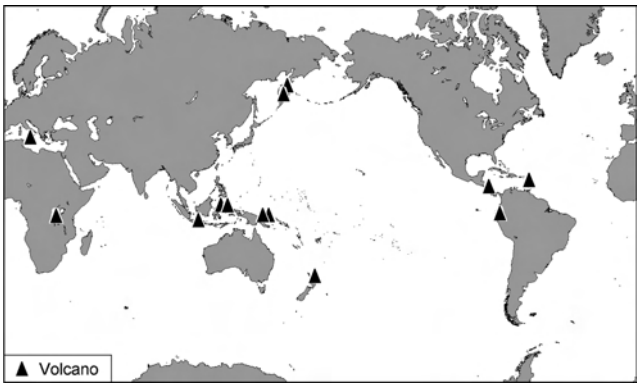
Bulletin of the Global Volcanism Network



Volume 28, Number 12, December 2003

Smithsonian
National Museum of Natural History

Global Volcanism Program · National Museum of Natural History, MRC 0119 · PO Box 37012 · Washington, DC 20013-7012 · USA
Telephone: (202) 357-1511 · Fax: (202) 357-2476 · Email: gvn@volcano.si.edu · URL: http://www.volcano.si.edu/

Subscriptions are provided by the American Geophysical Union (see the box on the last page for details).

Data are preliminary and subject to change; contact the original source or the Global Volcanism Program before using.

Cotopaxi

Ecuador
00.677ºS, 78.436ºW, summit elev. 5,911 m
All times are local (= UTC - 5 hours)

This report contains details of seismicity at Cotopaxi during May through December 2003. In general, seismicity was low and within normal levels, occasionally punctuated by increased activity. Fumarolic and inflationary activity varied throughout the period.

Seismicity during the first week of May was characterized by a high number of fracture-related volcano-tectonic events in the N, NE, and S zones, up to 15 km from the summit. These events were located at depths between 3 and 15 km below the summit. On 2 May at 0949 a volcano-tectonic event on the S flank occurred at ~ 3 km depth. Based on the coda, the event was calculated as M 3.2, a value considered moderate at this volcano. At 1918 on 2 May a long-period event was recorded at the Cotopaxi, Antisana, and Guagua Pichincha seismic stations. It lasted about 180 seconds. The earthquake was followed by a low-frequency (1.6 Hz) tremor signal lasting about 150 seconds.

Between 2 and 4 May deflation was recorded, with slight variations. On 2 May staff at the Refuge felt earthquakes. On 3 May the staff saw steam plumes at heights of 400-800 m above the crater, which blew W. On 3 and 4 May observations were made at the Refuge and the summit. Staff smelled sulfur halfway to the summit; and found new fumaroles in the Yanasacha area. On 4 May these fumaroles generated white steam plumes up to 50 m above the summit. Fumarole temperatures were 29-31°C.

A tectonic earthquake was recorded on 8 May, but although tremor episodes increased, volcano-tectonic earthquakes were fewer during 5-11 May than the previous week. Seismicity continued to drop during the week of 12-18 May. Although some low-amplitude tremor occurred during that interval, activity was dominated by long-period earthquakes. Earthquakes increased slightly the following week, but seismicity remained lower than average for the year. Low-frequency tremor lasting under 10 minutes was recorded on 23 May; tectonic activity on 24 May occurred in the zone of Saquisili and was determined to be unrelated to Cotopaxi. During the final week of May, long-period events and tremor signals increased slightly but seismicity continued to remain within the normal parameters established as of November 2001, when Cotopaxi entered a period of unusual seismic and fumarolic activity.

Activity remained generally constant through June, with episodes of harmonic tremor increasing slightly between 9 and 15 June and again on 23 June. White steam plumes reached 300 m high on 4 June, but later they were under 100 m high. At the end of June there was a slight tendency toward deflation; tremor events increased slightly and usually had fundamental frequencies of ~ 1.7 Hz.

Between 7 and 13 July the number of long-period events increased, as did the number of hybrid events. However, tremor decreased, and the average number of earthquakes per day (8) was lower than in recent periods of increased activity. The average number of earthquakes per day decreased again the following week. Notable tremor occurred on 20 July, with episodes lasting between 80 and 125 seconds and reduced displacement varying from 0.5 to 11 cm^2. During the week of 21-27 July activity increased slightly, from 6.6 to 8.3 events per day, but in general seismic data indicated a state of low activity during July.

In early August seismicity rose to an average of 20 events per day, and tremor signals increased, especially on 8-10 August. However, the released energy remained low throughout August. Earthquakes registered that month were generally small, and tremor signals were constant except for two periods of harmonic tremor on 28 August.

Although seismicity remained low in early September, on 6 September instruments registered a low-frequency (0.9 Hz), low-amplitude tremor lasting more than 3 hours. On 18 September a cluster of earthquakes (characterized by long-period events and hybrid events) began around 1300 and lasted ~ 4 hours. A second cluster occurred the next day, lasting ~ 6 hours. The earthquakes associated with these clusters were located between 1 and 4 km below the summit. Fumarolic activity was normal for most of September, although a gas discharge was reported on 21 September. After 21 September seismicity returned to normal levels, and continued to decrease through the following week.

Seismicity generally remained low for the next few months. Volcano-tectonic earthquakes and tremor increased slightly during 13-19 October. Three distinct episodes of tremor on 15, 17, and 18 October consisted of similar events with dominant frequencies of 0.8-0.9 Hz. Seismicity into November remained low, with no significant episodes of tremor and only small events.

By mid-December seismicity increased and although activity remained within normal levels, the occurrence of high-frequency tremor was noteworthy. Also through mid-December, a slight odor of sulfur was reported, as well as occasional columns of steam no higher than 300 m.

Correction: A brown plume mentioned on 7 December 2002 (*Bulletin* v. 27, no. 12) might be misinterpreted as evidence of an ash-bearing emission. Gorki Ruiz, a colleague of Pete and Patty Hall, clarified events and interpretations from that date. He interviewed guards at the Cotopaxi refugio, who stated that neither they nor others at the refugio that day had observed emissions. They discounted observations of ash emissions and noted that although fumarolic plumes frequently reach 300 m above the summit, no phreatic explosions had occurred. That time interval was also one of low seismicity.

Background. Symmetrical, glacier-clad Cotopaxi stratovolcano is Ecuador's most well-known volcano and one of its most active. The steep-sided cone is capped by nested summit craters, the largest of which is about 550 x 800 m in diameter. Deep valleys scoured by lahars radiate from the summit, and large andesitic lava flows extend as far as the base of Cotopaxi. The modern conical volcano has been constructed since a major edifice collapse sometime prior to about 5000 years ago. Pyroclastic flows (often confused in historical accounts with lava flows) have accompanied many explosive eruptions of Cotopaxi, and lahars have frequently devastated adjacent valleys. The most violent historical eruptions took place in 1744, 1768, and 1877. Pyroclastic flows descended all sides of the volcano in 1877, and lahars traveled more than 100 km into the Pacific Ocean and western Amazon basin. The last significant eruption of Cotopaxi took place in 1904.

Information Contact: *Geophysical Institute (IG)*, Escuela Politécnica Nacional, Apartado 17-01-2759, Quito, Ecuador (URL: http://www.igepn.edu.ec/).

Soufrière Hills

Montserrat, West Indies
16.72°N, 62.18°W; summit elev. 915 m

Weekly summaries of seismic activity at Soufrière Hills for the period 7 November 2003 to 16 January 2004 are given in table 1. During the week of 14 to 21 November a prominent swarm of hybrid earthquakes lasted for three days. Good views and surveys of the dome during this week confirmed that no growth or changes took place. On 9 December and on 31 December 2003 swarms of small hybrid earthquakes were observed on the drum records, but most of the events were too small to be recorded on the network. Visual observations confirmed that no new dome growth has occurred in the crater since July 2003, although there has been some slumping of old dome material from the crater walls, and degradation of the wall rocks by steam activity.

Table 2 shows a summary of the gas emissions (mainly sulfur dioxide, but one HCl estimate for 18 December). Instrument problems or unfavorable wind directions disrupted measurements for a number of days during the report interval (dashed lines).

Background. The complex andesitic Soufrière Hills volcano occupies the southern half of the island of Montserrat. The summit area consists primarily of a series of lava domes emplaced along an ESE-trending zone. Prior to 1995, the youngest dome was Castle Peak, which was located in English's Crater, a 1-km-wide crater breached widely to the east. Block-and-ash flow and surge deposits associated with dome growth predominate in flank deposits. Non-eruptive seismic swarms occurred at 30-year intervals in the 20th century, but with the exception of a 17th-century eruption, no historical eruptions were recorded on Montserrat until 1995. Long-term small-to-moderate ash eruptions beginning in that year were accompanied by lava dome growth and pyroclastic flows that forced evacuation of the southern half of the island and ultimately destroyed the capital city of Plymouth, causing major social and economic disruption to the island.

Information Contact: *Gill Norton*, Montserrat Volcano Observatory (MVO), Mongo Hill, Montserrat, West Indies (URL: http://www.mvo.ms/).

Date (2003-2004)	SO_2 emissions (metric tons/day)	HCl emissions (metric tons/day)
07 Nov-13 Nov	200-800	—
14 Nov-21 Nov	260-450	—
21 Nov-27 Nov	500	—
28 Nov-04 Dec	300-600	—
05 Dec-11 Dec	300-900	—
12 Dec-18 Dec	500-3,600	1,260 ($HCl:SO_2$ = 0.35)
19 Dec-25 Dec	—	—
26 Dec-01 Jan	500	—
02 Jan-08 Jan	300	—
09 Jan-15 Jan	200-590	—

Table 2. Summary of gas emissions recorded at Soufrière Hills, 7 November 2003 to 16 January 2004. The HCl data listed were collected on 18 December. Courtesy of Montserrat Volcano Observatory.

Date (2003-2004)	Rockfall signals	Long-period rockfalls	Long-period earthquakes	Hybrid earthquakes	Volcano-tectonic earthquakes
07 Nov-13 Nov	1	3	1	36	—
14 Nov-20 Nov	7	—	13	287	4
21 Nov-27 Nov	5	—	1	50	1
28 Nov-04 Dec	1	—	—	12	0
05 Dec-11 Dec	—	—	4	13	—
12 Dec-18 Dec	2	—	—	12	—
19 Dec-25 Dec	1	—	—	2	—
26 Dec-01 Jan	2	—	—	9	—
02 Jan-08 Jan	2	—	—	2	—
09 Jan-15 Jan	5	—	1	18	—

Table 1. Summary of seismicity recorded at Soufrière Hills, 7 November 2003 to 15 January 2004. Courtesy of Montserrat Volcano Observatory.

Irazú

Costa Rica
9.98°N, 83.85°W; summit elev. 3,432 m

This report consists of contributions from investigators at OVSICORI-UNA and UCR-ICE, who both monitor Irazú. Small-magnitude seismicity and stable fumarolic and crater lake conditions were noted in the previous Irazú report (*Bulletin* v. 26 no. 10). Weak seismicity and stable conditions continued through at least December 2003.

OVSICORI-UNA observations. Seismicity and fumarolic emissions at the volcano remained low over the reporting interval September 2001 to December 2003.

The color of the principal crater lake varied from greenish yellow (January, October, and December 2002; January and May 2003) to light yellow (June 2002), to yellow (February and March 2002), and strong yellow (February, March, and April 2003). From May 2003 on the color remained green, particularly dark green. The strong yellow color correlated with mass wasting from the crater walls, which introduced strongly colored fine-grained material into the lake. On 8 February 2003 the color briefly shifted from yellow to reddish due to mass wasting in zones along the E and ENE walls. The February mass-wasting events did not produce definable seismic signals at the volcano's sole station (IRZ2, located 5 km from the crater).

In January, September, October, and November 2002, the lake's surface was comparatively high, covering the crater floor. An interval of dry weather with consequent lower lake levels, bubbling along the lake's margins, and small landslides into the crater were noted during February and March 2002. In March and April 2002, the lake temperature was 17°C. During March 2002, fumaroles on the NE shore had temperatures of 39-50°C. The lake temperature measured 15°C

during November 2002, with one fumarole measuring 42°C. During August 2003 a fumarolic temperature of 47°C was measured on the NE lake shore.

The highest temperature of the reporting interval was in July 2003 when the NE-flank fumarole was measured at 88°C (N-flank fumarole temperatures over 80°C have been reported for almost 40 years).

Seismicity seldom averaged more than about one or two local earthquakes per day (table 3). A few volcano-tectonic and long-period earthquakes were reported (e.g., 6 LP earthquakes in September 2001; 2 in November 2002; and 4 in May 2003). Tremor was not reported.

UCR-ICE observations. Mora (2001 and 2002) presented monthly temperature and condensate-pH data for a sulfurous fumarole on the outer N slopes of Irazú. Measurements of the temperature began in 2001. The temperature remained at 90.0 ± 1°C throughout that year except in June (88.6°C) and December (86.0°C). The year 2002 began with the fumarole at 79.6°C in January, but by April it was at 89.6°C and remained relatively constant (87.5-89.6°C) until cooling in December to 86.5°C. The cooler fumarole temperatures seen annually around December-January are well established and are thought to be caused by cool water descending from the summit into the headwater regions.

During the period January-August 2002, the pH of the fumarole's condensate was 2.0; increasing to 3.5 in September, and remaining near that value (3.0-3.5) throughout the rest of year. During 2002 the crater lake level changed by less than ~ 2 m overall. Mora commented that the green-colored water seen frequently in 2002 was the result of algae adapting to the low-pH conditions.

Heavy rains during November and December 2001 formed an ephemeral lake on the floor of the inactive oblong-shaped Diego de la Haya crater (SE of the principal crater), which grew to ~ 100 x 20 m.

Month	Total earthquakes (days of operation)
Sep 2001	39 (20 days)
Oct 2001	56
Nov 2001	n.a.
Dec 2001	n.a.
Jan 2002	50
Feb 2002	23 (16 days)
Mar 2002	50
Apr 2002	n.a.
May 2002	n.a.
Jun 2002	54
Jul 2002	19
Aug 2002	11
Sep 2002	n.a.
Oct 2002	24
Nov 2002	29
Dec 2002	n.a.
Jan 2003	16
Feb 2003	20
Mar 2003	15
Apr 2003	7
May 2003	24
Jun 2003	11
Jul 2003	8
Aug 2003	23
Sep 2003	29
Oct 2003	43
Nov 2003	11
Dec 2003	n.a.

Table 3. Earthquakes registered at the Irazú seismic instrument, 5 km SW of the crater. The label "n.a." (not available) reflects a lack of mention or a malfunctioning system. When the system functioned for only part of the month, the number of functional days is in parenthesis. Courtesy of OVSICORI-UNA.

References: Mora, R., 2002, Informe anual de la actividad de la Cordillera Volcánica Central, 2002, Costa Rica (proofed and revised by Alvarado, G., Fernández, M., Mora, M., Paniagua S., and Ramírez, C.): Universidad de Costa Rica, Red Sismológica Nacional, UCR-ICE, Sección de Sismología, Vulcanología y Exploración Geofísica (published June 2003 as mini-CD Rom with PDF files).

Mora, R., 2001a, Informe semestral de la actividad de la Cordillera Volcánica Central, Enero-Junio 2001, Costa Rica: Universidad de Costa Rica, Red Sismológica Nacional, UCR-ICE, Sección de Sismología, Vulcanología y Exploración Geofísica (published November 2001 as mini-CD Rom with PDF files).

Mora, R., 2001b, Informe semestral de la actividad de la Cordillera Volcánica Central, Julio-Diciembre 2001, Costa Rica (proofed and revised by Alvarado, G., Fernández, M., Montero, W., and Ramírez, C.): Universidad de Costa Rica, Red Sismológica Nacional, UCR-ICE, Sección de Sismología, Vulcanología y Exploración Geofísica (published 6 May 2001 as mini-CD Rom with PDF files).

Background. Irazú, Costa Rica's highest volcano and one of its most active, rises to 3,432 m immediately E of the capital city of San José. The massive volcano covers an area of 500 km^2 and is vegetated to within a few hundred meters of its broad flat-topped summit crater complex. At least 10 satellitic cones are located on the southern flank of Irazú. No lava flows have been identified from Irazú since the eruption of the massive Cervantes lava flows from S-flank vents about 14,000 years ago, and all known Holocene eruptions have been explosive. The focus of eruptions at the summit crater complex has migrated to the W towards the historically active crater, which contains a small lake of variable size and color. Although eruptions may have occurred around the time of the Spanish conquest, the first well-documented historical eruption occurred in 1723, and frequent explosive eruptions have occurred since. Ashfall from the last major eruption of Irazú during 1963-65 caused significant disruption to San José and surrounding areas.

Information Contacts: *E. Fernández, E. Duarte, E. Malavassi, R. Sáenz, V. Barboza, R. Van der Laat, T. Marino, E. Hernández*, and *F. Chavarría*, Observatorio Vulcanológico y Sismológico de Costa Rica (OVSICORI-UNA), Apartado 86-3000, Heredia, Costa Rica (URL: http://www.una.ac.cr/ovsi/); *Jorge Barquero* and *Wendy Sáenz*, Laboratory de Química de la Atmósfera (LAQAT), Depto. de Química, Universidad Nacional, Heredia, Costa Rica; *María Martínez* (at both affiliations above); *Orlando Vaselli* and *Franco Tassi*, Department of Earth Sciences, University of Florence, Via La Pira 4, 50121 Florence, Italy; *R. Mora (Amador)*, *C. Ramírez*, and *M. Fernández*, Universidad de Costa Rica, Laboratory de Sismología, Vulcanología y Exploración Geofisico, Apptd. 560-2300, Curridabat, San José, Costa Rica (Email: raulmora@hotmail.com).

Rotorua

New Zealand
38.08°S, 176.27°E; summit elev. 757 m

Reported hydrothermal activity at Rotorua on 26 January 2001 involved the ejection of mud and ballistic blocks (*Bulletin* v. 26, no. 3). The New Zealand Institute of Geological and Nuclear Sciences reported that two subsequent hydrothermal eruptions in Rotorua caldera at Kuirau Park on 6 November 2003 blasted mud, rock, and ash 14 m into the air. Gray mud and small rocks littered a zone ~ 20 m wide and the eruption destroyed trees around the crater where it vented. The eruptions occurred just meters from the site of the large blowout in 2001. The area is known for this kind of geothermal activity.

Background. The 22-km-wide Rotorua caldera is the NW-most caldera of the Taupo volcanic zone. Rotorua is the only single-event caldera in the Taupo volcanic zone and was formed about 220,000 years ago during eruption of the > 500 km^3 rhyolitic Mamaku Ignimbrite. Although caldera collapse occurred in a single event, the process was complex and involved multiple collapse blocks. The major city of Rotorua lies at the S end of the lake that fills much of the caldera. Post-collapse eruptive activity, which ceased during the Pleistocene, has been restricted to lava dome extrusion without major explosive activity. The youngest eruptive activity at Rotorua consisted of the eruption of three lava domes less than 25,000 years ago. The major thermal areas of Takeke, Tikitere, Lake Rotokawa, and Rotorua-Whakarewarewa are located within the caldera or outside its rim. Whakarewarewa contains New Zealand's last remaining active geyser field.

Information Contact: *Brad Scott*, Wairakei Research Center, Institute of Geological and Nuclear Sciences (IGNS), Private Bag 2000, Taupo, New Zealand (Email: b.scott@gns.cri.nz; URL: http://www.gns.cri.nz/).

Pago

Papua New Guinea
5.58°S, 150.52°E; summit elev. 742 m

Pago remained quiet, with all vents continuing to release weak, thin white vapor during 10 October–14 December 2003. Seismicity was generally low, with daily averages of 5-7 small volcano-tectonic earthquakes. The highest number of daily events through 26 November were the 45 recorded on 28 October.

Background. Pago is a young post-caldera cone that was constructed within the 5.5 x 7.5 km Witori caldera. Extensive pyroclastic-flow deposits are associated with formation of the caldera about 3,300 years ago. The gently sloping outer flanks of Witori volcano consist primarily of dacitic pyroclastic-flow and airfall deposits produced during a series of five major explosive eruptions from about 5,600 to 1,200 years ago. Mount Pago may have formed less than 350 years ago, and has grown to a height above the Witori caldera rim. A series of ten dacitic lava flows from Pago covers much of the caldera floor. The youngest of these was erupted during 2002-2003 from vents extending from the summit nearly to the NW caldera wall.

Information Contact: *Ima Itikarai*, Rabaul Volcano Observatory (RVO), P.O. Box 386, Rabaul, Papua New Guinea (Email: rvo@global.net.pg).

Lamington

Papua New Guinea
8.95°S, 148.15°E; summit elev. 1,680 m

Lamington remained quiet during 10 October-14 December 2003. Cloud cover over the summit area made visual observations difficult, and the earthquake recorder did not function due to technical problems. Although it was difficult to make a reliable prognosis based on very limited data and information, Rabaul Volcano Observatory expected Lamington to remain quiet.

Background. Lamington is an andesitic stratovolcano with a 1.3-km-wide breached summit crater containing a lava dome. Prior to its renowned devastating eruption in 1951, the forested peak had not been recognized as a volcano. Mount Lamington rises to 1680 m above the coastal plain N of the Owen Stanley Range. A summit complex of lava domes and crater remnants rises above a low-angle base of volcaniclastic deposits that are dissected by radial valleys. A prominent broad "avalanche valley" extends northward from the breached crater. Mount Lamington sprang suddenly to life in 1951, producing a powerful explosive eruption during which devastating pyroclastic flows and surges swept all sides of the volcano, killing nearly 3000 persons. The eruption concluded with growth of a 560-m-high lava dome in the summit crater.

Information Contact: *Ima Itikarai*, Rabaul Volcano Observatory (see Pago).

Dukono

Indonesia, Halmahera Island
1.68°N, 127.88°E; summit elev. 1,185 m

Satellite imagery for 8 December showed ash plumes at ~ 3 km altitude extending 90-190 km WSW from Dukono. During 10-17 and 24-30 December, thin ash plumes were sometimes visible on satellite imagery extending E to a maximum distance of ~ 90 km. During 31 December to 6 January, low-intensity eruptions at Dukono continued to produce plumes to low levels that extended to ~ 185 km SE.

Background. Reports from this remote volcano in northernmost Halmahera are rare. More or less continuous explosive eruptions, sometimes accompanied by lava flows, occurred from 1933 until at least the mid-1990s, when routine observations were curtailed. During a major eruption in 1550, a lava flow filled in the strait between Halmahera and the N-flank cone of Gunung Mamuya. Dukono is a complex volcano presenting a broad, low profile with multiple summit peaks and overlapping craters. Malupang Wariang, 1 km SW of Dukono's summit crater complex, contains a 700 x 570 m crater that has also been active during historical time.

Information Contact: *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/).

Lokon-Empung

Sulawesi, Indonesia
1.358°N, 124.792°E; summit elev. 1,580 m

Ongoing seismicity at Lokon was reported in *Bulletin* v. 28, no. 10. The Volcanological Survey of Indonesia (VSI) report for 27 October-30 November showed continuing seismicity (table 4), and a white gas plume rising 75-150 m from the Tompaluan crater. The volcano remained at alert level 2 (on a scale of 1-4).

Dates (2003)	Volcanic A	Volcanic B	Tectonic
27 Oct-02 Nov	3	29	22
03 Nov-09 Nov	15	171	26
10 Nov-16 Nov	9	146	43
17 Nov-23 Nov	22	96	20
24 Nov-30 Nov	7	116	21

Table 4. Seismicity recorded at Lokon-Empung, 27 October -30 November. Courtesy of VSI.

Background. The twin volcanoes Lokon and Empung, rising about 800 m above the plain of Tondano, are among the most active volcanoes of Sulawesi. Lokon, the higher of the two peaks (whose summits are only 2.2 km apart), has a flat, craterless top. The morphologically younger Empung volcano has a 400-m-wide, 150-m-deep crater that erupted last in the 18th century, but all subsequent eruptions have originated from Tompaluan, a 150 x 250 m wide double crater situated in the saddle between the two peaks. Historical eruptions have primarily produced small-to-moderate ash plumes that have occasionally damaged croplands and houses, but lava-dome growth and pyroclastic flows have also occurred.

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

Ijen

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

The pattern of shallow volcanic earthquakes reported at Ijen in *Bulletin* v. 28, no. 10 continued over the period 27 October-30 November 2003. White gas emissions rose 50-150 m from the crater, and a earthquake was felt on 4 November of Modified Mercali intensity III. Data in table 5 show slight variations in seismicity during the report interval. The volcano remained at alert level 2 (on a scale of 1-4).

Background. 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 north 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 2799 m high point of the Ijen complex. Immediately west 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.

Information Contacts: *Dali Ahmad*, *Hetty Triastuty*, *Nia Haerani*, and *Suswati*, Volcanological Survey of Indonesia (VSI) (see Lokon-Empung).

Dates (2003)	Volcanic A	Volcanic B	Tremor	Tectonic	Emission
27 Oct-02 Nov	0	29	continuous (0.5-2 mm)	2	0
03 Nov-09 Nov	0	18	continuous (0.5-2 mm)	6	2
10 Nov-16 Nov	0	18	continuous (0.5-2 mm)	6	2
17 Nov-23 Nov	0	26	continuous (0.5-4 mm)	7	0
24 Nov-30 Nov	8	32	continuous (0.5-2 mm)	7	1

Table 5. Seismicity registered at Ijen, 27 October-30 November 2003. Courtesy of VSI.

Lamongan

Java, Indonesia
8.00°S, 113.342°E; summit elev. 1,651 m

When last discussed in 1988 (*Bulletin* v. 13, no. 2), a seismic swarm had occurred here. Except for an uncertain 1953 eruption, 20th- and 21st-century eruptions are unknown. Darwin Volcanic Ash Advisory 2003/1 notified aircraft personnel that, on 24 September 2003, ash was visible to ~ 900 m over Lamongan.

In this 2003 case, no confirmations of a plume or other signs of volcanism were available from observers on the scene. Concrete confirmations can establish that the plume did indeed vent here, rather than at another volcano and that it did not result from similar-looking processes of non-volcanic origin (eg., forest fires, crop burning, lofted dust).

Background. Lamongan, a small 1,631-m-high stratovolcano located between the massive Tengger and Iyang-Argapura volcanic complexes. The currently active cone has been constructed 650 m to the SW of Gunung Tarub, the volcano's high point. As many as 27 maars with diameters from 150 to 700 m, some containing crater lakes, surround the volcano, along with about 60 cinder cones and spatter cones. Lake-filled maars, including Ranu Pakis, Ranu Klakah, and Ranu Bedali, are located on the eastern and western flanks; dry maars are predominately located on the northern flanks. None of the Lamongan maars has erupted during historical time, although several of the youthful maars cut drainage channels from Gunung Tarub. Lamongan was very active from the time of its first histori-

cal eruption in 1799 through the end of the 19th century, producing frequent explosive eruptions and lava flows from vents on the western side of the volcano ranging from the summit to ~ 450 m elevation.

Information Contact: *Darwin Volcanic Ash Advisory Center (VAAC)* (see Dukono).

Dates (2003)	Volcanic A	Tremor	Tectonic	Explosion	Avalanche
27 Oct-02 Nov	1	—	—	—	2
03 Nov-09 Nov	22	15	11	41	8
10 Nov-16 Nov	4	13	12	3	7
17 Nov-23 Nov	565	585	524	596	568
24 Nov-30 Nov	11	17	14	15	7

Table 6. Seismicity recorded at Semeru, 27 October-30 November. Courtesy of VSI.

Semeru

Java, Indonesia
8.018°S, 112.92°E; summit elev. 3,676 m

Volcanic activity at Semeru continued at a high level over the period 27 October-30 November, with a white-grey ash plume 300-600 m above the crater. A summary of seismicity (table 6) shows a ~ 20 percent reduction in the number of explosions compared to the previous four weekly intervals (see *Bulletin* v. 28, no. 10). Semeru's hazard status remained at alert level 2 (on a scale of 1-4).

Background. Semeru, the highest volcano on Java, and one of its most active, lies at the S end of a volcanic massif extending north to the Tengger caldera. The steep-sided volcano rises abruptly to 3,676 m above coastal plains to the south. Gunung Semeru was constructed S 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. 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, Hetty Triastuty, Nia Haerani,* and *Suswati*, Volcanological Survey of Indonesia (VSI) (see Lokon-Empung).

Cereme

Java, Indonesia
6.892°S, 108.40°E; summit elev. 3,078 m

Seismic activity at Cereme was previously reported in *Bulletin* v. 28, no.10. Ongoing seismicity continued during 27 October-30 November 2003 (table 7). The number of A-type volcanic earthquakes peaked during 3-9 November (53 events). Hot spring temperature measurements were 47°C at Sangkan Hurip, 50°C at Cilengkrang, and 43°C at Ciniru. No significant visual activity was reported, and the hazard status remained at Alert Level 2 (on a scale of 1-4).

Background. The symmetrical stratovolcano Cereme, also known as Ciremai, is located closer to the northern coast than other central Java volcanoes. A steep-sided double crater elongated in an E-W direction caps 3078-m-high Gunung Cereme, which was constructed on the northern rim of the 4.5 x 5 km Geger Halang caldera. A large landslide deposit to the N may be associated with the origin of the caldera, although collapse may rather be due to a voluminous explosive eruption (Newhall and Dzurisin, 1988). Eruptions, relatively infrequent in historical time, have included explosive activity and lahars, primarily from the summit crater.

Dates (2003)	Volcanic type-A	Volcanic type-B	Tectonic
27 Oct-02 Nov	11	2	7
03 Nov-09 Nov	53	1	6
10 Nov-16 Nov	17	0	6
17 Nov-23 Nov	8	0	3
24 Nov-30 Nov	4	0	8

Table 7. Seismicity registered at Cereme, 27 October-30 November 2003. Courtesy of VSI.

Information Contacts: *Dali Ahmad, Hetty Triastuty, Nia Haerani,* and *Suswati*, Volcanological Survey of Indonesia (VSI) (see Lokon-Empung).

Koryaksky

Kamchatka Peninsula, Russia
53.320°N, 158.688°E; summit elev. 3,456 m

Our last report for Koryaksky was *Bulletin* v. 22, no.11, discussing seismicity in 1997. According to a Russian Information Agency Novosti press report, on 12 December 2003 instruments detected an M 3.6 earthquake followed by ~ 2 hours of seismicity at ~ 6 km depth beneath Koryaksky. A cyclonic weather system over the peninsula obstructed visual observations.

Background. The large symmetrical Koryaksky stratovolcano is the most prominent landmark of the NW-trending Avachinskaya volcano group, which towers above Kamchatka's largest city, Petropavlovsk. Erosion has produced a ribbed surface on the eastern flanks of the 3456-m-high volcano; the youngest lava flows are found on the upper western flank and below SE-flank cinder cones. No strong explosive eruptions have been documented during the Holocene. Extensive Holocene lava fields on the western flank were primarily fed by summit vents; those on the SW flank originated from flank vents. Lahars associated with a period of lava effusion from south- and SW-flank fissure vents about 3900-3500 years ago reached Avacha Bay. Only a few moderate explosive eruptions have occurred during historical time. Koryaksky's first historical eruption, in 1895, also produced a lava flow.

Information Contact: *Russian Information Agency Novosti* (Email: partners@rian.ru; URL: http://newsfromrussia.com/).

Karymsky

Kamchatka Peninsula
54.05°N,159.43°E; summit elev.1,536 m
All times are local (= UTC + 12 hours)

The intermittent explosions and elevated seismicity reported in *Bulletin* v. 28, no. 11 continued through December 2003. The Tokyo Volcanic Ash Advisory Center (VAAC) reported, for the period 28 November-5 December, that intermittent explosive eruptions emitted ash up to ~ 3.5 km altitude. The Kamchatkan Volcanic Eruption Response Team (KVERT) reported on 12 December 2003 that intermittent explosive eruptive activity at Karymsky was continuing, with occasional explosions sending ash up to 3.5 km above the volcano and local ashfall possible. Seismicity was above background levels, with 200-250 shallow long-period events per day during the previous week and possible ash-gas explosions rising up to 1-1.5 km above the volcano. Seismic data showed, at 0745 on December 5, a possible ash-gas explosion up to 4 km. Satellite data from 5-10 December showed a 1- to 5-pixel thermal anomaly over the volcano.

KVERT reported similar conditions for the week ending 19 December, with ash to 1-2.5 km above the crater and 160-240 events per day. On 16 December, they reported possible ash plumes up to 3 km above the crater and 1- to 5-pixel thermal anomalies on 11-17 December. These conditions continued during the week ending 26 December, with seismic events fluctuating at 40-200 per day and ash-and-gas plumes rising 1-2 km over the volcano. The number of earthquakes decreased during 18-20 December and increased during 21-24 December, with probable ash explosions to 3.5 km on 21 December.

At 0359 on 23 December and 1605 on 24 December possible explosions with pyroclastic flows were recorded. A 1- to 3-pixel thermal anomaly was observed by satellite on 21-22 and 24-25 December. For the week ending 2 January 2004, local shallow earthquakes took place 200-270 times per day with possible ash-gas explosions to 2-3.5 km. Possible explosions accompanied by pyroclastic flow were recorded on 25, 29, and 31 December; a 1- to 4-pixel thermal anomaly was also observed. On 29 December a very narrow gas-steam plume extended 97 km SE. The color code alert remained at orange during the month.

Background. Karymsky, the most active volcano of Kamchatka's eastern volcanic zone, is a symmetrical stratovolcano within a 5-km-wide caldera that formed during the early Holocene. The caldera cuts the S side of the Pleistocene Dvor volcano and is located outside the N margin of the large mid-Pleistocene Polovinka caldera, which contains the smaller Akademia Nauk and Odnoboky calderas. Most seismicity preceding Karymsky eruptions originated beneath Akademia Nauk caldera, immediately S of Karymsky volcano. Radiocarbon dating established that the caldera enclosing Karymsky formed about 7,600-7,700 years ago; construction of the 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: *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, 99508-4667, USA (Email: tlmurray@ usgs.gov; URL: http://www.avo.alaska.edu/), the Geophysical Institute, University of Alaska, P.O. Box 757320, Fairbanks, 99775-7320, USA (Email: eisch@dino.gi.alaska.edu), and the Alaska Division of Geological and Geophysical Surveys, 794 University Ave., Suite 200, Fairbanks 99709, USA (Email: cnye@ giseis.alaska.edu).

Kliuchevskoi

Kamchatka Peninsula
56.057°N,160.638°E; summit elev. 4835 m
All times are local (= UTC + 12 hours)

Ash explosions and Strombolian activity was reported at Kliuchevskoi through early December 2003 (*Bulletin* v. 28, no. 11). KVERT reported that unrest continued at Kliuchevskoi over the month of December, with occasional and repeated explosions containing ash, gas and steam rising to 7-8 km altitude, and possible lava flows from the central crater. Seismicity was above background levels over the month. The alert level remained Orange.

Strombolian activity was seen from the town of Klyuchi on 7 December. At 1300 on 6 December an ash explosion up to 1 km above the crater was registered and, on the same day, a 3 km high gas-steam plume was evident. Gas plumes, possibly containing small amounts of ash, rose 100-500 m on 7-16 December, generally extending in various directions and visible to distances of 3-10 km. During this time satellites detected 1- to 9-pixel thermal anomalies. Strombolian activity was again noted from Klyuchi on 12 December.

During the week ending 12 December there were approximately 150 large shallow earthquakes of M_L 1.2-2.25 and a large number of weak shallow earthquakes. For example, on 8 December, an earthquake of M_L greater than 1.75 was registered at a depth of 5 km under the central crater. On 11 December, 3 earthquakes of M_L 1.75-2.0 were registered at a depth of 3-6 km under the central crater. The number of earthquakes was similar during the week ending 19 December.

Tremor occurred often. An index of the tremor's size, reported in terms of relative velocity between the Earth and the seismograph's suspended mass (the ground motion), was 19-23 μm/s on 4-5 December, decreasing to ~ 6.7 μm/s on 9-10 December. On 12 December continuous spasmodic tremor had velocities of 2.5-9.2 μm/s. During the week ending 2 January, tremor had velocities of 2-4 μm/s.

During the week ending 26 December there were 135 large shallow earthquakes of M_L 1.9-2.3 and a large number of weak shallow earthquakes were reported. On 19 Decem-

ber, one earthquake at a depth of 11 km and two earthquakes at a depth of 30 km below the central crater (M_L less than 2.0) were registered. Continuous spasmodic tremor had velocities of 2.7-5.3 μm/s. Gas-steam plumes were seen rising up to 100 m above the crater on 22-23 December. The volcano was obscured by cloud at other times. A 1-pixel thermal anomaly over the volcano was registered by satellite on 23 December.

During the week ending 2 January 2004, the number of large (M_L1.9-2.2) shallow earthquakes dropped to ~ 33, with a large number of weak shallow earthquakes. A 1-pixel thermal anomaly was registered on 26-27 December. On 27-29 December, gas plumes were observed rising up to 50-500 m above the volcano, but the volcano was obscured at other times.

Background. Kliuchevskoi is Kamchatka's highest and most active volcano. Since its origin ~ 6,000 years ago, the stratovolcano has produced frequent moderate-volume explosive and effusive eruptions without major periods of inactivity. Kliuchevskoi flanks Kamen and Ushkovsky volcanoes. More than 100 flank eruptions have occurred during the past ~ 3,000 years, with most lateral craters and cones occurring along radial fissures between the unconfined NE-to-SE flanks at 500-3,600 m elevation. 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 numerous major explosive and effusive eruptions from flank craters.

Information Contacts: *Olga Girina*, Kamchatka Volcanic Eruptions Response Team (KVERT) (see Karymsky); *Alaska Volcano Observatory* (AVO) (see Karymsky).

Shiveluch

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

A lava dome continued to grow in the active crater at Shiveluch (also called Sheveluch). In accord with the hazard associated with lava dome growth, the level of concern from 7 November 2003 to 2 January 2004 was yellow. During this ~ 2-month interval, US and Russian satellites recorded thermal anomalies averaging 1-3 pixels.

Increasing seismicity in December was accompanied by gas-steam plumes with varying heights of 50-800 m. Sometimes the plumes extended over 10-30 km to the E, as was noted on 30 November and 2-3 December.

Seismicity was at background levels during most of November. On 29-30 November instruments detected a series of shallow events lasting 3-4 minutes. On November 29-30 and December 1-4, weak shallow earthquakes were registered. Similar earthquakes also occurred at depths of 0-5 km beneath the active dome during 19 December 2003 to 2 January 2004.

On 13 December geophysicists noted a series of weak, local, and continuous seismic events interpreted as possibly resulting from the descent of hot avalanches, but visual observations revealed only weak fumarolic activity. Later, on 11, 12, 15, and 16 December, people in the town of Klyuchi saw gas-steam plumes rise up to 100-400 m above the dome.

Eight strong earthquakes registered in December. Two occurred on 14 and 16 December; ;they were of M_L over 2.25 in the depth range 0-5 km. Three occurred on 20 December; they were of M_L 1.9-2.0 in the depth range 0-10 km. Three total earthquakes occurred in the two days 28 December and 1 January; they were of M_L 1.7-2.5 in the depth range 2-5 km.

Background. The high, isolated massif of Shiveluch volcano (also spelled Sheveluch) rises above the lowlands NNE of the Kliuchevskaya volcano group. The 1,300 cubic kilometer Shiveluch is one of Kamchatka's largest and most active volcanic structures. The summit of roughly 65,000-year-old Strary Shiveluch is truncated by a broad 9-km-wide late-Pleistocene caldera breached to the S. Many lava domes dot its outer flanks. The Molodoy Shiveluch lava dome complex was constructed during the Holocene within the large horseshoe-shaped caldera; Holocene lava dome extrusion also took place on the flanks of Strary Shiveluch. 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: *Olga Girina*, Kamchatka Volcanic Eruptions Response Team (KVERT) (see Karymsky); *Alaska Volcano Observatory* (AVO) (see Karymsky).

Etna

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

Bulletin v. 28, no. 8 reported ash emission at Etna during April 2003, and seismicity and ash emission during August 2003. A 12 September 2003 report noted that volcanic activity remained low at Etna's summit, with abundant SO_2 and steam emissions at the NE and Bocca Nuova craters. An M 3.3 earthquake occurred on 14 September. It struck beneath the Ionian sea well offshore of Sicily's southeastern-most point. The reported epicenter (36.74°N, 15.60°E) was ~ 120 km SSE of Etna's summit. A Volcanic Ash Advisory noted activity depicted by web camera starting at 0500 on 25 September, with an ash-and-steam plume drifting to the W and visible below 4.5 km altitude. No ash cloud was visible on satellite imagery at 0530.

On 9 November, aviation sources and web camera observations detected an ash-and-steam plume moving S from Etna. The plume rose to ~ 4 km altitude.

Background. 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 1,500 BC. Historical lava flows of basaltic composition cover much of the surface of this massive stratovolcano, 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 east. 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.

Information Contact: *Sonia Calvari*, Istituto Nazionale di Geofisica e Vulcanologia (INGV) Sezione di Catania, Piazza Roma 2, 95123 Catania, Italy (Email: calvari@ct.ingv.it; URL: http://www.ct.ingv.it/); *Toulouse Volcanic Ash Advisory Center (VAAC)*, Météo-France, 42 Avenue G. Coriolis, 31057 Toulouse, France (URL: http://www.meteo.fr/).

Nyamuragira

Democratic Republic of Congo, central Africa
1.408°S, 29.20°E, Summit elev. 3,058 m

On 15 December 2003, the Goma Volcano Observatory (GVO) reported growing seismicity around Nyamuragira during the past few weeks. Because of political instability, the team lacked access to the field. The seismic observations have been made using the distant seismic network. According to the data they acquired, GVO felt that a new eruption was likely in the next weeks.

Because the volcano is located inside the National Park ~ 40 km NNW of Goma, potential lava flows were not expected to threaten the city. Other areas on the W side of the volcano could be affected by gas and dust clouds or by ash falls.

Background. Africa's most active volcano, Nyamuragira is a massive basaltic shield volcano that rises about 25 km north of Lake Kivu across a broad valley NW of Nyiragongo volcano. Nyamuragira, also known as Nyamulagira, has a volume of 500 cu km, and extensive lava flows from the volcano blanket 1500 sq km of the East African Rift. The broad low-angle shield volcano contrasts dramatically with its steep-sided neighbor Nyiragongo. The 3058-m-high summit of Nyamuragira is truncated by a small 2 x 2.3 km caldera that has walls up to about 100 m high. Historical eruptions have occurred within the summit caldera, frequently modifying the morphology of the caldera floor, as well as from the numerous fissures and cinder cones on the volcano's flanks. A lava lake in the summit crater, active since at least 1921, drained in 1938, at the time of a major flank eruption. Historical lava flows extend down the flanks more than 30 km from the summit, reaching as far as Lake Kivu.

Information Contacts: *Baluku Bajope* and *Kasereka Mahinda*, Observatoire Volcanologique de Goma, Departement de Geophysique, Centre de Recherche en Sciences Naturelles, Lwiro, D.S. Bukavu, DR Congo (Email: ocha.volcan@wfp.org); *Jacques Durieux*, UN-OCHA resident volcanologist, c/o UN Office for the Coordination of Humanitarian Affairs, United Nations Geneva , Palais des Nations,1211 Geneva 10, Switzerland (URL: http://www.unog.ch).

Nyiragongo

Democratic Republic of Congo, central Africa
1.52°S, 29.25°E, Summit elev. 3,470 m

In December 2003 activity at Nyiragongo remained at relatively low levels, with the constant presence of an active lava lake inside the crater. Goma residents saw voluminous gas plume and intense red glow at night; however, activity was considered normal and the alert level remained at yellow.

Background. One of Africa's most notable volcanoes, Nyiragongo contained a lava lake in its deep summit crater that was active for half a century before draining catastrophically through its outer flanks in 1977. In contrast to the low profile of its neighboring shield volcano, Nyamuragira, 3470-m-high Nyiragongo displays the steep slopes of a stratovolcano. Benches in the steep-walled, 1.2-km-wide summit crater mark levels of former lava lakes, which have been observed since the late-19th century. Two older stratovolcanoes, Baruta and Shaheru, are partially overlapped by Nyiragongo on the N and S. About 100 parasitic cones are located primarily along radial fissures south of Shaheru, E of the summit, and along a NE-SW zone extending as far as Lake Kivu. Many cones are buried by voluminous lava flows that extend long distances down the flanks of the volcano. The extremely fluid 1977 lava flows caused many fatalities, as did lava flows that inundated portions of the major city of Goma in January 2002.

Information Contacts: *Baluku Bajope* and *Kasereka Mahinda*, Observatoire Volcanologique de Goma, Departement de Geophysique, Centre de Recherche en Sciences Naturelles, Lwiro, D.S. Bukavu, DR Congo (Email: ocha.volcan@wfp.org); *Jacques Durieux*, UN-OCHA (see Nyamuragira).

Subscriptions: The *Bulletin of the Global Volcanism Network* (ISSN: 1050-4818) is available by subscription from the American Geophysical Union (2000 Florida Avenue NW, Washington, DC 20009, phone 202:462-6900 or 800:966-2481, fax 202:328-0566, Email: service@agu.org). Annual subscription price is $22 to US addresses and $39 to all other countries. Back issues can be ordered through AGU Separates; contact AGU for current pricing information. Orders must be prepaid; make checks payable to AGU; VISA/MC are accepted. The Smithsonian does not handle any *Bulletin* orders.

Internet Access: The complete text of the *GVN Bulletin* is distributed by electronic mail through the VOLCANO Listserv mailing list (volcano@asu.edu) maintained by Jonathan Fink at Arizona State University (subscribe via listserv@asu.edu). Text, figures, and photographs can also be accessed via the World Wide Web at URL: http://www.volcano.si.edu/.