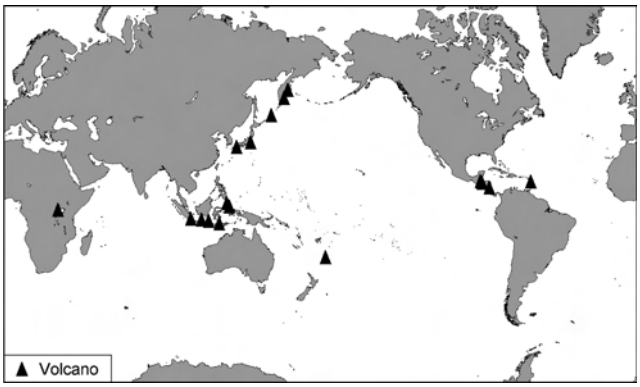
Bulletin of the Global Volcanism Network



Volume 28, Number 10, October 2003

Smithsonian
National Museum of Natural History

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Fuego

Guatemala
14.47°N, 90.88°W; summit elev. 3,763 m
All times are local (= UTC - 6 hours)

Explosive and effusive activity, last reported through January 2003 (*Bulletin* v. 28, no. 1) has continued through October 2003. Plumes identified on satellite imagery between April and September 2003 were described in aviation advisories issued by the Washington Volcanic Ash Advisory Center (VAAC). Regular reports of daily activity provided by the Instituto Nacional de Sismologia, Vulcanologia, Meteorologia e Hidrologia (INSIVUMEH) on their website have been summarized for many days in the second half of October.

Activity during April-September 2003. The Washington VAAC reported that on 28 April 2003 Fuego generated intermittent ash eruptions. One cloud was observed at ~ 7 km altitude moving SW at 19-29 km/hour. On 2 May the VAAC reported possible ash around the summit, but as of 1515, none was visible. INSIVUMEH indicated that although Fuego was active with explosions, most ash was confined to near the summit.

On 29 June INSIVUMEH reported a moderate eruption during 1745-2200 that consisted mainly of lava effusion. Lava flows were observed on the E flank, in the Lajas, Jute, and Barranca Honda ravines. Avalanches generated sounds similar to a locomotive, with strong rumblings and acoustic waves. Fuego's Observatory 2, on the SW flank, reported 2 cm of ashfall. Ashfall also occurred in San Pedro Yepocapa, Patulul Suchitepequez, Cocales, and villages W and SW of the volcano. At about 2335 there was a reduction in seismic activity at the Fuego 3 station.

INSIVUMEH reported on 1 July that explosive activity continued with weak to sometimes strong explosions ejecting grayish ash up to 900 m above the crater, with occasional degassing sounds and rumblings. Pyroclastic-flow material moved into the W-flank Seca and Santa Teresa valleys, 1.5 km from the village of Sangre de Cristo. A pyroclastic flow was reported by the Washington VAAC at 1130 on 9 July. INSIVUMEH reported strong explosions with ash to 2 km above the summit, a plume extending 5-7 km W, and ashfall to the W and SW. GOES-12 imagery showed a 3.7-km-wide plume extending ~ 11 km W.

The Washington VAAC reported on 7 August that a brief puff of ash was ejected at about 1600; the small plume moved to the NW and dissipated by 1745. On 28 September the Washington VAAC, based on visible and multi-spectral IR techniques, reported an ash eruption at about 1100. This plume, which was ~ 5 x 5 km, moved S toward the coast and was no longer discernable on imagery by 1400. A second ash emission between 1415 and 1432, with an approximate altitude of 6 km, was partially obscured by clouds.

Activity during 15-30 October 2003. On 15 October INSIVUMEH reported the continuation of eruptive activity, with degassing and small rumbling sounds. Incandescence was seen above the crater at night. The ejected ash was dispersed around the volcanic edifice. A small eruption that began at 0007 on 17 October ended at 0040 after five moderate explosive pulses, each 2-3 minutes in duration, generated thick columns of grayish ash ~ 1,500 m high. Before and after this eruptive event moderate and strong explosions caused rumbling and shock waves felt at the OVFGO and FG2 observatories. Small incandescent avalanches moved towards the Santa Teresa valley.

Harmonic tremor was registered at the FG3 station at 1630 on 20 October. On 21 October, INSIVUMEH reported explosions after 0350. The majority were strong, expelling abundant incandescent material. Ash columns caused small and moderate avalanches, mainly in the Santa Teresa and Trinidad valleys, and occasionally in the Taniluyá. Shock waves were felt by communities around the volcano. Slight ashfall occurred in the Morelia and Santa Lucia villages located 7 and 10 km, respectively, SSW of the active crater.

On 23 October, INSIVUMEH reported moderate, weak and occasionally strong explosions producing grayish and blackish plumes up to one km high. Moderate and strong explosions generated rumbling and lava flows that traveled toward the Santa Teresa and Trinidad valleys. Ashfall occurred in the upper portion of the Fuego-Acatenango complex. At 0945 a strong explosion, lasting 1.5 minutes, produced a thick ash cloud that reached a height of ~ 1 km and dispersed to the SW. Two short pulses lasting 45-60 minutes between 1200-1300 and 1800-1900 on 23 October generated a series of 7-9 moderate explosions that produced a grayish column to ~ 1 km over the central crater.

A strong explosion at 0910 on 27 October was preceded by five moderate explosions at intervals of 3-7 minutes that produced gas clouds and ash 700 m high. The first event produced a heavy ash column of a height of ~ 1 km which dispersed to the SW. An explosion at 0625 caused a pyroclastic flow toward the Trinidad and Santa Teresa valleys, and produced light ashfall in the village of Sangre de Cristo. On 29 October INSIVUMEH reported predominantly weak and moderate explosions 1-3.5 minutes long with gas-and-ash columns up to 1 km high. The last of these produced ashfall, shock waves felt at OVFGO, and avalanches of incandescent material toward the Santa Teresa and Trinidad valleys.

On 30 October an effusive eruption during 2300-0600 produced incandescent lava fountains 75-100 m high with pulses of 5-6 minutes, changing to fountains ~ 50 m high and 15-20 minutes long. A short lava flow descended SW from the crater rim, reaching ~ 250 m in length and splitting into three short branches. Short avalanches and pyroclastic flows descended to the top of the Santa Teresa valley. The eruption produced moderate to weak sounds lasting ~ 2 minutes. At dawn, a thick fumarolic plume was observed blowing NW. There was no ash emission during this activity, but at 0625 hours a small explosion sent a column of gas and ash ~ 400 m high. The seismic station at FG3 registered harmonic tremor (2-4 mm amplitude).

Background. Volcan Fuego, one of Central America's most active volcanoes, is one of three large stratovolcanoes overlooking Guatemala's former capital, Antigua. The scarp of an older edifice, Meseta, lies between Fuego and its twin volcano to the north, Acatenango. Collapse of the ancestral Meseta volcano about 8500 years ago produced the massive Escuintla debris-avalanche deposit, which extends about 50 km onto the Pacific coastal plain. Growth of the modern Fuego volcano followed, continuing the southward migration of volcanism that began at Acatenango. Frequent vigorous historical eruptions have been recorded since 1524, and have produced major ashfalls, along with occasional pyroclastic flows and lava flows.

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Santa María

Guatemala
14.756°N, 91.552°W; summit elev. 3,772
All times are local (= UTC - 6 hours)

Long term eruptive activity at the Santiaguito lava-dome complex of Santa María has continued during 2003 following lahars, explosions, and pyroclastic flows reported during much of 2002 (*Bulletin* v. 28, no. 5). Plumes identified on satellite imagery between February and September 2003 were described in aviation advisories issued by the Washington Volcanic Ash Advisory Center (VAAC). Regular reports of daily activity provided by the Instituto Nacional de Sismologia, Vulcanologia, Meteorologia e Hidrologia (INSIVUMEH) on their website have been summarized for many days in the second half of October.

Satellite observations, February-September 2003. Based on GOES-8 imagery the Washington VAAC reported that explosions occurred during the evening of 16 February 2003 and the following morning. Plumes rose to 600 m above the summit, forming an ash plume that was visible on satellite imagery. Imagery from GOES-12 indicated an eruption at about 1330 on 23 July. The plume moved W and had largely dissipated by 1615 after extending ~ 80 km. Washington VAAC reported that the volcano had been active in recent days and that INSIVUMEH had reported an ash column rising to ~ 4.6 km altitude, causing ashfall on farms W of the summit.

The Washington VAAC identified another ash cloud in GOES-12 imagery on 14 August from 0715 through 0745 that was ~ 25 km long and 5 km wide. On 28 September the Washington VAAC reported an ash emission, again based on GOES-12 imagery, that reached an estimated 4.3 km altitude. By 1532 the plume appeared to have detached from the summit and begun to slowly dissipate.

Activity observed during October 2003. Weak and moderate explosions on 15 October continued to expel gray ash to heights of 300-600 m, dispersing to the W and SW. At night blocks of incandescent lava were seen down to the base of the Caliente dome. On 17 October, as during 16 October, most of the nearly 50 explosions were considered moderate, generating avalanches of block lava and ash on the SSW flanks and NE of the Caliente cone. However, at 1745 on 16 October, a strong explosion caused the collapse of a sector of the SW flank of the crater, forming a pyroclastic flow that lasted more than 3 minutes and stopped as it neared the front of the active lava flow ~ 4 km S of Santiaguito.

On 21 October, explosions sent gas-and-ash columns 200-700 m high, which were dispersed by winds to the W, causing slight ashfall of very fine particles to fall in the dome complex. During the night of 22-23 October incandescence on the edge of the crater rim of Caliente cone was observed. Avalanches lasting 3-4 minutes continued with abundant block lava and ash descending primarily down the SSW flank with a minor component to the NE. The ash columns tended to be carried W, causing fine ashfall in sparsely populated mountainous areas. On 24 October there were 26 moderate explosions, 41 weak ones, and about 20 avalanches of lava blocks and ash originating from the S edge of the lava dome in the Caliente cone crater and from the edge of the active lava flow.

During the night of 27 October incandescence along the edge of the lava dome was observed, and weak white fumarolic emissions reached ~ 200 m above the crater in the morning; explosions and avalanches persisted. On 29 October, predominantly moderate and weak explosions produced columns 200-700 m high, and very fine ash fell in nearby mountainous areas. Many of the moderate explosions produced avalanches of block lava and ash to the NE and SW. On 30 October, three small collapses of large blocks occurred from the crater rim, and more than a dozen avalanches, each preceded by explosions and lasting 2-3 minutes, produced abundant fine ash that partially covered the S flank.

Background. Symmetrical, forest-covered Santa María volcano is one of the most prominent of a chain of large stratovolcanoes that rises dramatically above the Pacific coastal plain of Guatemala. The 3772-m-high stratovolcano has a sharp-topped, conical profile that is cut on the SW flank by a large, 1.5-km-wide crater. The oval-shaped crater extends from just below the summit of Volcán Santa María to the lower flank and was formed during a catastrophic eruption in 1902. The renowned plinian eruption of 1902 that devastated much of SW Guatemala followed a long repose period after construction of the large basaltic-andesite stratovolcano. The massive dacitic Santiaguito lava-dome complex has been growing at the base of the 1902 crater since 1922. Compound dome growth at Santiaguito has occurred episodically from four westward-younging vents, accompanied by almost continuous minor explosions and periodic lava extrusion, larger explosions, pyroclastic flows, and lahars.

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Pacaya

southern Guatemala
14.38°N, 90.60°W; summit elev. 2,552 m
All times are local (= UTC - 6 hours)

Although incandescence from the long-term lava lake ended after June 2001, SO_2 emission rates remained high when measured in January 2002 (*Bulletin* v. 27, no. 7). On 30 May 2002, the Washington Volcanic Ash Advisory Center (VAAC) received a report from Guatemala City indicating that Pacaya was active. Satellite imagery showed possible low-level ash near the summit. A very thin SW-drifting plume was again visible in satellite imagery on

Figure 1. View of Pacaya looking NNE on 24 August 2002. Only white steam emissions were visible. Courtesy of Jacquelyn Gluck.

17 June 2002, but the composition of the plume was unknown. A faint hotspot at the summit was also visible on infrared imagery. Visual observation on the afternoon 24 August 2002 from the SW showed copious white steam emissions from the summit crater (figure 1).

The Washington VAAC reported that on 5 July 2003 at 0715, a very thin ash and/or gas plume was visible on satellite imagery at an altitude of ~ 3 km extending ~ 7.5 km SW. By 1430 the plume was no longer visible, possibly obscured by thunderstorm clouds in the area. INSIVUMEH reported that only steam was emitted. Visible imagery on 9 August 2003 showed a narrow plume below 3 km altitude extending SW from the volcano, but its composition was unknown.

Reports provided by INSIVUMEH during the latter half of October 2003 indicated that during 15-21 October constant steam and abundant emissions of water and gas were being blown to the NNW and W of the volcano. These emissions continued through the end of the month. On 23 October, during periods of visibility, observers saw a line of off-white smoke across the S flank, which was dispersed in the area of the lava field near the Chupadero and the Caracol rivers. The next day observers saw a heavy column of off-white smoke rising ~ 600 m over the MacKenney crater. The plume continued through 27 October, but only to a height of ~ 400 m. The heavy gaseous cloud continued at the same height through 30 October.

Background. Eruptions from Pacaya, one of Guatemala's most active volcanoes, are frequently visible from Guatemala City, the nation's capital. Pacaya is a complex basaltic volcano constructed just outside the southern topographic rim of the 14 x 16 km Pleistocene Amatitlán caldera. A cluster of dacitic lava domes occupies the southern caldera floor. The post-caldera Pacaya massif includes the Cerro Grande lava dome and a younger volcano to the SW. Collapse of Pacaya volcano about 1100 years ago produced a debris-avalanche deposit that extends 25 km onto the Pacific coastal plain and left an arcuate somma rim inside which the modern Pacaya volcano (MacKenney cone) grew. A subsidiary crater, Cerro Chino, was constructed on the NW somma rim and was last active in the 19th century. During the past several decades, activity at Pacaya has consisted of frequent strombolian eruptions with intermittent lava flow extrusion that has partially filled in the caldera moat and armored the flanks of MacKenney cone, punctuated by occasional larger explosive eruptions that partially destroy the summit of the cone.

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San Cristóbal

Nicaragua
12.702°N, 87.004°W; summit elev. 1,745 m

This report summarizes the recorded activity at San Cristóbal during August 2002-September 2003. Reports from Instituto Nicaragüense de Estudios Territoriales (INETER) include observations from frequent visits to the volcano.

August-December 2002. During August-December 2002, abundant gas emanations were accompanied by small gas explosions. Incandescence was frequently observed. Seismicity was relatively high, but fluctuated from month to month (table 1). On 12 August, ash emissions with columns up to 800 m high were observed. More ash explosions were reported on 17 and 21 August. Gas emissions and small ash explosions continued in September, and incandescence was observed during 1-7 September. A strong explosion was reported on 6 October, and a dark gas column was observed. Throughout the month gas emissions were abundant, occasionally with columns to 600 m high. Temperatures at the South Point and El Zopilote fumaroles increased in October from the previous month. Gas emissions and ash explosions continued in November and December, with increased activity on 22 November and 16 December. Trees and fruit plants were affected by the gases in the community of Las Banderas. At the end of December, a volcano observer discovered that the path to the volcano was blocked by a deposit of sand-sized material.

January-March 2003. Activity decreased in the first few months of 2003. No changes were observed in the crater in January, and temperatures increased only at two

Month	Number of earthquakes
Aug 2002	2,183
Sep 2002	2,792
Oct 2002	1,017
Nov 2002	technical problems–no earthquakes recorded
Dec 2002	200-250 per day
Jan 2003	5,671
Feb 2003	2,595
Mar 2003	5,329
Apr 2003	1,713
May 2003	5,491
Jun 2003	4,855

Table 1. Number of earthquakes at San Cristóbal between August 2002 and June 2003. Courtesy of INETER.

fumaroles; those temperatures were low again in February. On 19 February the observer heard loud sustained noises and noted that the crater walls were colored green and yellow, indicating the presence of sulfur.

April-September 2003. Between April and September, fumarole temperatures were measured on each of the monthly visits to San Cristóbal, and showed very little change. The highest temperatures were generally found at South Point and were between 91 and 95°C. At El Munecho temperatures varied between 81 and 91°C, and at El Conejo between 77 and 86°C. Temperatures remained moderate at the other fumaroles.

Gas emissions were noted in particular between 20 and 23 April, days on which there were small increases in tremor; on 10 May gas emissions were strong enough to impede a visit. Activity increased in June, with abundant ash and gas emissions noted on 17 and 21 June. On 21 June incandescence was noted, and strong rumbling was heard in the evening. On 13 July gas emissions were dense, followed during 14-23 July by a dark column. Seismicity dropped from more than 350 events per day to 69 events on 3 July. By 9 July, only eight events per day were recorded; tremor remained constant at 35 RSAM units.

Gas emissions remained constant through August and September, with reports of gas explosions during a visit on 10 August and abundant gases during the 17 September visit. The strong noises and sounds of gas pressure being released decreased over these months, and no noise was noted on the September visit. Seismicity was very low in August and September, with no earthquakes and very low tremors in August, and only six earthquakes in September.

Background. The San Cristóbal volcanic complex, consisting of five principal volcanic edifices, forms the NW end of the Marrabios Range. The symmetrical 1745-m-high youngest cone, named San Cristóbal (also known as El Viejo), is Nicaragua's highest volcano and is capped by a 500 x 600 m wide crater. El Chonco, with several flank lava domes, is located 4 km to the west of San Cristóbal; it and the eroded Moyotepe volcano, 4 km to the NE of San Cristóbal, are of Pleistocene age. Volcán Casita, containing an elongated summit crater, lies immediately east of San Cristóbal and was the site of a catastrophic landslide and lahar in 1998. The Plio-Pleistocene La Pelona caldera is located at the eastern end of the San Cristóbal complex. Historical eruptions from San Cristóbal, consisting of small-to-moderate explosive activity, have been reported since the 16th century. Some other 16th-century eruptions attributed to Casita volcano are uncertain and may pertain to other Marrabios Range volcanoes.

Information Contact: *Virginia Tenorio, Emilio Talavera*, and *Martha Navarro*, Instituto Nicaragüense de Estudios Territoriales (INETER), Apartado Postal 2110, Managua, Nicaragua (Email: ineter@ibw.com.ni; URL: http://www.ineter.gob.ni/geofisica/).

Masaya

Nicaragua
11.95°N, 86.15°W; summit elev. 625 m

This report summarizes the activity at Masaya during June-September 2003. Activity was generally constant, with fumarole temperature measurements similar to those from previous months (*Bulletin* v. 28, no. 8). In June, July, and August, during visits made every two weeks, Jaime Cárdenas of Masaya Volcano National Park measured the fumarole temperatures at the Comalito and San Fernando craters (table 2). No changes were observed from previous months. During these months, seismic tremor remained constant with 20 units RSAM. No earthquakes were registered, but on both 21 June and 21 July landslides were reported in the Santiago crater. In September, temperatures obtained from the Santiago crater with a Pyrometer were 187ºC and 123ºC. It was noted during this visit that the lava sounded like ocean waves, and incandescence was observed at night. Temperatures at El Comalito remained moderate.

Background. Masaya is one of Nicaragua's most unusual and most active volcanoes. It is a broad, 6 x 11 km basaltic caldera with steep-sided walls up to 300 m high. The caldera is filled on its NW end by more than a dozen vents erupted along a circular, 4-km-diameter fracture system. Masaya lies within the massive Pleistocene Las Sierras pyroclastic shield volcano. The twin volcanoes of Nindirí and Masaya, the source of historical eruptions, were constructed at the southern end of the fracture system and contain multiple summit craters. A major basaltic plinian tephra was erupted from Masaya about 6500 years ago. Historical lava flows cover much of the caldera floor and have confined a lake to the far eastern end of the caldera. A lava flow from the 1670 eruption overtopped the north caldera rim. Masaya has been frequently active since the time of the Spanish Conquistadors, when an active lava lake prompted several attempts to extract the volcano's molten "gold."

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Date (2003)	EC #1	EC #2	EC #3	EC #4	EC #5	EC #6	SF #1	SF #2	SF #3	SF #4
10 Jun	65.4	74.5	76.8	72.5	73.4	60.2	59.2	54.8	57.2	55.8
28 Jun	66.4	75.4	78.4	73.6	73.8	60.4	60.2	55.6	58.8	56.7
12 Jul	55	76	78.2	74	73.6	60	60	60.2	59.5	57
26 Jul	66.8	78.4	79.4	75.6	74.2	61	61.2	61.4	60.2	58.2
15 Aug	66.6	78.2	79.5	76	74.5	61.5	59.7	59.7	57.2	56.2
29 Aug	67.8	75.6	76.6	74.8	76.4	64.2	59.3	57.4	56.9	57
22 Sep	68.6	72.3	68.3	65.2	—	—	—	—	—	—

Table 2. Temperatures recorded at the El Comalito (EC) and San Fernando (SF) fumaroles of Masaya, 10 June-22 September 2003. All temperatures are in degrees Celsius. Courtesy INETER.

Shiveluch

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

Eruptive activity continued during August-October 2003, including growth of a lava dome in the active crater. Seismicity remained above background levels, and weak, shallow earthquakes were recorded throughout the period. Slightly higher seismic activity was recorded on 30 October with magnitudes in the range of 2.0-2.4. Short-lived eruptions each week sent ash-and-gas plumes to heights of 100-1,500 m above the dome. Thermal anomalies were often recorded by US and Russian satellites.

Weak volcanic tremor was detected during 22-31 August. Tremor was accompanied by gas-and-steam plumes as high as 800 m during 26-27 August, and 2-4-pixel thermal anomalies on 26-30 August. Small thermal anomalies (1-4 pixels) and 500-800-m-high steam plumes were common through 19 September, with an 11-pixel anomaly on the 18th. Similar small thermal anomalies and plumes appeared again during 25-30 September. Thermal anomalies continued to be detected during 1-4, 7-8, 10-12, 16-20, 26, and 29-30 October. Steam plumes were also common, with varying heights of 100-800 m. Small steam plumes and a 1-pixel anomaly occurred 2-3 November.

Background. The high, isolated massif of Shiveluch volcano (also spelled Sheveluch) rises above the lowlands NNE of the Kliuchevskaya volcano group. The 1300 cu km 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 south. 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.

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Bezymianny

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

A large explosive eruption of Bezymianny on 26 July 2003 sent an ash plume 8-11 km high and 86 km long (*Bulletin* v. 28, no. 7). A later KVERT report noted that the active eruption phase lasted ~ 4 hours after beginning on 2057. Longer plumes on 27 July extended to 192 km, 217 km and ~ 250-300 km W of the vent. Probable pyroclastic deposits were identified on the SE flank.

No seismicity was registered during 27 July-3 August. The Color Code was lowered from Red to Orange on 28 July, and reduced to Yellow on 1 August. A 1-2-pixel thermal anomaly was detected on 1 August, and observers saw gas-and-steam plumes extending ~ 15 km NW on 2 August. On 8 August the hazard status was returned to Green. Clouds frequently obscured the volcano, but another gas-and-steam plume extended SE on 19 August when a 2-pixel thermal anomaly was also noted on satellite imagery. No further seismicity was recorded through 22 August, although large volcanic tremor at nearby Kliuchevskoi volcano would have masked smaller events.

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

Alaid

Kurile Islands, Russia
50.858°N, 155.55°E; summit elev. 2,339 m

On 4 November 2003 the Level of Concern Color Code was raised to Yellow due to volcanic tremor that began on 31 October. Weak seismicity continued through 7 November. Volcanic tremor during this time was 0.5-3.3 x 10^{-6} mps, and a large number of weak local events were registered. On satellite images the volcano was obscured by clouds all week.

The Kamchatkan Volcanic Eruption Response Team notes that Alaid is characterized by two types of eruptions: central crater eruptions and lateral eruptions. Central crater eruptions are stronger and more dangerous then the lateral ones. The strongest central crater eruptions of Alaid were in February 1793, June 1854, July 1860, 1894, and April

1981. The April 1981 eruption sent an ash plume to 8,000-9,000 m altitude that extended for more than 1,500 km (*Bulletin* v. 6, nos. 4-5). Two eruptions in 1933-1934 and 1972 (*CSLP Cards* nos. 1405, 1406, 1410, and 1518) ejected ash columns 3 km high.

Satellite imagery indicated possible activity in March 1982 (*Bulletin* v. 7, no. 3, and v. 12, no. 4), 3 December 1996 (*Bulletin* v. 21, no. 12), and 23 August 1997 (*Bulletin* v. 22, no. 9).

Background. The highest and northernmost volcano of the Kurile Islands, Alaid is a symmetrical stratovolcano when viewed from the north, but has a 1.5-km-wide summit crater that is breached widely to the south. Alaid is the northernmost of a chain of volcanoes constructed west of the main Kuril archipelago and rises 3,000 m from the floor of the Sea of Okhotsk. Numerous pyroclastic cones dot the lower flanks of Alaid, particularly on the NW and SE sides, including an offshore cone formed during the 1933-34 eruption. Strong explosive eruptions have occurred from the summit crater beginning in the 18th century. Explosive eruptions in 1790 and 1981 were among the largest during historical time in the Kurile Islands.

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Miyake-jima

Izu Islands, Japan
34.079°N, 139.529°E
summit elev. 815 m

Volcanic activity at Miyake-jima since the eruption during the summer of 2000 (Bulletin v. 25, no. 7) has continued at lower levels through August 2003. The flux of SO_2 gas remained high (~ 4, 000-9, 000 tons/day), and has been nearly constant since October 2002 (figure 2). A compilation of seismic data and plume observations through April 2003 (table 3) doc-

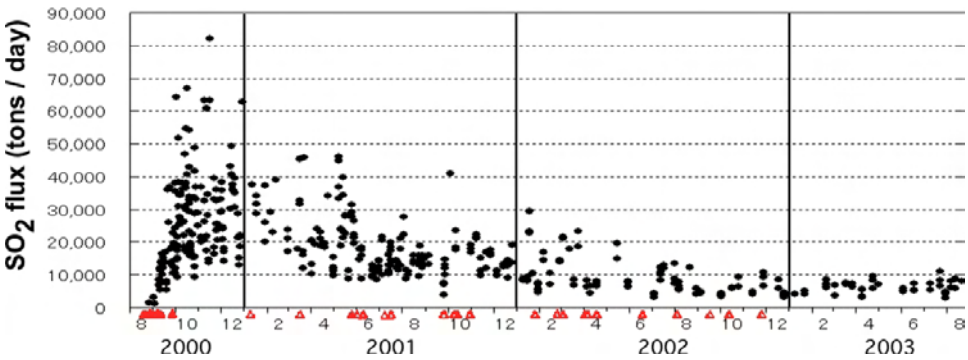

Figure 2. SO_2 flux at Miyake-jima during August 2000-August 2003. Triangles along the timeline indicate explosions. Courtesy of the Geological Survey of Japan and the Japan Meteorological Agency.

Month	Volcanic earthquakes	Max. Plume Height (km) (date)	Plume Color (date)
Jan 2000	2	-	-
Feb 2000	4	-	-
Mar 2000	1	-	-
Apr 2000	5	-	-
May 2000	3	-	-
Jun 2000	> 13,840	-	-
Jul 2000	> 24,494	1.5 (8, 14)	W (8) colored (14, 15)
Aug 2000	> 10,175	14 (18)	Mix of white and colored almost daily all after 10th
Sep 2000	146	3.5 (26), frequently >1	W (almost daily), C (3, 24, 27)
Oct 2000	16	2.7(10)	W
Nov 2000	5	2.5(26)	W
Dec 2000	6	2.0 (22, 27)	W
Jan 2001	214	1.8 (22, 31)	W, GW (11)
Feb 2001	260	2.0 (17)	W
Mar 2001	299	2.0 (2, 16, 24)	W, GW (19)
Apr 2001	191	2.0 (4)	W
May 2001	707	2.2 (6)	W, G (27)
Jun 2001	192	2.2 (10)	W, G (3, 10)
Jul 2001	249	1.6 (16, 21)	W, G (10)
Aug 2001	306	2.0 (24, 25, 27, 28)	W
Sep 2001	234	3.0 (16)	W
Oct 2001	116	1.5 (16, 21, 22, 24, 29, 31)	W, GW
Nov 2001	124	2.0 (20)	W, GW (1)
Dec 2001	123	1.7 (29)	W
Jan 2002	41	2.0 (6)	W, GW
Feb 2002	88	1.7 (14)	W, GW
Mar 2002		No JMA report received this month	
Apr 2002	104	1.0 (10)	W, GW (2, 3)
May 2002	265	1.5 (29)	W
Jun 2002	176	0.8 (9)	W, GW (15)
Jul 2002	78	0.8 (27)	W
Aug 2002	45	1.0 (3)	W
Sep 2002	57	1.5 (4)	W
Oct 2002	47	1.0 (6, 30)	W, GW (8)
Nov 2002	55	1.0 (6, 29)	W
Dec 2002	66	0.8 (28)	W
Jan 2003	202	1.0 (25)	W
Feb 2003	313	0.8 (13)	W
Mar 2003	212	1.2 (28)	W
Apr 2003	450	1.0 (28)	W

Table 3. Summary of seismicity and plume observations at Miyake-jima, January 2000-April 2003. All reported plumes originated from the summit crater, and were described as either white (W), light white (LW), grayish white (GW), or gray (G). No months during this time had more than six plumes observed on any single day. Data courtesy of JMA.

uments this continuing activity. Plume heights following the June-September 2000 activity have not been greater than 2.2 km above the summit (table 3), and their color has been described as white or grayish white.

The number of monthly earthquakes was very low (1-4/month) until late June through early September 2000. Except for 5 May 2001 when 447 volcanic earthquakes occurred, daily totals have been less than 50. Monthly earthquake totals since August 2000 have been less than 300, except for May 2001 (707) and April 2003 (450). Volcanic tremor also began in July 2000 and became continuous in September 2000. Tremor through April 2003 totaled less than 500 events per month, except for May 2001, when 1, 362 events were recorded (444 on the 22nd). The unusually high seismicity noted in May 2001 corresponded to a period of continuous steam plumes with abundant SO_2 content (*Bulletin* v. 27, no. 3), after which SO_2 flux declined (figure 2).

Seismicity at Miyake-jima is recorded by three seismographs maintained by the Japan Meterological Agency (JMA): station "A" is ~ 1.9 km NNE of the summit at 530 m elevation, station "AKOC" is ~ 4.6 km W at 42 m elevation, and station "RST" is ~ 1.9 km SSE at 463 m elevation.

Background. The circular, 8-km-wide island of Miyake-jima forms a low-angle stratovolcano that rises about 1100 m from the sea floor in the northern Izu Islands about 200 km SSW of Tokyo. The basaltic volcano is truncated by two summit calderas, the youngest of which, 3.5 km wide, was formed during a major eruption about 2500 years ago. A central cone, Oyama, rises 120 m from the floor of a nested 1.5-km-wide caldera at the eastern end of the larger caldera. Parasitic craters and vents, including maars near the coast and radially oriented fissure vents, dot the flanks of the volcano. Frequent historical eruptions have occurred since 1085 AD at vents ranging from the summit to below sea level, causing much damage on this small populated island. After a three-century-long hiatus ending in 1469, activity has been dominated by flank fissure eruptions sometimes accompanied by minor summit eruptions. A 1.6-km-wide summit caldera was slowly formed by subsidence during an eruption in 2000; by October of that year the crater floor had dropped to only 230 m above sea level.

Information Contacts: *Japan Meteorological Agency (JMA)*, Volcanological Division, 1-3-4 Ote-machi, Chiyoda-ku, Tokyo 100, Japan (URL: http://www.kishou.go.jp/english/); *Akihiko Tomiya*, Geological Survey of Japan, AIST, 1-1 Higashi, 1-Chome Tsukuba, Ibaraki 305-8567, Japan (URL: http://staff.aist.go.jp/a.tomiya/tomiyae.html; Email: a.tomiya@aist.go.jp).

Aso

Kyushu, Japan
32.881°N, 131.106°E; summit elev. 1, 592 m
All times are local (= UTC - 9 hours)

Recent noteworthy activity at Aso consisted of elevated tremor in August 2002 and a phreatic eruption in July 2003. Seismicity recorded by the Japan Meteorological Agency (JMA) between January 2000 and April 2003 (table 4) was generally constant, with continuous volcanic tremor every month in addition to isolated tremor events. The number of tremor events was high through October 2000, during April 2002, and from August 2002 through March 2003. Also during this extended period, white plumes were observed approximately once a month, with two or more plumes occurring in July, October, and December 2002, and February and March 2003. These plumes were usually less than 500 m high.

Activity during August 2002. For the first time since 1992, isolated volcanic tremor events occurred at a rate of more than 300 events/day in Naka-dake Crater 1. These events were recorded between 5 and 21 August and totalled nearly 4,000 (table 5), with the highest number, 340 events, on 15 August. During this period, the water temperature of the pool in the crater remained between 57 and 60°C. On 14 August, infrared cameras measured the maximum tempera-

Month	Number of volcanic earthquakes	Number of volcanic tremors
Jan 2000	19	1,466
Feb 2000	16	926
Mar 2000	73	1,232
Apr 2000	39	732
May 2000	39	537
Jun 2000	30	802
Jul 2000	29	1,234
Aug 2000	21	2,104
Sep 2000	36	1,445
Oct 2000	38	1,448
Nov 2000	43	202
Dec 2000	33	129
Jan 2001	51	60
Feb 2001	161	739
Mar 2001	76	537
Ap 2001	40	81
May 2001	40	85
Jun 2001	99	188
Jul 2001	84	282
Aug 2001	60	471
Sep 2001	40	86
Oct 2001	91	32
Nov 2001	52	17
Dec 2001	45	5
Jan 2002	38	5
Feb 2002	59	20
Mar 2002	No JMA report received this month	
Apr 2002	114	1,138
May 2002	91	14
Jun 2002	191	36
Jul 2002	238	37
Aug 2002	153	4,413
Sep 2002	144	1,438
Oct 2002	103	1,440
Nov 2002	652	3,391
Dec 2002	154	8,496
Jan 2003	122	6,981
Feb 2003	178	4,183
Mar 2003	92	1,965
Apr 2003	70	474

Table 4. Seismicity at Aso between January 2000 and April 2003. The seismograph station is located ~ 13 km W of the summit. Courtesy of JMA.

Date (2002)	Number of isolated tremor events
05 Aug	129
06 Aug	238
07 Aug	241
08 Aug	137
09 Aug	244
10 Aug	304
11 Aug	315
12 Aug	335
13 Aug	299
14 Aug	336
15 Aug	340
16 Aug	287
17 Aug	257
18 Aug	208
19Aug	162
20 Aug	104
21 Aug	37 as of 1100

Table 5. Daily number of isolated volcanic tremor events at Aso, August 2002. Courtesy of Japan Meteorological Agency.

ture of the southern crater wall at 307°C; this increased to 314°C the following week.

Activity during July 2003. JMA reported on 11 July 2003 that tephra had fallen at Aso that morning. According to the report, a tremor event with an intermediate amplitude was recorded at 1718 on 10 July. Staff from the Aso Weather Station confirmed that small amounts of tephra had been newly deposited at Hakoishi-Toge (Hakoishi Pass), ~ 6 km ENE of the Nakadake crater. Kazunori Watanabe (Kumamoto University) and other geologists surveyed the deposit on 11 July and estimated the total mass of ejected material at roughly 130 tons. Ash was deposited as far as 14 km from the crater. A small amount of fresh vesicular glass particles were noted in the ejecta under the microscope. According to Yasuaki Sudo (Aso Volcanological Laboratory, Kyoto University), who inspected the crater area, the event was a small phreatic eruption of mud. The deposit consisted of wet ash aggregates and was ~ 1 mm thick, even at the crater rim. A spray of mud was blown off the crater rim by strong winds to 10 km from the crater.

Seismic signals implied a series of small phreatic eruptions between 12 and 14 July. Then on 27 July continuous volcanic tremor started around 1400. Observations that day noted that the water in Crater 1 was gray and boiling in the center; the temperature of the water was 76°C.

Background. The 24-km-wide Aso caldera was formed during four major explosive eruptions from 300, 000 to 80, 000 years ago. These produced voluminous pyroclastic flows that covered much of Kyushu. A group of 17 central cones was constructed in the middle of the caldera, one of which, Naka-dake, is one of Japan's most active volcanoes. It was the location of Japan's first documented historical eruption in 553 AD. The Naka-dake complex has remained active throughout the Holocene. Several other cones have been active during the Holocene, including the Kometsuka scoria cone as recently as about 210 AD. Historical eruptions have largely consisted of basaltic to basaltic-andesite ash emission with periodic strombolian and phreatomagmatic activity. The summit crater of Naka-dake is accessible by toll road and cable car, and is one of Kyushu's most popular tourist destinations.

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Karangetang

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

Explosive activity has been common at Karangetang in recent years, producing ashfall and lava avalanches as recently as May and June 2003 (*Bulletin* v. 28, nos. 5 and 7). However, Karangetang was not included in reports by the Volcanological Survey of Indonesia (VSI) between 16 June and 28 September 2003. A report for the week of 29 September-5 October indicated that there had been a decrease in multiphase and emissions earthquakes compared to the previous week (table 6). At that time white gas emissions were observed rising 400 m above the S crater and 50 m above the N crater. Red glow was seen at night over the S crater that week. No lava avalanches occurred. Similar observations were reported through 19 October. Although surface observations of activity were consistent, seismic data showed that shallow volcanic earthquakes increased and emission events decreased during 6-19 October. The hazard status remained at Alert Level 2 (on a scale of 1-4) through at least 19 October.

Background. Karangetang (Api Siau) volcano lies at the northern end of the island of Siau, north of Sulawesi. The 1784-m-high stratovolcano contains five summit crat-

Date (2003)	Deep Volcanic	Shallow Volcanic	Multiphase	Emission	Tectonic
02 Jun-08 Jun	11	348	233	46	26
09 Jun-15 Jun	32	438	228	21	20
16 Jun-28 Sep			No data available		
29 Sep-05 Oct	15	84	50	121	38
06 Oct-12 Oct	19	103	33	74	32
13 Oct-19 Oct	18	135	5472		33

Table 6. Seismicity at Karangetang during 2 June-19 October 2003. Courtesy of VSI.

ers 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*, *Hetty Triastuty*, *Nia Haerani*, and *Suswati*, 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).

Lokon-Empung

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

The hazard status at Lokon-Empung throughout the report period of 2 June-19 October was at Alert Level 2 (on a scale of 1-4). Between 2 June and 5 October a white gas plume consistently rose 25-50 m above Tompaluan crater. The gas plume rose slightly higher, to 75 m, during the following two weeks. Seismicity remained above normal background levels during this time, with some variation (table 7). Shallow volcanic earthquakes increased in late July, but by September the weekly count was lower than in early July, eventually reaching a low the week of 15-21 September when no such events were detected. Seismicity quickly returned to high values of 138-209 shallow events per week in October.

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.

Date (2003)	Deep Volcanic	Shallow Volcanic	Tectonic
02 Jun-08 Jun	13	45	20
09 Jun-15 Jun	25	88	27
30 Jun-06 Jul	18	81	19
07 Jul-13 Jul	17	48	15
14 Jul-20 Jul	9	91	19
21 Jul-27 Jul	25	232	21
28 Jul-03 Aug	16	157	10
01 Sep-07 Sep	11	44	11
08 Sep-14 Sep	7	36	20
15 Sep-21 Sep	12	0	22
22 Sep-28 Sep	34	22	20
29 Sep-05 Oct	33	209	24
06 Oct-12 Oct	5	159	14
13 Oct-19 Oct	24	138	14

Table 7. Seismicity at Lokon-Empung, 2 June-19 October 2003. Data was not available for 16-29 June and 04-31 August. Courtesy of VSI.

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

Soputan

Sulawesi, Indonesia
1.108°N, 124.725°E; summit elev. 1,784 m

Increased activity during 18-22 July 2003 at Soputan consisted of frequent ash explosions and large glowing lava avalanches (*Bulletin* v. 28, no. 8). Seismicity from August through mid-October was dominated by avalanche events, with a few tectonic earthquakes (table 8). White gas emissions in this period were commonly seen rising 25-50 m above the crater, but were also reported as high as 1,000 m in late August and September. On 31 August there was ash explosion accompanied by ejection of incandescent material. The ash column reached 1,000 m above the summit. Lava flowed 750 m down the SW slope, and some descended to the N. Volcanic tremor that week (18-31 August) had an amplitude of 10-38 mm. The hazard status remained at Alert Level 2 (on a scale of 1-4) through 19 October.

Date (2003)	Avalanche Earthquakes	Tectonic Earthquakes
18 Aug-31 Aug	71	—
29 Sep-05 Oct	80	12
06 Oct-12 Oct	30	8
13 Oct-19 Oct	62	9

Table 8. Seismicity at Soputan, 18 August-19 October 2003. Courtesy of VSI.

Background. The small Soputan stratovolcano on the southern rim of the Quaternary Tondano caldera on the northern arm of Sulawesi Island is one of Sulawesi's most active volcanoes. The youthful, largely unvegetated volcano rises to 1784 m and is located SW of Sempu volcano. It was constructed at the southern end of a SSW-NNE trending line of vents. During historical time the locus of eruptions has included both the summit crater and Aeseput, a prominent NE-flank vent that formed in 1906 and was the source of intermittent major lava flows until 1924.

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

Gamalama

Halmahera, Indonesia
0.80°N, 127.325°E; summit elev. 1,715 m

A series of explosive eruptions on 31 July 2003 produced ashfall and pyroclastic flows (*Bulletin* v. 28, no. 7). Several small ash explosions occurred throughout August

and September (*Bulletin* v. 28, no. 9). Activity was similar during 29 September-5 October 2003, with white gas emissions rising 25-100 m and some small ash explosions. Volcanic seismicity consisted of one deep earthquake, two shallow earthquakes, and 24 emission events. Activity remained low the following week, 6-12 October, with gas emissions rising 25-50 m. The number of daily seismic events this week had returned to normal levels, so the hazard status was downgraded to Alert Level 1 (on a scale of 1-4) on 13 October.

Background. Gamalama (Peak of Ternate) is a near-conical stratovolcano that comprises the entire island of Ternate off the western coast of Halmahera and is one of Indonesia's most active volcanoes. The island of Ternate was a major regional center in the Portuguese and Dutch spice trade for several centuries, which contributed to the thorough documentation of Gamalama's historical activity. Three cones, progressively younger to the north, form the summit of Gamalama, which reaches 1715 m. Several maars and vents define a rift zone, parallel to the Halmahera island arc, that cuts the volcano. Eruptions, recorded frequently since the 16th century, typically originated from the summit craters, although flank eruptions have occurred in 1763, 1770, 1775, and 1962-63.

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

Lewotobi

Lesser Sunda Islands, Indonesia
8.53°S, 122.775°E; summit elev. 1,703 m

Explosive ash eruptions from the summit crater of Lewotobi sent dark gray plumes 300-350 m high between 2 June and 13 July. Detonation sounds accompanied explosions on 3, 5, and 6 June. Ash fell in the villages of Bawalatang, Duang, and Boru in early June, and was reported at the volcano observatory post in early July. Ash explosions continued during 14-20 July with plumes rising 150 m above the summit. Poor weather conditions prevented observations in late July, although seismic records indicated continued activity; no reports were available for August. In early September an ash plume was reported to rise 25 m above the crater.

Seismicity during June and July was dominated by emissions events, but included tremor, explosion, and shallow volcanic earthquakes (table 9). Early September seismicity consisted of a high number of shallow volcanic events and some deep volcanic earthquakes, but all seismicity ceased after 3 September. Only four tectonic earthquakes were detected after this date, during 6-19 October. The 29 September-5 October report noted an ash plume rising to 25 m above the crater, but over the next two weeks the 25-m-high plume was described as gas emissions. The hazard status was downgraded to Alert Level 1 (on a scale of 1-4) the week of 13-19 October.

Background. The Lewotobi "husband and wife" twin volcano (also known as Lewetobi) in eastern Flores Island is composed of the Lewotobi Lakilaki and Lewotobi Perempuan stratovolcanoes. Their summits are less than 2 km apart along a NW-SE line. The conical 1584-m-high Lewotobi Lakilaki has been frequently active during the 19th and 20th centuries, while the taller and broader 1703-m-high Lewotobi Perempuan has erupted only twice in historical time. Small lava domes have grown during the 20th century in the crescentic summit craters of both volcanoes, which are open to the north. A prominent flank cone, Iliwokar, occurs on the east flank of Lewotobi Perampuan.

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

Date (2003)	Deep Volcanic	Shallow Volcanic	Explosion	Emission	Tremor	Tectonic
02 Jun-08 Jun	0	13	7	29	20	12
09 Jun-15 Jun	0	24	—	40	33	9
30 Jun-06 Jul	0	8	14	26	11	3
07 Jul-13 Jul	0	16	10	52	4	1
14 Jul-20 Jul	4	17	19	24	10	4
21 Jul-27 Jul	1	10	5	25	5	4
28 Jul-03 Aug	0	9	8	20	6	3
01 Sep-03 Sep*	27	257	0	0	0	5

Table 9. Seismicity at Lewotobi, 2 June-19 October 2003. Note that no seismicity was recorded after 3 September 2003. Courtesy of VSI.

Ijen

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

The hazard status of Ijen was upgraded to Alert Level 2 (on a scale of 1-4) on 8 October. Seismicity the week of 6-12 October comprised four deep volcanic earthquakes, 21 shallow volcanic earthquakes, one emission event, and continuous tremor (0.5-2 mm amplitude). Only 16 shallow volcanic earthquakes were recorded the following week, along with continuous tremor (0.5-2 mm amplitude). Continuous tremor (0.5-4 mm amplitude) was recorded during 20-26 October, a week when the number of shallow volcanic events increased to 30. Gas plumes emitted from the crater rose up to 150 m high during October. Elevated seismicity at Ijen was last reported during December 2002-January 2003 (*Bulletin* v. 28, no. 3).

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 Karangetang).

Semeru

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

Frequent ash explosions at Semeru during 29 September-26 October 2003 produced white-gray ash plumes 400-500 m over the summit. The hazard status remained at Alert Level 2 (on a scale of 1-4) during this time. Although tectonic earthquakes, tremor events, shallow volcanic earthquakes, and avalanches were all detected seismically, the record was dominated by explosions (table 10). Explosions over this 4-week period averaged 95 per day, or one every 15 minutes.

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*, *Hetty Triastuty*, *Nia Haerani*, and *Suswati*, Volcanological Survey of Indonesia (VSI) (see Karangetang).

Cereme

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

Data from the Volcanological Survey of Indonesia (VSI) indicated a tectonic and volcanic earthquake at Cereme on 25 March, followed by one more volcanic event on 28 March. Activity picked up on 2 April with three more volcanic events, with 17 events through 14 April. Daily highs of 8 and 11 events were recorded on 24 April and 3 May, respectively (2-4 May had 22). Seismicity remained generally low (0-3/day) until 29 events occurred on 7 October.

After a felt earthquake on 7 October, volcanic earthquakes increased. This increased seismicity was accompanied by elevated visually observed activity, resulting in the hazard status being upgraded to Alert Level 2 on 13 October. Seismic activity during 6-12 October consisted of 46 deep volcanic earthquakes and 15 shallow volcanic earthquakes; 36 deep volcanic events occurred the following week of 13-19 October. There was a felt earthquake on 19 October that lasted for 95.5 seconds (35 mm amplitude). Seismic activity declined during 20-26 October, when only seven deep volcanic earthquakes were recorded. The temperature measured at the Sangkan Hurip hotspring in late October was 48°C, unchanged from previous measurements.

Reference: Newhall C G, Dzurisin D, 1988. Historical unrest at large calderas of the world. U S Geol Surv Bull, 1855: 1108 p, 2 vol.

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 north 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. The most recent eruption occurred in March 1951.

Information Contacts: *Dali Ahmad*, *Hetty Triastuty*, *Nia Haerani*, and *Suswati*, Volcanological Survey of Indonesia (VSI) (see Karangetang).; *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/; Email: a.tupper@bom.gov.au).

Krakatau

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

A report of activity at Krakatau for the period 18-24 August was provided by the Volcanological Survey of Indonesia. There was increase in volcanic earthquakes during this time, while tectonic earthquakes decreased. No visual observations were made due to foggy weather. Seismicity consisted of 12 deep volcanic earthquakes, 56 shallow volcanic earthquakes, and three tectonic events. The hazard status was at Alert Level 2 (on a scale of 1-4).

Date (2003)	Explosion	Avalanches	Tremor	Tectonic
29 Sep-05 Oct	636	20	9	4
06 Oct-12 Oct	567	10	—	7
13 Oct-19 Oct	687	19	22	4
20 Oct-26 Oct	768	16	3	11

Table 10. Seismicity at Semeru, 29 September-26 October 2003. Four shallow volcanic earthquakes were also detected during 6-12 October. Courtesy of VSI.

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.

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Figure 4. Closeup of beached pumice clasts from the unnamed volcano in the Tofua volcanic arc fouled by algae and goose barnacles (Lepas pectinata). Courtesy of Scott Bryan.

Unnamed

NW of Vava'u, Tonga Islands, Pacific Ocean
18.325°S, 174.365°W; summit elev. -300? m

A felsic shallow marine explosive eruption from a previously unknown volcano along the Tofua volcanic arc (Tonga) in September-October 2001 (*Bulletin* v. 26, no. 11, and v. 27, no. 1) produced floating pumice rafts in Fiji in November 2001, approximately one month after it occurred. These sea-rafted pumice are the only recorded output of this subaqueous eruption at a remote location where direct observations are limited.

A new influx of sea-rafted pumice reached the eastern coast of Australia in October 2002 (figure 3), approximately one year after the eruption was first indicated by seismic activity and pumice stranding in Fiji. Pumice was stranded along at least two-thirds (>2,000 km) of the coastline of eastern Australia, extending from N of Townsville to Sydney. Typical amounts of pumice initially stranded on beaches were 500-4,000 individual clasts per m^2; a minimum volume estimate of pumice deposited along the eastern Australian coastline is 1.25 x 10^5 m^3. Most stranded pumice clasts are 1-5 cm diameter, although some outsized clasts are up to 10 cm. Many clasts were fouled by a variety of organisms, and dark algal coverings were common to all clasts that concealed the primary character of the pumice (figure 4). This is in contrast to pumice stranded on beaches in Fiji ~ 1 month after the eruption, which were clean of fouling organisms. Fouling organisms include algae, Bryozoa, serpulid worms, corals and, oysters with goose barnacles particularly abundant.

The pumice have a low phenocryst content (<5% modal) with the phenocryst assemblage consisting of calcic plagioclase (An_{88-74}), pigeonite (En_{45} Fs_{46} Wo_9), augite (En_{35} Fs_{29} Wo_{36}), and titanomagnetite. Preliminary

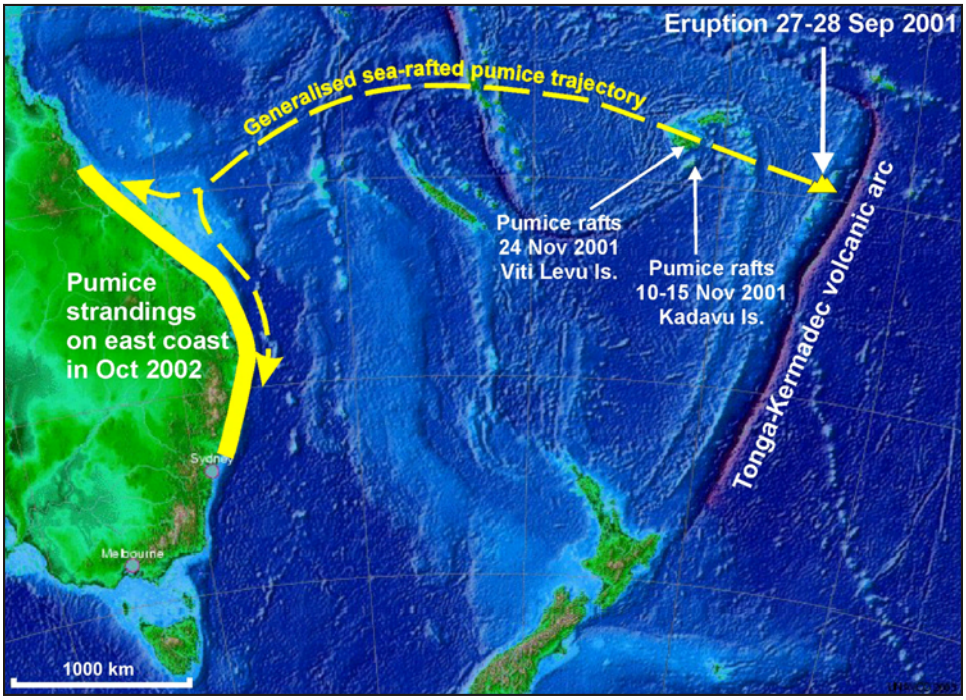

Figure 3. Map of the southwest Pacific Ocean showing the location of the unnamed volcano in the Tofua volcanic arc that erupted in September-October 2001 producing the pumice rafts. The general dispersal trajectory of the sea-rafted pumice is shown by the dashed line, and the pumice reached the eastern Australian coastline ~ 1 year after the eruption. Courtesy of Scott Bryan.

Element	HI1[A]	GC1[A]	P1[B] (n=3)	P2[B] (n=3)
SiO_2	71.30	65.90	66.84	67.33
TiO_2	0.36	0.58	0.51	0.50
Al_2O_3	12.80	12.31	12.29	12.16
$Fe_2O_3^T$	5.50	9.88	--	--
FeO^T	--	--	8.05	8.04
MnO	0.10	0.18	0.16	0.15
MgO	1.07	1.43	0.93	0.92
CaO	4.34	5.77	5.40	5.23
Na_2O	3.45	3.20	2.71	2.80
K_2O	0.90	0.60	0.71	0.72
P_2O_5	0.18	0.15	0.18	0.20
BaO	--	--	0.03	0.05
SrO	--	--	0.17	0.16
LOI	0.92	1.87	--	--
Raw Total	99.50	99.80	97.99	98.27

Table 11. Major element data on sea-rafted pumice clasts from eastern Australia, 2002. A, major element data for whole pumice clasts determined by the atomic absorption method of silicate rock analysis using Inductively-Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES) at the University of Queensland. B, averaged pumice glass compositions analysed at the Centre for Microscopy & Microanalysis, University of Queensland, using a JEOL 8800-L (wavelength dispersive) electron microprobe. Analyses were performed with an accelerating voltage of 15 kV and with a probe current of 15 nA and a probe diameter of 10 microns to avoid volatilisation of alkali elements. Courtesy of Scott Bryan and Alex Cook.

petrographic observations indicate that the pumice is compositionally homogenous, although there is considerable variation in vesicularity within and between clasts. Tubed pumice is a minor but distinctive clast type. The pumice, like previously stranded pumice on the Great Barrier Reef (Bryan, 1968, 1971), is low-K dacite in composition (table 11), characterized by low alkalis and high iron and silica. This composition is similar to other pumice-forming eruptions from the Tonga region (Bryan, 1968).

References: Bryan, W.B., 1968, Low-potash dacite drift pumice from the Coral Sea: Geological Magazine, v. 105, p. 431-439.

Bryan, W.B., 1971, Coral Sea drift pumice stranded on Eua Island, Tonga, in 1969: Geological Society of America Bulletin, v. 82, p. 2799-2812.

Background. A submarine volcano along the Tofua volcanic arc was first observed in September 2001. The newly discovered volcano lies NW of the island of Vava'u about two-thirds of the way between Late and Fonualei volcanoes. The site of the eruption is along a NNE-SSW-trending submarine plateau south of Fonualei with an approximate bathymetric depth of 300 m. T-phase waves were recorded on September 27-28, and on the 27th local fishermen observed an ash-rich eruption column that rose above the sea surface. No eruptive activity was reported after the 28th, but water discoloration was documented during the following month. In early November pumice rafts and strandings were reported along the coast of Kadavu and Viti Levu in the Fiji Islands. The depth of the submarine vent following the eruption is not known.

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Nyiragongo

DR Congo, central Africa
1.52°S, 29.25°E; summit elev. 3,469 m

During the 3-month period from 2 August to 8 November 2003, volcanic activity was concentrated inside the Nyiragongo crater. An almost permanently boiling lava lake occupies the crater at the depth of 700 m. Although the level of the lake inside the crater seems to remain constant, its size is slowly growing due to collapses of the pit walls. Degassing has been significant, marked by a large gas plume above the crater which is generally blown W by the prevailing winds and extends several tens of kilometers. The impact of this activity on the environment is growing; inside the National Park, a 50 km^2 area of forest was totally destroyed by volcanic gases and acid rains, and a zone with 50% destruction covers more than 700 km^2, affecting crops such as potatoes, corn, beans, and bananas. In the same areas significant fluoride pollution has been detected, and tanks collecting rain water are showing fluoride concentrations up to 23 mg/l (WHO tolerance = 1.5 mg/l).

In the Nyiragongo area, long-period events are commonly detected but at reduced number and are mainly located NW and SW of the volcano. Seismicity is largely dominated by permanent tremor generated by the activity of the lava lake. Earthquakes related to fracturing continue, mainly S of Nyiragongo and NE of Nyamuragira (~ 15 km NW of Nyiragongo). No noticeable deformation change has been recorded along the fracture system between the two volcanoes.

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 north and south. About 100 parasitic cones are located primarily along radial fissures south of Shaheru, east 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.

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Nyamuragira

DR Congo, central Africa
1.408°S, 29.20°E; summit elev. 3,058 m

During the 3-month period from 2 August to 8 November 2003, seismicity in the Nyamuragira area was dominated by long-period (LP) events localized along a main NNE-SSW fracture between Nyamuragira and Nyiragongo volcanoes. Intermittent swarms of LP events (60-80 events each time) occurred on Nyamuragira two to three times per week. A larger swarm was observed on 23 July (100 LP events). This activity remained fairly stable for the whole period. Earthquakes related to fracturing continued, mainly S of Nyiragongo (N of Lake Kivu) and NE of Nyamuragira. No noticeable deformation change has been recorded along the fracture system.

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 has a volume of 500 km^3, and extensive lava flows from the volcano blanket 1500 km^2 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.

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Soufriére Hills

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

Activity at Soufriére Hills remained at a relatively low level from mid-September into early November 2003. Seismicity consisted mostly of hybrid earthquakes and rockfall signals (table 12). Access continues to be prohibited to some areas after the major dome collapse and explosive activity of 12-13 July 2003 (*Bulletin* v. 28, no. 8), and there is a maritime exclusion zone around the S part of the island extending 3.7 km beyond the coastline from Trant's Bay in the E to Isles Bay on the W coast.

During the week of 12-19 September, no growth of the new lava dome was observed. Activity was at a slightly higher level during the week of 26 September-3 October, especially hybrid earthquakes, most of which occurred in a swarm between 1100 and 2100 on 27 September. Some of the hybrids could be located at 2-4 km depth. A period of low-amplitude tremor was also recorded between 0800 on 30 September and 0400 on 1 October coincident with vigorous ash venting, which resulted in ash clouds reaching 2,000-2,500 m altitude and drifting W over Plymouth. Observations on 30 September and 3 October suggested that no new dome growth had occurred.

From 3 October to 7 November, activity returned to a low level. A period of low-amplitude tremor was recorded between 3 and 8 October, and some mudflow signals were also recorded during periods of heavy rain. The tremor coincided with light ash venting. Visibility was poor during this period, so no direct observations of the summit area were possible. The dome was observed clearly on 23 October and a volume survey was carried out from Galways and Perches Mountains. The small dome that extruded in July 2003 had not grown further and appeared to be stagnant, with alteration and degradation occurring such that it appears to be breaking up. The pit crater associated with the explosions of July 2003 had widened slightly, although this was thought to be due to passive slumping of material. Sulfur dioxide and hydrogen chloride emission rates were high

Date (2003)	Rockfall signals	Long-period earthquakes	Hybrid earthquakes
05 Sep-12 Sep	2	3	27
12 Sep-19 Sep	9	4	20
19 Sep-26 Sep	13	1	20
26 Sep-3 Oct	4	—	241
03 Oct-10 Oct	1	—	15
10 Oct-17 Oct	12	—	9
17 Oct-24 Oct	8	2	12
24 Oct-31 Oct	11	2	19
31 Oct- 07 Nov	8	—	16

Table 12. Summary of seismic activity at Soufriére Hills, 5 September-7 November 2003. No volcano-tectonic earthquakes were recorded during this period, but one long-period rockfall event occurred 23-31 October. Courtesy of the Montserrat Volcano Observatory.

Date (2003)	SO_2 emissions (tons/day)	HCI emissions (tons/day)
12 Sep-19 Sep	700-900	230-300
19 Sep-26 Sep	500-600	—
26 Sep-28 Sep	400-500	—
28 Sep-01 Oct	900-1,200	—
04 Oct	3,100	—
05 Oct	1,900	—
06 Oct-08 Oct	800-1,200	—
04 Oct & 07 Oct	—	600-1,000
10 Oct-12 Oct	600-800	—
13 Oct	1,900	—
16 Oct	720	—
17 Oct-24 Oct	950-1,200	—
22 Oct	1,850	1,500
24 Oct-27 Oct	800-900	—
28 Oct-31 Oct	400-600	—
31 Oct- 07 Nov	800-1,350	—

Table 13. Gas emissions at Soufriere Hills, 5 September-7 November 2003. Hydrogen chloride emissions are calculated from hydrogen chloride to sulfur dioxide mass ratios measured in the volcanic plume using Fourier transform infrared. Values are in metric tons/day. Courtesy of the Montserrat Volcano Observatory.

during several days around 13-15 October and on 22 October (table 13). An observation flight on 28 October yielded clear views of the scar area and the W scar wall. No changes were observed in the morphology of the scar and no new lava was observed in the vent area.

According to the Washington VAAC, on 1 November resuspended ash was seen in satellite imagery. The ash was moving N to NNW at ~ 10 km/hour from Montserrat between Nevis and Antigua, and the resuspended ash was concentrated in a narrow plume.

Background. The complex andesitic Soufriére 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 Contacts: *Montserrat Volcano Observatory (MVO)*, Mongo Hill, Montserrat, West Indies (URL: http://www.mvo.ms/); *Washington Volcanic Ash Advisory Center (VAAC)*, Satellite Analysis Branch (SAB), NOAA/NESDIS E/SP23, NOAA Science Center Room 401, 5200 Auth Rd., Camp Springs, MD 20746 USA (URL: http://www.ssd.noaa.gov/).

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