESE; separate ash explosions to 2,000 m above volcano.
15-16 July	1-2	Separate or series ash explosions to 1,000 m above volcano; strong ash explosions to 2,000 m above volcano.
20-24 July	1-4	Gas-and-steam plumes rose from 100-1,000 m above volcano and extended 15 km to SW.
27-29 July, 1 August	1-4	Temperature from 12º to 50ºC in a background of -5º to 20ºC; gas and steam plumes rose 500-700 m and extended 5 km SW.
1, 4-7 August	2-6	Gas-and-steam plumes rose 800-2,000 m above volcano and extended to NW and, later, S.
9, 11 August	2-3	—

Table 7. Kliuchevskoi thermal anomalies and plumes observed via Russian and United States satellites, 2 June-11 August 2003. Courtesy of KVERT.

Date(s) (2003)	Thermal Anomaly (pixels)	Comments
30 May	1-4	No ash plumes observed.
6-9 June	1-6	Gas/steam plumes rose 100-700 m above dome and extended E.
13-14, 16-17 June	1-6	Gas/steam plume rose 100 m above dome and extended 5 km NE.
21-22 June	1-4	Gas/steam plumes rose 100 m above dome.
28-30 June, 2 July	1-5	Gas/steam plumes rose 100 m above dome.
5-6, 10 July	1-2	Gas/steam plumes rose 500 m above dome.
11, 13-16 July	1-2	Gas/steam plumes rose 200-800 m above dome.
19-22, 24 July	1-2	Gas/steam plumes rose 500-600 m above dome.
27, 31 July, 1 Aug	1-3	Temperatures of 10-19EC in background of 0-5EC; gas/steam plumes rose 100 m above dome.
8-10 August	2-3	—

Table 8. US and Russian satellite data summarizing thermal anomalies associated with Sheveluch from late May to early August 2003. Courtesy of Kamchatkan Volcanic Eruptions Response Team (KVERT).

Yellowstone

Wyoming, USA
44.43°N, 110.67°W; summit elev. 2,805 m

Yellowstone National Park press releases indicated unusual hydrothermal activity at the Norris geyser basin in the NW-central portion of the Park. A press release on 22 July 2003 announced that high ground temperatures and increased thermal activity had resulted in the temporary closure of a portion of the Back Basin.

The press release noted "Norris is the hottest and most seismically active geyser basin in Yellowstone. Recent activity in the Norris geyser basin has included formation of new mud pots, an eruption of Porkchop geyser (dormant since 1989), the draining of several geysers, creating steam vents and significantly increased measured ground temperatures (up to 200°F [93°C]). Additional observations include vegetation dying due to thermal activity and the changing of several geysers' eruption intervals. Vixen geyser has become more frequent and Echinus geyser has become more regular."

A press release on 7 August advised of a hydrothermal monitoring program by the Yellowstone Volcano Observatory to begin at Norris geyser basin. The Observatory is a collaborative partnership between the US Geological Survey, the University of Utah, and Yellowstone National Park. It was deploying a temporary network of seismographs, Global Positioning System receivers, and temperature loggers. Goals included identification of hydrothermal steam sources, the relationship of the behavior of Norris geyser basin to the general seismicity, and locating crustal deformation in the caldera.

Background. The Yellowstone Plateau volcanic field developed through three volcanic cycles spanning two million years that included some of the world's largest known eruptions. Eruption of the 2450 cu km Huckleberry Ridge Tuff about 2 million years ago created the more than 75-km-long Island Park caldera. The second cycle concluded with the eruption of the Mesa Falls Tuff around 1.3 million years ago, forming the 16-km-wide Henrys Fork caldera at the western end of the first caldera. Activity subsequently shifted to the present Yellowstone Plateau and culminated 640,000 years ago with the eruption of the 1000 cu km Lava Creek Tuff and the formation of the present 45 x 85 km caldera. Resurgent doming subsequently occurred at both the NE and SW sides of the caldera and voluminous (1000 cu km) intracaldera rhyolitic lava flows were erupted between 150,000 and 70,000 years ago. No magmatic eruptions have occurred since the late Pleistocene, but phreatic eruptions took place near Yellowstone Lake during the early Holocene. Yellowstone is presently the site of one of the world's largest hydrothermal systems including Earth's largest concentration of geysers.

Information Contacts: *Yellowstone Volcano Observatory*, a cooperative arrangement that includes *Robert L. Christiansen*, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025; *Robert B. Smith*, Department of Geology and Geophysics, University of Utah, Salt Lake City, Utah 84112 USA; *Henry Heasler*, National Park Service, P.O. Box 168, Yellowstone National Park, WY 82190-0168 USA; and others (URL: www.volcanoes.usgs.gov/yvo/yvo/html/).

Colima

western México
19.514°N, 103.62°W; summit elev. 3,850 m
All times are local (= UTC - 6 hours)

Explosive activity at Colima continued in May and July 2003. A small explosive eruption reported at 1024 on 2 May 2003 produced an ash cloud visible on satellite imagery and monitoring cameras, but rising to no more than 500 m above the crater. The Mexico City Meteorological Watch Office stated that the plume moved SW of the summit at 5-10 knots (9-18 km/hour). The Washington VAAC described the plume as very small.

Nick Varley pointed out on 18 May that the GVP/USGS Weekly Volcanic Activity Report for 7-13 May 2003 incorrectly reported lava flows at Colima. He noted that "No lava has been produced since the beginning of March [2003]. The current activity comprises small explosions, on average some 25 per day, some containing ash. The dispersal of the ash is limited to approximately 7 km from the summit."

More significant explosions were reported on 17 July 2003. The first, at 0527, threw incandescent material 500 m high and an ash column to ~ 3 km height that blew SW . Small forest fires caused by the incandescent material 2.5-4 km SW of the crater suggested that the explosion was also directed to this sector. An explosion at 1400 on 17 July, produced an ash-laden cloud 1,000 m high, again dispersing SW. The seismic energy released by the 0527 explosion was reported to be less than half that released in the 1999 explosions.

Background. The Colima volcanic complex is the most prominent volcanic center of the western Mexican Volcanic

Belt. It consists of two southward-younging volcanoes, Nevado de Colima (the 4320 m high point of the complex) on the north and the 3850-m-high historically active Volcán de Colima at the south. A group of cinder cones of probable late-Pleistocene age is located on the floor of the Colima graben west and east of the Colima complex. Volcán de Colima (also known as Volcán Fuego) is a youthful stratovolcano constructed within a 5-km-wide caldera, breached to the south, that has been the source of large debris avalanches. Major slope failures have occurred repetitively from both the Nevado and Colima cones, and have produced a thick apron of debris-avalanche deposits on three sides of the complex. Frequent historical eruptions date back to the 16th century. Occasional major explosive eruptions (most recently in 1913) have destroyed the summit and left a deep, steep-sided crater that was slowly refilled and then overtopped by lava dome growth.

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Soufrière Hills

Montserrat, West Indies
16.72°N, 62.18°W; summit elev. 915 m
All times are local (= UTC - 4 hours)

Although detailed reports about the activity and monitoring of Soufrière Hills are provided on a regular basis by the Montserrat Volcano Observatory, this report contains observations made by visitors Stephen O'Meara and Robert Benward. They monitored Soufrière Hills visually and, using some novel electronics, collected data and images for 12 days beginning on 7 February 2003. This visit was similar to one in February 2002 (*Bulletin* v. 27, no. 6).

The visual observations took place primarily on Jack Boy Hill, 6 km N of the volcano. At the new Montserrat Volcano Observatory, Benward set up a black and white CCD video camera that took a frame every eight (8) seconds and relayed it to a digital video recorder. The camera's low-light sensitivity provided round-the-clock surveillance of dome activity. However, orographic and rain clouds caused problems, and much of the volcanic activity was away from the camera view.

Since the visit in 2002, the dome had increased significantly in size (figure 4). The rockfalls and pyroclastic flows that dominated the activity in February 2002 were concentrated in the E portions of the dome and the Tar River Valley. In 2003, activity occurred in a broader arc that extended from Tar River in the E to Farrell's Plain in the N. Several pyroclastic flows traveled into Tuitt's Ghaut and the upper reaches of Tyre's Ghaut, and onto Farrell's Plain. These events were captured on the surveillance camera and in higher-definition color video taken from Jack Boy Hill.

The dome was impressive at night. The summit was often crowned with thick, blocky spines and sharp pinnacles. An array of spiny ridges (speckled with incandescence) that lined the upper portions of the dome helped channelize many of the rockfalls and pyroclastic flows, the flow channels remaining incandescent. The glow was strong throughout the observation period, but especially during 13-19 February, when episodes of prolonged activity made the dome appear to be melting like candle wax. The glowing dome could be seen from the northernmost reaches of the island at night. Its light was so intense that a homemade spectrograph (attached to a 3-inch telescope brought by Benward) revealed a continuous spectrum.

O'Meara visually observed the dome through a 60 power, 60 mm refractor scope and noticed two curious phenomena. At one point, a mass of viscous, but mobile, lava pushed out of the downslope edge of an incandescent ridge. It slumped onto the dome and formed a pad of molten material that quickly cooled and solidified into linear veins. The behavior was similar to that of a budding toe of pahoehoe lava where internal pressure forces fluid lava through its cooling skin. O'Meara also observed what appeared to be a tiny lateral explosion from the downslope edge of an incandescent ridge which shot out glowing gas and rock fragments like buckshot from a gun.

Figure 4. Illustration of dome growth at Soufriere Hills between February 2002 and February 2003. The outline of the volcano's profile in February 2002 is superimposed on a photograph taken at the same location in February 2003. Courtesy of Robert Benward, Volcano Watch International.

A significant difference in the style of eruption from that reported in 2002 was the periodic mass dumping of dome material. During these episodes, dome material calved off the highest portions of the dome, creating a wide avalanche of incandescent material which flowed down much of the dome's visible face in a matter of seconds. These episodes differed from the classical pyroclastic flows in that they produced comparatively little ash, being comprised principally of extremely massive and widespread rock and block fall.

A dramatic episode of rockfall and pyroclastic-flow activity occurred during 1745-2000 on 13 February. Massive movement of large, house-sized blocks, many of which self-destructed during their descent, preceded the pyroclastic flows. The subsequent pyroclastic flow activity was accompanied by roiling steel-gray ash clouds that drifted N. One particularly strong pyroclastic flow created an incandescent channel in Tuitt's Ghaut that glowed long into the night. Smaller pyroclastic flows followed this channel downslope, while larger ones overflowed the channel's levees or changed course. Often, when one flow slowed, another would push through it. At times pieces of incandescent rocks appeared to be sliding down the dome in the flow with no detectable rolling motion. At other times, linear threads of glowing gases appeared to advance like the treads of a tank. Another series of pyroclastic flows during 0614-0730 on 14 February were directed N, and spread out across Farrell's Plain. As in February 2002, the night activity was most spectacular when viewed and videotaped in the near-IR using Benward's homemade nightscope.

One purpose of the visit was to chronicle changes in visible behavior when the full Moon approached Earth and at perigee. With the approach of the full Moon, the team reported an apparent rise in the number of visible indicators, particularly an increase in the number of large and prolonged rockfalls and pyroclastic flows, and in the average number of events per hour. There was an impressive episode of spine growth in the 24 hours near the time of full Moon, similar to that in 2002. The limited duration of the observations, however, thwart conclusions about the relationships between lunar positions and volcanism. Convincing theories require baseline data over a considerably longer time period.

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Cerro Negro

Nicaragua
12.506°N, 86.702°W; summit elev. 728 m

Seismic activity has been monitored at Cerro Negro for the past 15 months. From April 2002 seismicity remained low with eight earthquakes registered in May and June. Earthquake activity was moderate in August (32), September (28), and October (28); no earthquakes were registered in November or December. Activity increased again in January 2003, when 91 tectonic events were registered. Activity dropped in February to 14 tectonic events but increased again in March (44 tectonic earthquakes, two of which were located underneath Cerro Negro), April (45), and May (41 volcano-tectonic earthquakes). Tremors remained low (5 RSAM units).

Gas emissions and fumarole temperatures measured by hand-held infrared instrument (table 9) were also monitored over this period. A visit on 12 April 2002 by Pedro Perez of INETER, Eliecer Duarte and Eric Fernandez of OVSICORI-UNA, Costa Rica, and Franco Tassi and Orlando Vaselli of the University of Florence, Italy, found that fumarole temperatures were down from February. Monthly visits to the volcano started in June 2002.

On 5 June, following heavy rain, steam was observed exiting the fissure SE of the volcano. Observations on 18 July noted abundant gas emissions at all fumaroles and a strong scent of sulfur around the entire crater. Emissions continued on the SE fissure and in Este del Cerro La Mula. On 28 August, Perez observed gas emissions at fumarole 4 and a continued sulfur odor. Falling rocks were observed in the inner crater. Few gas emissions were observed on 9 September and 18 October, but the strong scent of sulfur persisted. No landslides were observed. Gas emissions were observed at the fumaroles of Este del Cerro La Mula with greater abundance than in previous months.

Perez visited again on 21 November and during 25-27 November, accompanied by Matthias Frische, Kris Garofalo, Thor Hansten, and Boo Gall (GEOMAR Germany). The maximum measured temperature in the new crater was 564°C and for fumarole 1of the old crater the temperature was 334°C.

The sampling that began in November continued in the following months. On 5 December temperatures continued to be high in the cone formed in 1995. The maximum fumarole temperature on the new cone was 494°C. The visit on 10 February included more sampling, but no physical change was observed at the volcano. Recorded temperatures did not vary from those made in January.

Temperature measurements at fumarole 1 on 21 March 2003 revealed an increase of 66°C from February. On 30 and 31 March there was a slight increase of 20 RSAM units and officials observed the volcano for several hours, witnessing no anomolies. On 4 April more temperature measurements and gas sampling were performed and rock was noted to be loosening in fumarole 4. On 3 May the temperatures of the fumaroles located within the crater were constant with respect to the previous months, with the exception of fumarole 6, which had an increase of 100°C. Strong gas emissions were observed in parts of the inner crater.

Background. Central America's youngest volcano, Cerro Negro, was born in April 1850 and has since been

Date	1	2	3	4	6	7	8
05 Jun 02	252	—	—	—	—	—	—
28 Aug 02	255	—	—	—	—	184	189
09 Sep 02	257	—	—	—	175	184	189
18 Oct 02	326	—	—	—	157	223	188
21 Nov 02	475	564	245	475	—	—	—
22 Nov 02	448	479	200	207	—	—	—
05 Dec 02	403	508	385	208	—	—	316 / 278
09 Jan 03	402	486	494	402	—	—	—
10 Feb 03	402	486	494	402	—	—	—
21 Mar 03	468	—	—	—	—	—	—
04 Apr 03	388	—	—	—	—	—	—
03 May 03	399	78.6	226	—	239	203	255

Table 9. Temperatures (°C) o ffumaroles (identified by number) at Cerro Negro, June 2002-Mayy 2003. Fumaroles 2-4 are in the crater formed in 1995. Courtesy of INETER.

one of the most active volcanoes in Nicaragua. Cerro Negro is the largest, southernmost, and most recent of a group of four youthful cinder cones constructed along a NNW-SSE-trending line in the central Marrabios Range 5 km NW of Las Pilas volcano. Strombolian-to-subplinian eruptions at Cerro Negro at intervals of a few years to several decades have constructed a roughly 250-m-high basaltic cone and an associated lava field that is constrained by topography to extend primarily to the NE and SW. Cone and crater morphology have varied significantly during its eruptive history. Although the volcano lies in a relatively unpopulated area, heavy ashfalls during eruptions of Cerro Negro have caused damage to crops and buildings in populated regions of the Nicaraguan depression.

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Arenal

Costa Rica
10.463°N, 84.703°W; summit elev. 1,657 m
All times are local (= UTC - 6 hours)

During September 2000-October 2001 Arenal issued frequent Strombolian eruptions, occasional avalanches, and several episodes with sizable pyroclastic flows (PFs). Crater D remained fumarolic, with the eruptive activity centered at crater C. Crater C also emitted lava flows (as many as three simultaneously) down Arenal's NE-NW sides. In some cases the site of pyroclastic-flow (PF) generation came from outside crater C, emerging where lava flows perched on the slopes, broke open, and violently released blocks, ash, and gas (block-and-ash flows).

In September-November 2000, OVSICORI-UNA reports noted that the lava flows that began after the 23 August PFs descended the N flank, and during that month had fronts at ~ 900 m elevation. Sporadic avalanches broke off the lava flow fronts. One such episode at 0630 on 11 September 2000 produced a small ash column. September-November ash columns remained under 500 m above crater C. In September and later months cold loose debris came down parts of the edifice, entering the drainages Calle de Arenas, Manolo, Guillermina, and the larger Tabacón and Agua Caliente rivers.

Deformation, as measured by surveys of the distance network, lacked significant changes during August 2000-November 2000. However, between December and April 2000 there were sudden changes in line length, on the order of a centimeter on all lines, and most appreciable on NE-sector lines. The N-NE sectors are also where most of the lava flows and avalanche instability has occurred. Deformation and tilt changes through 2001 were otherwise described as minor.

Two noteworthy PFs , in August 2000 and March 2001, did not correlate with short-term increases in precursory seismicity. Crater C emitted Strombolian eruptions and N-directed lava flows in late February, and produced PFs during March 2001.

Eruptive episode of late March 2001. During 24 and 26 March 2001 PFs descended Arenal (figure 5) in a series of pulses traveling NNE towards Cedeño lake. Both reports from ICE and OVSICORI-UNA presented the eruptive time as about 1245 on the 24th and continuing until about 1600, with OVSICORI-UNA reporting under six pulses and ICE reporting under 10 pulses. ICE reported that the strongest pulses took place at 1258, 1331, and 1400. After that, the pulses became more frequent but of minor size.

ICE reports concluded that PFs reappeared on the 25th, with four pulses between 1348 and 1430. In contrast, OVSICORI-UNA's March report did not conclude that PFs occurred on the 25th and only described pulses on 24 and 26 March. ICE described PFs on the 26th as occurring in fewer than 8 pulses, between the hours of 0917 and 1400. OVSICORI-UNA stated that on the 26th there were fewer than three pulses in the early afternoon. It is clear that a series of PFs occurred over the 3-day (24-26 March) period, with few or none on the 25th.

Seismic signals interpreted by OVSICORI-UNA as PFs typically had durations lasting 100-200 seconds. This provided some measure of their time of origin and descent. These workers found that some very large (up to 36 x 17 x 5 m) incandescent blocks yielded temperatures of over 700°C two days after emplacement. They also reported that on Arenal's slopes the PFs excavated a gully 4 m wide by 500 m long. Field observations also disclosed that PFs or other processes removed part of the summit area, including segments of the cone's upper raised walls.

OVSICORI-UNA noted that the largest PFs accompanied dense clouds of lofted fine ash carried SW. The most distant ash fell over the main entrance to the park, in a pueblo known as El Castillo, and as far as 12 km from the source. OVSICORI-UNA scientists reported the lowest margins of the PFs reached ~ 660 m elevation.

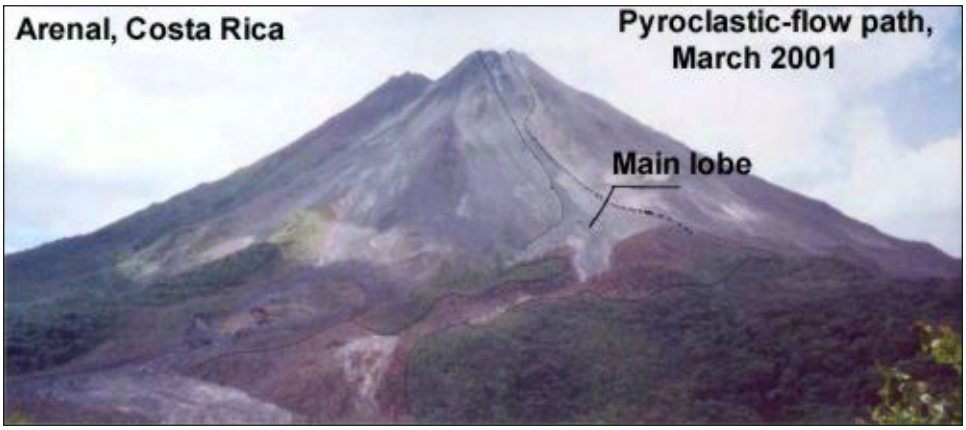

Figure 5. Annotated photograph of Arenal's N flanks showing the sketched-in outline of March 2001 pyroclastic-flow (PF) paths. The lower margins of the March 2001 PFs branched into transverse lobes, but the "main lobe" contained the bulk of the deposited material. The 23 August 2000 PFs descended to 620 m elevation, ~ 40-100 m lower, but Cedeño lake and the distal ends of the various PF deposits are absent from this photo. The PFs of March 2001 also produced some erosion on the upper walls of crater C. At the distal end, fine material was deposited atop the August 2000 PF deposits. Courtesy of OVSICORI-UNA.

Field work by ICE scientists Guillermo Alvarado and Francisco Arias revealed PF deposits forming three lobes. The main one was 10-50 m wide and reached 2 km in length. It reached down to 720 m elevation and covered 240,000 m^3. When investigated (at an unstated date), its temperature measured over 200°C. The PFs had devastated 6-10 hectares (1 hectare is 10^4 m^2) of primary forest, and the PFs, or related ash fall, heat, or singeing gases, had affected another 15 hectares. After the PFs diminished, lava flows began to escape following the same channel, their fronts later attaining ~ 1,400 m elevation.

This 24-26 March 2001 episode of PFs was judged to have been of smaller magnitude than the episode of 23 August 2000, a day when 27 pulses of PFs were observed, also directed towards lake Cedeño (*Bulletin* v. 25, nos. 7 and 8). On that occasion two people died and another was seriously injured. The March 2001 PFs were without reported injuries or fatalities, although the affected zone was somewhat similar.

According to the ICE report, Alvarado and Arroyo (2000) listed five occasions when Arenal discharged a sequence of PFs for longer than one day (17-21 June 1975, 21-22 February 1989, 9-10 December 1991, 29-30 September 1996, and 19-20 August 1997). Only the sequence during 17-21 June 1975 and their interpretation of one during 24-26 March 2001 lasted more than 2 days. PFs in both of these multi-day sequences attained runout distances of over 1 km; by comparison, the flows during 1989 and 1996 did not surpass half kilometer runout distances. The longest PF occurred in 1975, reaching a 3.5 km runout distance, with the PF's distal portions following the Tabacón river.

April-December 2001. In their report for April 2001 OVSICORI-UNA reported that a lava flow had emerged from crater C decending along the path of the previous month's PFs, with lavas extending from the crater rim to the lava's front at ~ 1,400 m elevation. Blocks falling off the front reached 950 m elevation in N and NE directions. By the end of May 2001 OVSICORI-UNA noted the descending lavas took the form of three distinct flows that each crossed a different portion of crater C's rim. The three flows continued during June. At that time a sudden change was noted at a thermal spring along the Tabacón valley (NW of Arenal's summit). It's surface dropped by ~ 60 cm; the temperature of the spring remained stable, however, at 52°C. Deformation in the first half of 2001 showed only minor changes in both surveyed lines and tilt meters. The precise leveling lines on the W flank continued to show deflation on the order of 7μrad/year.

OVSICORI-UNA stated that on 16 June at 0610 a small PF erupted. Although it failed to cause reported damage, it descended the NW flank in the direction of Balneario de Tabacón (a popular lodging and spa complex with thermal pools) situated farther downslope. During July two of the lava flows (the N- and NE-flank lavas) erupted during May and June stopped progressing. Meanwhile, the third lava flow, which exited crater C on the NW flank, remained active and mobile. During July and August, the eruptive vigor stood at modest levels; still, some eruption columns during July rose 500 m. The August and September reports stated that the one remaining actively progressing lava flow reached 950 and then 900 m elevation, respectively. It descended the same channel followed by the 16 July PF but had advanced little if any farther through October.

More PFs on 19 September 2001, during 1633-1640, and at 1646, were generated by lateral loosening of the lava flow at ~ 1,300 m elevation; it reached ~ 900 m elevation. The larger had an associated coffee-colored, mushroom-shaped cloud reaching more than 1 km in height. The associated ash cloud blew SE. PFs descended again on 18 October at 1035 from ~ 1,200 m elevation NE to 900 m elevation. Winds carried the associated ash cloud W.

Background. Conical Volcán Arenal is the youngest stratovolcano in Costa Rica and one of its most active. The 1657-m-high andesitic volcano towers above the E shores of Lake Arenal, which has been enlarged by a hydroelectric project. The earliest known eruptions of Arenal took place about 7,000 years ago, and it was active concurrently with Cerro Chato until the activity of Chato ended about 3,500 years ago. Growth of Arenal has been characterized by periodic major explosive eruptions at several-hundred-year intervals and periods of lava effusion that armor the cone. Arenal's most recent eruptive period began with a major explosive eruption in 1968. Continuous explosive activity accompanied by slow lava effusion and the occasional emission of pyroclastic flows has occurred since then from vents at the summit and on the upper western flank.

Reference: Alvarado, G.E., and Arroyo, I., 2000, The pyroclastic flows of Arenal (Costa Rica) between 1975 and 2000: Origin, frequency, distribution and related hazards: Bulletin Osivam, v. 12, no. 23-24, p. 39-53.

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