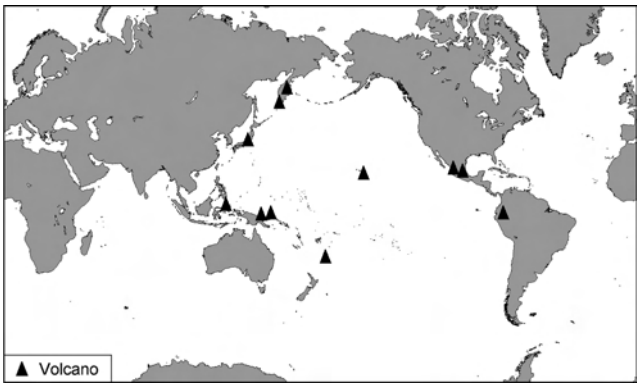
Bulletin of the Global Volcanism Network



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Tungurahua

Ecuador
1.467°S, 78.442°W; summit elev. 5,023 m

The Instituto Geofísico (IG) provided Tungurahua reports discussing the year 2003. Ash-bearing eruptions sent plumes as high as 9.4 km altitude, with resulting noticeable ashfall 40 km distant. Lahars were common and occasionally incandescent material descended the upper flanks. Activity was low during January and February, and increased slightly in March and again in June. In August activity increased again, and for the rest of the year it generally remained elevated. IG recognized a new phase of eruptive activity beginning 20 August. That phase consisted of long-period earthquakes followed by emissions reaching up to 3 km above the volcano (~ 8 km altitude).

Activity during January-February 2003. During these months volcanism generally remained low, with occasional emissions of gas and ash that produced low-level plumes. Incandescence was sometimes visible in the crater at night. Seismicity was low and was characterized by sporadic long-period earthquakes and low intensity emissions. Activity increased slightly beginning 12 February with an emission that rose to low levels and drifted W. A moderate explosion on 19 February deposited a small amount of ash on the ENE flanks (Cerro de Ulba and the Ulba valley). Seismicity increased slightly during the eruption, but returned to low levels afterwards. Volcanic and seismic activity remained low through early March with continuing gas and ash emissions.

Activity during March 2003. Activity began to intensify on 5 March when lahars descended the gorges on Tungurahua's NW flank, obstructing the road between the towns of Baños (~ 8 km N of the summit) and Pelileo (~ 13 km NNW of the summit). Around 7 March ash rose to ~ 7 km altitude and drifted SW. No ash was visible on satellite imagery. By 9 March several low-to-moderate explosions had occurred and this activity continued. On 11 March three small-to-moderate explosions deposited ash in the W-flank village of Pillate (8 km from the summit). That day a pilot reported ash to ~ 8.2 km altitude.

On 16 March a fine layer of ash accumulated in Baños. Sporadic explosions continued for the rest of the month, with one on 19 March that sent incandescent material ~ 1 km down the flanks. Explosions during this period were accompanied by Strombolian activity, gas-and-ash emissions, and loud roaring. Seismicity was dominated by tremor and long-period earthquakes, with tremor starting to decrease after 13 March.

Activity during April-May 2003. During early April, explosions occasionally occurred at the volcano. A pilot reported seeing ash at a height of around 2.3 km over Tungurahua on 6 April. No ash was detected on satellite imagery, however. Three explosions occurred on 7 April, with the largest plume rising to ~ 3 km above the volcano. Very little ash was visible in the plume. Activity dropped slightly for a few days, with sporadic explosions, until a large explosion occurred on 10 April, producing a plume with low ash content to ~ 2 km above the volcano. Volcanic explosions, generally small, continued the following week; minor vapor columns were also noted. Cloud cover obscured the volcano on some days, but an aviation report on 16 April mentioned that IG staff reported an ash cloud rising up to ~ 7 km altitude (~ 2 km above the summit). On 17 April two ash columns rose 1.5 and 2 km above the summit and blew SW and W, respectively. The volcano generally appeared relatively placid, but concern about mudflows and sudden increases in eruptive output remained. Limited visibility often prevailed, but it was noted that Tungurahua's behavior alternated between days of tranquility and those with small to moderate explosions. Few earthquakes occurred.

On 1 May an explosion sent ash to 2 km above the summit; incandescent material fell onto the flanks up to 0.8 km from the crater. Based on information from IG, the Washington VAAC reported that a small 6 May explosion yielded a cloud composed mainly of gas, with some ash. The cloud drifted W and seismic activity decreased after the explosion.

Activity during June-July 2003. Volcanic activity increased in early June. On 6 June, strong Strombolian activity hurled incandescent volcanic blocks ~ 500 m from the summit; plumes of mainly steam rose to around 2 km above the volcano and drifted W. Ash fell in the settlements of Pillate (8 km W of the summit), San Juan (~ 40 km WSW of the summit), and Riobamba (32 km SW of the summit), with accumulations of less than 1 mm. There were reports of airborne ash interfering with main flight routes across Ecuador. Emissions on 9 June reached 3-6 km above the volcano. On 10 June vibrations from an explosion were felt in Baños, explosions could be heard in towns near the volcano, and ash fell in several villages.

On 15 June incandescent blocks were hurled to ~ 150 m above the crater and rolled ~ 1 km down the N flank. During the evening of 17 June, Strombolian activity was visible at the summit, and an explosion on 18 June deposited ash on the settlements of Cusúa (~ 8 km NW of the summit), Juive (7 km NNW), and Pillate. Gas emissions with small amounts of ash occurred regularly, and on 19 June observers saw ash rise to 3 km above the summit.

During the last week of June, several explosions produced ash clouds; on 25 June ash fell in Pillate and in the town of Mocha (25 km W). Ash was visible on satellite imagery, with the highest-rising ash cloud reaching ~ 9.4 km altitude on 27 June. Emissions on 29 June deposited ash in Pillate, and in the towns of Cotaló (8 km NW of summit) and Cevallos.

On 1 and 2 July ash plumes rose to ~ 2 km above the volcano and ash fell in several towns near the volcano. Strombolian activity also occurred, and ash from the eruptions damaged crops and livestock near the volcano. A state of emergency was declared on 3 July, and food rations were distributed to residents of the town of Chimborazo. After 2 July, eruptive vigor remained relatively low through the rest of the month and into August. Reports noted mainly steam and gas emissions and low plumes.

Activity during August 2003. Tungurahua entered a new phase of activity on 20 August. The new phase was characterized by a short sequence of long-period earthquakes followed by gas-and-ash emissions that reached a maximum height of 3 km above the volcano.

A small amount of ash fell in Cusúa on 20 August. During the evening the volcano hurled incandescent blocks ~ 300 m above the summit and some traveled ~ 1 km downslope. On 21 August emissions of mostly steam and small amounts of ash rose ~ 1 km above the volcano and

drifted W; ash fell in the Riobamba, Ambato (~ 33 km NW), and Santa Fé de Galán areas. On 23 August plumes rose to 0.5-2.5 km above the volcano, and ash fell in the town of Guaranda. On 24 August an explosion, heard in the town of Baños, ejected blocks that traveled ~ 1 km down the volcano's flanks. An emission on 27 August deposited ash in Ambato and caused flight restrictions to and from the airport there. During this week, volcanic block-and-ash emissions continued, with ash plumes rising to heights of ~ 4 km above the volcano. These drifted primarily W and SW and deposited ash in several towns.

Activity during September-October 2003. Moderate ash emissions and ashfall continued during September and October, accompanied in mid-September by tremor related to gas discharge. Seismicity ranged from moderate levels in September to a series of long-period earthquakes and explosions in early October.

Incandescence was observed in the crater on the evening of 7 September. On 15 September two emissions produced gas-and-ash plumes that reached a maximum height of 2 km above the volcano; ash fell predominately W of the volcano. On 22 September ash clouds reached a height of 3 km above the volcano and drifted W. On 24 September ash emissions produced plumes that drifted NW, depositing small amounts of ash in the towns of Quero (~ 20 km WNW of the summit), Puela (~ 8 km SW), Juive, and Cusúa. Volcanic blocks emitted during the eruption rolled ~ 1 km down the NW flank.

On 1 October gas-and-ash emissions reached a height of ~ 4 km and drifted NE and NW, depositing ash in San Juan (~ 40 km WSW), Pillate, and Valle del Patate. On 9 October ash fell on northerly sectors near the volcano, including Runtún (~ 6 km NNE of the summit), Juive, and Baños. Strombolian activity was seen during the evening of 12 October. Associated gas-and-ash plumes up to 2 km high drifted NNE and ash fell in Ambato. On the night of 18 October incandescent blocks rolled down the crater's W side. Incandescence and Strombolian activity were observed the following night. Activity decreased slightly on 20 October with fewer explosions and no major gas-and-ash eruptions recorded. Ash plumes were frequently visible on satellite imagery during 15-20 October.

Activity during November-December 2003. Tungurahua maintained generally low activity in early November, increasing towards month's end. Following a week of small-to-moderate eruptions of gas and ash, an eruption on 2 November produced a plume that rose to ~ 3 km above the volcano and drifted W. Over the next few days, occasional ash-poor plumes rose to less than 1 km above the summit; a few ash-bearing emissions did occur, including ashfalls of low intensity on 5, 6, and 7 November to the E. Also on 6 November seismic stations recorded two larger-than-average explosions, one associated with an ash column rising to 2 km. Seismicity returned to low levels, with relatively few earthquakes, but tremor continued.

During 12-18 November, small-to-moderate eruptions of steam, gas, and some ash continued; plumes rose to ~ 2.5 km above the volcano, but there were no reports of ashfall in nearby towns. Strombolian activity was visible at the crater and avalanches of incandescent volcanic material rolled ~ 1 km down the volcano's flanks. Activity increased to high levels beginning 19 November; numerous moderate explosions produced plumes that were frequently visible on satellite imagery and rose up to 2 km above the crater. Ash was dispersed SSW and SW on 19 and 20 November and WNW and NW on 23 and 24 November, respectively. Throughout the week Strombolian activity was visible at night.

During 22 November to 1 December, a large number of emissions of gas, steam, and ash occurred, depositing ash to the SW, W, and NW. Plumes were visible on satellite imagery at a maximum of ~ 7 km altitude.

During 11-16 December, volcanic activity remained relatively high with several explosions producing ash-and-gas plumes to a maximum of 9 km altitude. There were also many long-period earthquakes, occurring with nearly constant gas-and-ash emissions. Explosions on 11 December deposited ash in the towns of Quero, Santa Fe de Galán, and lesser amounts in Bilbao. Ash-and-gas plumes were visible on satellite imagery several times during the week.

Background. Tungurahua is a steep-sided stratovolcano that towers 3 km above its northern base. Historical eruptions have originated from the summit crater and have included strong explosions and sometimes lava flows, lahars, and pyroclastic flows that reached populated areas at the volcano's base. The volcano's complex historical record includes sudden, violent eruptions.

Information Contact: *Geophysical Institute (IG)*, Escuela Politécnica Nacional, Apartado 17-01-2759, Quito, Ecuador (URL: http://www.igepn.edu.ec/); *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/); *El Comercio*, Quito, Ecuador (URL: http://www.elcomercio.com/); *Agence France-Presse*.

Cotopaxi

Ecuador
00.677°S, 78.436°W, summit elev. 5,911 m

This report contains details of seismicity at Cotopaxi during January through 2 May 2003. The seismicity was generally low (averaging ~ 20 earthquakes per day), as it has been since 24 November 2001. Despite the low seismicity, during January seismic signals suggestive of emissions registered, although these lacked visual confirmations at the volcano. Moreover, a cluster composed of a variety of kinds of shallow earthquakes took place in mid-March. This was the first such cluster since 19 July 2002.

Activity during January-February 2003. Seismicity was generally low in January 2003 and located earthquakes commonly had focal depths down to 5 km below the summit. During the first week of January one volcano-tectonic (VT) event occurred N of the volcano. Around this time the rate of energy release was very low and no unusual observations were reported. Seismicity decreased after the first week of January, although some long-period (LP) events occurred, including one of high frequency (10 Hz) on 9 January that was followed immediately by another with a slowly decaying coda or tail (a so-called "tornillo" event, with a dominant frequency of 2.7 Hz). Two LP events were located at depths of 1 km. The rate of energy release remained very low, with some peaks on 8 January. Seismicity stayed low through the next week; some hybrid and LP

events did occur. Some signals characteristic of emissions were received, although these were not visually confirmed.

During 20-26 January the number of hybrid events increased slightly, to above average. Emission signals were again received, similar to the previous week. No LP earthquakes were recorded this week, but a small group of earthquakes were located at the headwaters of the Pita river. Events such as these were also noted in November 2001. During the last week of January, seismicity remained low, on a par with activity seen since 24 November 2001. However, the low number of events registered or located was partly because arrivals were not clear at many stations.

Seismicity remained low in February, particularly for the first week. During 10-16 February it rose slightly due to larger numbers of hybrid events. No other changes in the volcano were noted. Although the third week of February brought no important variations in seismicity, beginning in late February LP events dominated the record. Still, the number of LP event stayed below the 2002 average.

Activity during March-April 2003. Although low seismicity generally prevailed throughout this interval, there was some variations in the abundance of earthquake types and a mid-March cluster of earthquakes occurred. During early March hybrid earthquakes increased to slightly higher than the 2002 average; in addition another LP-type tornillo was recorded on 6 March. On 7 March LP earthquakes were common.

On 16 March a cluster of hybrid, VT, and LP earthquakes was located 1-3 km below the volcano. Following eight months of low seismicity (averaging ~ 20 events per day), this was the first seismic swarm registered at Cotopaxi since 19 July 2002. However, the energy released per number of events was similar to earlier activity.

Seismicity increased after 16 March. Clusters similar to that of the 16th continued, but with lower magnitudes. By the beginning of April seismicity decreased to within the base level, although on 4, 7, and 8 April VT events were recorded to the S and SE, approximately 3 km below the summit. No significant changes were noted at the volcano, although the usual smell of sulfur was noted on a visit to the summit. During 14-20 April, the number of LP events decreased from the previous week, but VT events of M 2.5-M 3.4 continued to the N. VT events persisted through the rest of April, particularly in late April, which on 23 April included an M 3.6 event. VT events occurred on the N, NE, and S sides of the volcano up to 15 km from the summit at depths between 3 and 15 km. The VT events were interpreted as related to rock fracturing.

On the morning of 2 May a VT event registered on the S flank, located ~ 3 km deep. It was M 3.2, moderate for Cotopaxi. Later that day an event registered at the seismic stations at Cotopaxi, Antisana, and Guagua Pichincha. This event had a duration of 180 seconds and was made up of an LP earthquake followed by a tremor-like signal with a duration of 150 seconds that was of low frequency (1.6 Hz).

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)* (see Tungurahua).

Reventador

Ecuador
0.078°S, 77.656°W, summit elev. 3,562 m

This report contains updates from Reventador for July through November 2003. During this time seismicity varied from generally low to occasionally high. Lahars recurred, as rain and drainage systems continued to move tephra left after the eruptions that began on 3 November 2002 (*Bulletin* v. 27, no. 11 and v. 28, nos. 2 and 6). Except for degassing, steam plumes, and the cooling of lava flows, further eruptive behavior (or cessation of activity) was not mentioned.

Activity during July-August 2003. Rainfall at Reventador during 7-13 July caused renewed movement of ash on the volcano's flanks. This led to lahars down the Montana River, and a consequent interruption in highway travel. Tremor associated with degassing was noted, with an increase during the last week of July and early August. Steam plumes were noted on 30 July and 2 August and lahars coincident with tremors were observed on 30 July. Seismicity was moderate, with about five volcano-tectonic (VT) events per day and a total of four tectonic events between 30 July and 3 August. These four events were located between 5.4 and 35 km away. The tectonic earthquake on 3 August registered the highest magnitude, M 3.2.

On 9 August detectors in three locations registered a lahar; this was later confirmed by staff from the Chaco-Santa Rosa station. Seismicity was low between 4 and 10 August, with six local tectonic events. Three of these occurred on 8 August, at varying depths, but all were within 10-12 km of the volcano. The second of these was the largest of any event that week, M 2.9. Seismicity stayed low through the end of the month, with an average of one VT event per day during the last week of August. Small fracture events related to the cooling of lava flows were noted. However, no rains capable of generating lahars were recorded, and there were no reports of steam or gas emissions.

Activity during September-October 2003. Reports were not available for the first three weeks of September and the first two weeks of October. During the week of 22-28 September, two lahar signals were registered, as well as 44 hybrid events, 43 VT events, and seven long-period (LP) events. During the following week, hybrid and LP events dropped to 17 and two events, respectively, but the number of VT events increased considerably, to 78. Lahars lasting ~ 4 hours each were recorded on 30 September and 1 October, following moderate rain on the 30th. During 13-19 October instruments registered 77 VT and 17 LP earthquakes (i.e., averaging 11 VT earthquakes and two LP earthquakes

per day). Lahars were reported on 13, 14, and 19 October. During the following week, seismicity stayed at similar levels. Due to intense rains, more lahars were registered, on 20 and 22 October and again on 28 and 29 October. Traffic was again affected as a route had to be closed. Also between 27 October and 2 November, there was a small increase in the number of volcano-tectonic events.

Activity during November 2003. Seismicity remained constant, averaging 8-9 earthquakes each day. Following strong rains on 7 and 9 November, seismometers detected signals attributed to lahars. After the lahar signals had diminished, tremor was again detected. Lahar signals were also recorded on 11, 12, 14, and 26 November.

Background. Reventador is the most frequently active of a chain of Ecuadorian volcanoes in the Cordillera Real, well E of the principal volcanic axis. The forested stratovolcano rises to 3562 m above the remote jungles of the western Amazon basin. A 4-km-wide caldera widely breached to the E was formed by edifice collapse and is partially filled by a young, unvegetated stratovolcano that rises about 1,300 m above the caldera floor to a height above the caldera rim. Reventador has been the source of numerous lava flows as well as explosive eruptions that were visible from Quito in historical time. Frequent lahars in this region of heavy rainfall have constructed a debris plain on the eastern floor of the caldera. The largest historical eruption at Reventador took place in 2002, producing a 17-km-high eruption column, pyroclastic flows that traveled up to 8 km, and lava flows from summit and flank vents.

Information Contact: *Geophysical Institute (IG)* (see Tungurahua).

Cayambe

Ecuador
0.029°N, 77.986°W; summit elev. 5,790 m

This report largely discusses seismicity at Cayambe during January-October 2003 (figure 1). On the whole, the numbers of daily earthquakes remained fairly constant at low to moderate levels (typically fewer than 25 earthquakes per day). On six days the number of daily earthquakes approached 50 or greater (1 January, 15, 28, 29, and 30 March, and 1 April). Epicenters were concentrated on the SW flank, similar to the pattern in December 2002. During the year, residents did not report feeling earthquakes at Cayambe, but did notice sulfurous odors. Although some seismic signals had an uncertain origin, others were interpreted as related to magma movement.

Observers saw no changes at Cayambe during January, although strong sulfurous odors were reported early in the month. Very low seismicity prevailed, with an average of five earthquakes per day during the second week in January. In general, the earthquakes registered since 2 January 2003 were long-period earthquakes; a few hybrid events and fracture events also were recorded. Some small volcano-tectonic (VT) earthquakes registered. On 31 January, following a week of low to moderate seismicity, two larger earthquakes were recorded: the first under the volcano, M 3.9; the second to the E, M 3.5. Neither earthquake was felt by area residents. Associated, small long-period (LP) earthquakes also registered, although the late-January daily totals were still low to modest. Following this activity, seismicity dropped and generally remained low through February and early March.

On 8 March an M 3.6 earthquake triggered about 2 hours of small VT earthquakes beneath Cayambe's S flanks. Seismicity again dropped to low levels until 14 March when there was a small cluster of shallow VT earthquakes lasting about 1 hour. These events were under M 2, and afterwards seismicity dropped to background levels.

The high for the year occurred during 24-30 March when earthquakes peaked at approximately 335 per day. Clusters of events were noted. Those on 27 March included an M 3.9 earthquake, and those on 29 March included two M 3.6 earthquakes. The events were located at 5-6 km depth below the SW flank. This was the same area in which seismic clusters occurred during December 2002. There were 99 earthquakes counted on 31 March. None larger than M 3, they consisted of up to 95 VT and four hybrid events.

In early April seismicity again dropped to low levels, increasing slightly in the second week of the month. The recorded LP and hybrid events registered were thought likely related to fluid movement inside cracks. Small VT earthquakes were recorded on 13 April; otherwise, seismicity remained low through the rest of the month. The smell of sulfur was noticed during a 14-20 April visit, but no other changes were noted. Seismicity remained low throughout May, with only occasional VT, LP, and hybrid events.

Seismicity increased slightly in early June, but still remained close to background levels. A new signal appeared at the Refugio station, characterized by high frequency at the beginning and a very long coda (tail). Thereafter, activity dropped and remained low for the rest of June.

A series of VT earthquakes occurred during the first week of July; the maximum activity was on 1 July, with 16 events. Nevertheless seismicity remained near background levels, and stayed low until early August. A VT earthquake

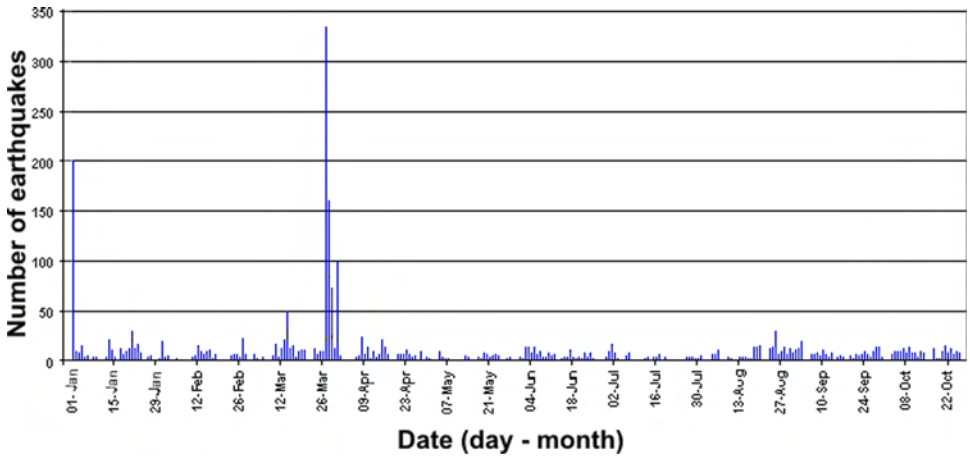

Figure 1. The total number of earthquakes each day at Cayambe between 1 January and 27 October 2003. Courtesy of the Instituto Geofisico–Escuela Politecnica Nacional, Ecuador.

occurred on 4 August beneath the W flank; on 6 August seismicity increased slightly and was characterized by hybrid events. Activity was low through mid-August. A series of VT events related to rock fracturing occurred between 18 and 31 August; the majority occurred on 22 and 25 August, with events reaching M 3.5. These events beneath the SW flank were similar to the spike in activity in March. Activity dropped again during the following month.

For the last week of September, seismicity was still at background levels. A single VT event registered, with a magnitude of 3.2, located beneath the volcano at a depth of 4 km. As with the previous cases, the event was too small to be felt by area residents. Between 13 and 19 October, seismicity generally remained normal, but on 15 October, a small cluster of VT earthquakes occurred S of the crater. On 23 October another small cluster of VT earthquakes (M <3) was recorded beneath the SE flank, in a part of the same zone as the events of the previous week.

Over these weeks the base seismicity level seemed to increase slightly (figure 1). During 3-9 November, about nine earthquakes occurred per day, near the daily average since August 2003 and about twice the daily average of 4/day before that. Seismicity also included small clusters of tectonic earthquakes with magnitudes less than 3. There were reports of a strong scent of sulfur in the vicinity of Picos Jarrína at an elevation of about 5,460 m. The scent was strongest near cracks.

Background. The massive compound Cayambe stratovolcano is located on the isolated western edge of the Cordillera Real, E of the inter-Andean valley. The 5,790-m-high volcano, whose southern flanks lie astride the equator, is capped by glaciers, which descend down to 4,200 m on the eastern Amazonian side. The modern Nevado Cayambe volcano, constructed to the E of an older volcanic complex, contains two summit lava domes located about 1.5 km apart, the westernmost of which is the highest. Several other lava domes on the upper flanks have been the source of pyroclastic flows that reached the flanks of the volcano. A prominent Holocene pyroclastic cone fed thick lava flows that traveled about 10 km to the E. Nevado Cayambe was recently discovered to have produced frequent explosive eruptions during the Holocene, and to have had a single historical eruption, during 1785-86.

Information Contact: *Geophysical Institute (IG)* (see Tungurahua).

Popocatépetl

central México
19.023°N, 98.622°W; summit elev. 5,426 m
All times are local (= UTC - 6 hours)

The Centro Nacional de Prevención de Desastres (CENAPRED) provided daily reports for Popocatépetl describing the comparatively quiet interval of 1 August-5 December 2003. When the volcano was visible it typically gave off minor gas plumes characterized by statements such as "low fumarolic activity" and "without important emissions." The hazard status remained at Yellow–Phase II.

A series of aerial photos enabled scientists to view the state of the crater floor on 21 July, 25 August, 17 October, and 6 November 2003. All of these failed to disclose the growth of an external lava dome. In addition, some of the reports suggested that the floor of the inner crater had subsided.

On the vast majority of days during the reporting interval there were fewer than 10 exhalations, and on ~ 45% of these days, four or fewer exhalations. Although some resulting plumes contained ash, the vast majority of exhalations (which are detected seismically) were described as low intensity. In a few cases, particularly in August and on 1 September, exhalations occurred 20-89 times per day and reached moderate intensity. Daily reports on some of those days cited elevated groundwater levels due to recent snow or rainfall (rather than deeper magmatic processes) as the cause of increased exhalations.

The most exhalations were registered during August 2003, a month when six days had 12 or more exhalations. In contrast, during September-November 2003 there were only four days reported to have had more than 10 exhalations. Exhalations exceeded twenty on 2 August (35), 23 August (60), 28 August (89), and 1 September (43). On days when exhalations exceeded twenty, often (though not always) one or more of the plumes contained small amounts of ash. For example, an ash-bearing plume was noted at 0300 on 2 August. On that day low-amplitude tremor registered for about 1 hour. The 60 exhalations on 23 August were described as small to moderate, generating plumes composed of gas and steam. They were thought to be related to intense rains during the preceding days. The 89 exhalations on 28 August 2003 were similarly described as low to moderate and accompanied by small steam and gas emissions. On 28 August at 1330 an eruption occurred that bore a low density of ash. The plume reached a height of about 1,500 m above the crater; it dispersed towards the W with no reported ashfall. This event was accompanied by episodes of high-frequency and low-amplitude tremor.

Tremor frequently went unreported. When mentioned, CENAPRED said it took place for up to approximately 2 hours per day, but in some cases only several minutes per day. Small (M ~ 2-3) earthquakes were repeatedly noted during the interval, including a few in the last half of August, several in September, two in October, and seven in November. During 1-5 December one such earthquake occurred. During the August-5 December interval the largest earthquake, M 2.9, took place on 5 November 2003.

Several examples can serve to illustrate the reported data on many of these earthquakes, which occurred in vicinity of the volcano at depths of a few kilometers. On 20 August seismometers recorded an M 2 volcano-tectonic earthquake 1 km N of the summit at 4.8 km depth. At 2312 on 7 September there was a M 2.2 volcano-tectonic earthquake 6.5 km SE of the crater. At 2137 on 8 September a M 2.3 volcano-tectonic earthquake 5 km below the crater registered.

Background. Volcán Popocatépetl, whose name is the Aztec word for smoking mountain, towers to 5426 m 70 km SE of Mexico City to form North America's 2nd-highest volcano. The glacier-clad stratovolcano contains a steep-walled, 250-450 m deep crater. The generally symmetrical volcano is modified by the sharp-peaked Ventorrillo on the NW, a remnant of an earlier volcano. At least three previous major cones were destroyed by gravitational failure during the Pleistocene, producing massive debris-avalanche deposits covering broad areas south of the volcano. The modern volcano was constructed to the south of the late-Pleistocene to Holocene El Fraile cone. Three

major plinian eruptions, the most recent of which took place about 800 AD, have occurred from Popocatépetl since the mid Holocene, accompanied by pyroclastic flows and voluminous lahars that swept basins below the volcano. Frequent historical eruptions, first recorded in Aztec codices, have occurred since precolumbian time.

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Colima

western Mexico
19.514°N, 103.62°W, summit elev. 3,850 m

As previously reported (*Bulletin* v. 28, no. 8) a new crater formed at the summit following large explosions in July and August 2003. Smaller ash-bearing eruptions continued during September-December 2003.

On 6 September a strong ash emission resulted in an ash cloud that rose to ~ 6.7 km and drifted N. Ash was not visible on satellite imagery, but a second ash emission on 8 September was visible on the Colima video camera. Into early October, volcanic activity consisted of an average of two explosions per day, producing ash clouds that rose ~ 2 km above the crater and drifted predominately W. Tropical storm Olaf inundated the Colima area on 7 October, dropping 150 mm of rain in less than 2 hours. The heavy rain mixed with material on the S flank, producing a lahar down the Montegrande ravine. On 9 and 10 October ash clouds were visible on satellite imagery rising to a maximum of ~ 5 km above the volcano.

On 16 October ash rose to a height of ~ 6 km; a second plume followed on 18 October, rising to ~ 7.3 km. Neither plume was visible on satellite imagery. Two small eruptions consisting mainly of steam and some ash on 30 October rose to ~ 7.3 km altitude and mainly drifted W.

A subtle ash plume, visible in satellite imagery, was emitted on 18 November and rose to ~ 5.5 km altitude. On 1 and 2 December, ash clouds were visible on satellite imagery at a maximum altitude of ~ 7 km. As of 12 December, the volcano continued with an average of three explosions a day, usually to 2 to 3 km above the crater. The majority of these explosions have produced ash that drifted toward the ENE. The most significant of these early December explosions occurred early on 11 December, when materials descended the SE, NE, and N flanks, and ashfall was reported in the town of Guzman (25 km NE of Colima volcano).

Background. The Colima volcanic complex is the most prominent volcanic center of the western Trans-Mexican Volcanic Belt. It consists of two southward-younging volcanoes, Nevado de Colima (the 4,320-m-high point of the complex) on the north and the historically active Volcán de Colima at the south. A group of cinder cones of probable late-Pleistocene age is located on the floor of the Colima graben west and east of the Colima Complex. Volcán de Colima (also known as Volcán Fuego) is a youthful stratovolcano constructed within a 5-km-wide caldera, breached to the south, that has been the source of large debris avalanches. Slope failure has occurred repetitively from both the Nevado and Fuego cones, and has produced a thick apron of debris-avalanche deposits on three sides of the complex. Frequent historical eruptions from Colima's summit crater have produced vertical pyroclastic columns, pyroclastic flows, and lava flows.

Information Contact: *Observatorio Vulcanológico de la Universidad de Colima*, Colima, Col., 28045, México (Email: vzobin@cgic.ucol.mx, tonatiuh@cgic.ucol.mx; URL: http://www.ucol.mx/volcan/); *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/)

Kilauea

Hawaii, USA
19.425°N, 155.292°W; summit elev. 1,222 m

Through September and into early October, lava was moving along the E and W sides of the Mother's Day flow. The E-side lava (known as the 9 August breakout) came from the 9 August rootless shield (see figure 2 in *Bulletin* v. 28, no. 9), itself fed by the main Mother's Day tube from Pu`u `O`o. The W side lava, known as the Kohola arm of the Mother's Day flow, branched off the tube system below the rootless shield. In early October the 9 August breakout stopped, the Kohola died back to a trickle, and the rootless shield gained prominence. By 16 October, however, the shield had partly collapsed, leaving several drained perched ponds behind. Upstream from the shield, many hornitos and small flows formed over the Mother's Day tube.

During 1-7 October, surface lava flows were sometimes visible on Kilauea's coastal flat and upslope areas. On 2 October lava began to flow W after filling West Gap Pit on the W flank of Pu`u `O`o cone. Fairly vigorous spattering was visible in the pit, but died to only sporadic bursts later in the day. The flow appeared to have stopped by 4 October when no glow was observed coming from the pit. During 8 October-17 November, a few areas of surface lava were visible upslope of Kilauea's coastal flat. On 5 November, two small breakouts occurred. The freshly escaping lava was seen on the Kohola arm of the Mother's Day flow just below the top of Pulama pali. Observers watching a 30-40-m-diameter crater on the SW side of Pu`u `O`o noted a new lava pond, a new lava flow, and a fuming cone-pit. Visits to active flow fields on 7 November resulted in observations of hornitos, a 200-m-wide rootless shield, and the leading edge of a 45-m-wide flow.

Seismicity at the summit continued at moderate levels, with 1-2 small low-frequency earthquakes per minute occurring at shallow depths beneath the summit caldera during October and November 2003. Volcanic tremor at Pu`u `O`o remained moderate to high, as is the norm. There were some larger earthquakes at depths of a few kilometers.

Also, there were small inflation and deflation events during this period. Tiltmeters on the NW side of Kilauea's caldera rim (Uwekahuna) and on the NW flank of the active vent along the East rift zone (Pu`u `O`o cone) showed several microradians of radial tilt during 5-11 November, but the patterns were complex and plagued by instrument problems. During 12-17 November, small amounts of inflation and deflation occurred, including inflation on 17 November that started when the surface waves from a M 7.5 earthquake at Rat Island in the Aleutians reached Kilauea. The inflation was small, ~ 0.5 µrad at Pu`u `O`o tilt station and 0.3 µrad at Uwekahuna station. Small amounts of inflation and deflation were recorded through the week of 19-25 November with sharp deflation beginning at both Uwekahuna and Pu`u O`o early on the morning of 25 November.

Moderate, shallow seismicity was recorded beneath the summit, and moderate to high seismicity occurred beneath Pu`u O`o. The seismic record at Kilauea's summit during 15-16 December was nearly devoid of earthquakes, though the background is steady weak tremor. Tremor at Pu`u `O`o was continuously at a moderate level. Otherwise, seismicity at Kilauea was at a low level during this period.

Background. Kilauea volcano, which overlaps the east flank of the massive Mauna Loa shield volcano, has been Hawaii's most active volcano during historical time. Eruptions of Kilauea are prominent in Polynesian legends; written documentation extending back to only 1820 records frequent summit and flank lava flow eruptions that were interspersed with periods of long-term lava lake activity that lasted until 1924 at Halemaumau crater, within the summit caldera. The 3 x 5 km caldera was formed in several stages about 1500 years ago and during the 18th century; eruptions have also originated from the lengthy East and SW rift zones, which extend to the sea on both sides of the volcano. About 90% of the surface of Kilauea is formed of lava flows less than about 1100 years old; 70% of the volcano's surface is younger than 600 years. A long-term eruption from the East rift zone that began in 1983 has produced lava flows covering more than 100 sq km, destroying nearly 200 houses and adding new coastline to the island.

Information Contact: *Hawaiian Volcano Observatory (HVO)*, U.S. Geological Survey, Hawaii Volcanoes National Park, P.O. Box 51, Hilo, HI 96718, USA (URL: http://hvo.wr.usgs.gov/; Email: hvo-info@hvo-mail.wr.usgs.gov).

Kliuchevskoi

Kamchatka Peninsula, Russia
56.06°N, 160.64°E; summit elev. 4,835 m

Significant activity from Kliuchevskoi continued throughout 1 August to 5 December 2003, so the hazard status remained at Color Code Orange. Activity included ash explosions that generated long plumes, Strombolian activity in the central crater, thermal anomalies seen in satellite imagery, relatively strong shallow seismicity, and continuous spasmodic tremor. Kamchatka Volcanic Eruptions Response Team (KVERT) reports obtained via the Alaska Volcano Observatory (AVO) provided detailed reports of significant daily activity that is summarized below.

Gas-and-steam plumes, sometimes with ash, were frequently seen rising above the crater to heights of less than 1,500 m. However, on some days plumes were seen rising as high as 2,500-3,000 m. Most of the plumes dissipated after reaching distances described as greater than 10 or 20 km downwind. Satellite imagery showed that on 8-9 September ash-and-gas plumes extended 172 km to SW and 153 km to W. Long ash plumes to distances of 18-63 km SE were seen on 4 October. During mid-October (12, 16, 17, and 18) gas-and-steam plumes reached distances of 25-70 km in many directions. On 24 October an airline pilot reported an ash plume at ~ 6,800 m altitude extending to the NNE. A gas-and-steam plume approximately 50-55 km long extending to the ESE was noted on 10 November, and another with minor ash extended ~ 40 km E on the 16th.

Strombolian activity at the central crater was detected on 26 August, when volcanic bombs rose up to 200 m above the crater and explosions occurred at intervals of about 5 minutes. More Strombolian activity was seen by observers in Klyuchi and Kozyrevsk on 25 and 30 September, 2-4, 6-8, and 10-11 October, and 9-10, 14-15, 21, 27, and 29 November. Thermal anomalies were detected every week by USA and Russian satellites, sometimes as large as 8-9 pixels.

Recorded earthquakes at 30-km depth usually ranged up to 9/day through early November, with up to 18/day the week of 1-7 August, and 30 on 3 October; magnitudes were 1.6-2.6. Continuous spasmodic tremor had geophone velocities below 8 x 10^{-6} m/s until 4 October, when velocities increased into the 8-20 x 10^{-6} m/s range. Geophone velocities dropped again to 5-11 x 10^{-6} m/s during 22 November-2 December, then rose to 18 x 10^{-6} m/s through 5 December. Large shallow seismic events (M 1.7-2.6) were first reported during the week of 11-17 October. Nine such events that week were followed by totals of 4, 22, 48, and 43 per week over the next month. Counts increased to 75 for the week of 15-21 November, 80 during 22-28 November, and 130 for the week ending on 5 December. Large numbers of weak shallow earthquakes (counts not reported) were also recorded every week.

Background. Kliuchevskoi is Kamchatka's highest and most active volcano. Since its origin about 6,000 years ago, the beautifully symmetrical, 4,835-m-high basaltic stratovolcano has produced frequent moderate-volume explosive and effusive eruptions without major periods of inactivity. Kliuchevskoi flanks Kamen volcano to the SW and Ushkovsky volcano to the NW. More than 100 flank eruptions have occurred during the past roughly 3,000 years, with most lateral craters and cones occurring along radial fissures between the unconfined NE-to-SE flanks of the conical volcano between 500 m and 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), a cooperative program of the Institute of Volcanic Geology and Geochemistry, Far East Division, Russian Academy of Sciences, Piip Ave. 9, Petropavlovsk-Kamchatskii 683006, Russia (Email: girina@kcs.iks.ru), the Kamchatka Experimental and Methodical Seismological Department (KEMSD), GS RAS (Russia), and the Alaska Volcano Observatory (USA); *Alaska Volcano Observatory (AVO)*, a

cooperative program of the U.S. Geological Survey, 4200 University Drive, Anchorage, AK 99508-4667, USA (URL: http://www.avo.alaska.edu/; Email: tlmurray@usgs.gov), the Geophysical Institute, University of Alaska, P.O. Box 757320, Fairbanks, AK 99775-7320, USA (Email: eisch@dino.gi.alaska.edu), and the Alaska Division of Geological and Geophysical Surveys, 794 University Ave., Suite 200, Fairbanks, AK 99709, USA (Email: cnye@giseis.alaska.edu).

Karymsky

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

From late August through 5 December seismic activity at Karymsky was above background levels (100-230 events per week) and intermittent explosions continued. The Level of Concern Color Code was Yellow through most of September and October, with a week at the higher Orange status during 3-10 October. The color code was raised to Orange again on 31 October and remained at that level through 5 December. Thermal anomalies identified in satellite data were usually 1-4 pixels in size, with a maximum of 6 pixels on 30 August, and 10, 11, 14, and 16 October. However, the weather was frequently cloudy after 12 September, obscuring observations.

Ash explosions rising up to 4.0 and 4.7 km were observed from aircraft on 29 August. About 2 hours of continuous spasmodic tremor (6.0×10^{-6} m/s) on 30 August, followed by the detection of a thermal anomaly (6 pixels) less than an hour later, may have been caused by a pyroclastic flow.

On 9 and 10 September, continuous high-frequency spasmodic tremor and a series of shallow seismic events indicated possible ash-and-gas explosions to heights of 1.5-2.0 km above the volcano. A gas-and-steam plume extending 100 km E was noted on 9 September. On 14 September an ash-and-gas plume was seen rising 500 m above the crater. On 23 September there was an explosive ash plume up to 5 km altitude according to visual data from the Institute of Volcanology.

The number of shallow seismic events increased during 4-24 October to weekly highs of 350; these events indicated possible ash-and-gas explosions to heights of 1-1.5 km. Ash plumes extending 60 and 30 km SE and NE were observed on 4 and 7 October, respectively. An extensive gas-and-steam plume extending 85 km SE was noted on 10 October. Continuous high-frequency spasmodic tremor detected for almost an hour on 10 October probably indicated pyroclastic flows. Ash plumes extending 45-50 km NW were observed on 16 October. On 31 October, a possible plume extending ~ 65 km NNE was observed in a satellite image. Gas-and-steam plumes with possible minor ash ~ 40-60 km long were detected on 20, 21, 24, and 26 November; clouds obscured the volcano on other days.

Background. Karymsky, the most active volcano of Kamchatka's eastern volcanic zone, is a symmetrical stratovolcano constructed within a 5-km-wide caldera that formed during the early Holocene. The caldera cuts the south side of the Pleistocene Dvor volcano and is located outside the north margin of the large mid-Pleistocene Polovinka caldera, which contains the smaller Akademia Nauk and Odnoboky calderas. Most seismicity preceding Karymsky eruptions originated beneath Akademia Nauk caldera, which is located immediately south of Karymsky volcano. The caldera enclosing Karymsky volcano formed about 7,600-7,700 radiocarbon years ago; construction of the Karymsky stratovolcano began about 2,000 years later. The latest eruptive period began about 500 years ago, following a 2300-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) (see Kliuchevskoi); *Alaska Volcano Observatory (AVO)* (see Kliuchevskoi).

Alaid

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

From 8 November through mid-December 2003 the hazard status of Alaid remained at Yellow. Weak seismic activity has remained slightly above background levels since 31 October. The volcano was also obscured by clouds during this period. Continuous spasmodic volcanic tremor was recorded ($0.15\text{-}3.4 \times 10^{-6}$ m/s), and a large number of weak local events were registered, during each week. The report for the week of 12-19 December indicated that seismologists have now decided that the tremor is probably not of volcanic origin, but has probably been a result of strong winds. The Level of Concern Color Code was lowered to Green on 19 December 2003.

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.

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

Asama

Honshu, Japan
36.403°N, 138.526°E; summit elev. 2, 568 m

Asama has been seismically active since 18 September 2000. Heightened seismicity occurred in June 2002, when the daily number of volcanic earthquakes exceeded 300 (*Bulletin* v. 27, no. 6). The Asama Volcano Observatory (ERI, University of Tokyo) and Japan Meteorological

Agency (JMA) reported a new episode of elevated seismicity during 18-19 September 2002 (*Bulletin* v. 28, no. 4). According to JMA there were brief ash eruptions on 6 February, 30 March, 7 April, and 18 April 2003 to heights of 200-300 m above the crater with minor ashfall around the summit (*Bulletin* v. 28, no. 4).

Seismic data and plume observations compiled from JMA reports for September 2000 through April 2003 (table 1) reflect this recent activity. White plumes were reported from the Kama-yama crater during every month in this period, with the addition of grayish white plumes on 6 February, 7 April, and 18 April. These white plumes only rose to 1 km or above in April and May 2001, and June and August 2002. In addition, short isolated episodes of volcanic tremor were recorded in October 2001, February 2003, and March 2003. However, 12 episodes occurred in April 2003, with five on the 29th.

Month	Number of volcanic earthquakes		Plume Height (m) (date)	Plume Color
	Total	Maximum (date)		
Jan 2000	5	1 (4, 5, 9, 14, 18)	300 (25, 26, 28)	W
Feb 2000	3	2 (26)	300 (10)	W
Mar 2000	8	3 (29)	300 (1, 10)	W
Apr 2000	75	27 (17)	400 (17)	W
May 2000	10	2 (19, 27)	500 (5, 30)	W
Jun 2000	26	6 (4)	300 (4, 5, 15)	W
Jul 2000	13	3 (11, 29)	300 (9)	W
Aug 2000	20	3 (5)	200 (2, 21, 26)	W
Sep 2000	419	149 (19)	500 (21)	W
Oct 2000	79	27 (31)	400 (19)	W
Nov 2000	322	34 (25)	300 (4, 6, 23, 27)	W
Dec 2000	234	18 (4, 6)	500 (27)	W
Jan 2001	41	7 (2)	700 (30)	W
Feb 2001	128	46 (19)	500 (15)	W
Mar 2001	162	29 (24)	800 (12, 21, 24)	W
Apr 2001	182	41 (10)	1000 (28)	W
May 2001	20	3 (3, 36)	1200 (17)	W
Jun 2001	11	2 (6, 7)	800 (3)	W
Jul 2001	115	24 (13)	600 (5)	W
Aug 2001	36	5 (18)	400 (13, 28, 29)	W
Sep 2001	99	14 (23)	500 (24, 25)	W
Oct 2001	113	12 (29)	700 (27)	W
Nov 2001	144	13 (9)	600 (11)	W
Dec 2001	80	7 (4)	200 (many)	W
Jan 2002	150	11 (15)	300 (6, 24)	W
Feb 2002	57	5 (many)	400 (24)	W
Mar 2002	No JMA report received this month			
Apr 2002	979	103 (9)	600 (29)	W
May 2002	953	49 (9)	700 (28)	W
Jun 2002	1434	360 (22)	1000 (2, 24)	W
Jul 2002	1499	119 (9)	500 (many)	W
Aug 2002	1464	176 (9)	1500 (6)	W
Sep 2002	1358	243 (18)	600 (19)	W
Oct 2002	837	40 (6)	700 (12)	W
Nov 2002	630	40 (11)	400 (6)	W
Dec 2002	601	58 (22)	300 (23, 26)	W
Jan 2003	775	42 (20)	500 (20, 30)	W
Feb 2003	594	43 (3)	500 (19)	W, GW (6)
Mar 2003	614	41 (15)	300 (20, 30)	W
Apr 2003	458	31 (18)	400 (22)	W, GW (7, 18)

Table 1. Summary of seismicity and plume observations at Asama, January 2000-April 2003. All reported plumes originated from the Kama-yama crater, and were described as either white (W) or grayish white (GW). Data courtesy of JMA.

Background. Asama, Honshu's most active volcano, overlooks the resort town of Karuizawa, 140 km NW of Tokyo. The volcano is located at the junction of the Izu-Marianas and NE Japan volcanic arcs. The modern cone of Maekake-yama forms the summit of the volcano and is situated east of the horseshoe-shaped remnant of an older andesitic volcano, Kurofu-yama, which was destroyed by a late-Pleistocene landslide about 20,000 years before present (BP). Growth of a dacitic and rhyolitic lava cone was accompanied by pumiceous pyroclastic flows, the largest of which occurred about 14,000-11,000 years BP, and by growth of the Ko-Asama-yama lava dome on the east flank. Maekake-yama is probably only a few thousand years old and has an historical record dating back at least to the 11th century AD. It has had several major plinian eruptions, the last two of which occurred in 1108 and 1783 AD.

Information Contact: *Volcanological Division*, Japan Meteorological Agency (JMA), 1-3-4 Ote-machi, Chiyoda-ku, Tokyo 100, Japan (URL: http://www.kishou.go.jp/).

On-take

Honshu, Japan
35.890°N, 137.48°E
summit elev. 3,063 m

Seismic activity at On-take has been ongoing in recent years. Data provided by the Japan Meteorological Agency indicates that from January 2000 through April 2003 an average of 140 volcanic earthquakes per month were recorded by the local seismic station. The number usually ranged between 90 and 200 each month. Activity was higher in July 2001 (300 total events, with 65 on the 1st) and December 2002 (206 total events, with 63 on the 4th). No volcanic tremor was registered. White plumes rising no higher than 300 m were observed once in June 2000 and March 2001, and more frequently during November 2001-January 2002. Small white plumes were seen once per month in September-November 2002 and January-March 2003.

Background. The massive On-take stratovolcano, the second highest volcano in Japan, lies at the southern end of the Northern Japan Alps. On-take is con-

structed within a largely buried 4 x 5 km caldera and occupies the southern end of the Norikura volcanic zone, which extends northward through Norikura volcano to Yake-dake volcano. The broad, elongated summit is cut by a series of small explosion craters along a NNE-trending line. On-take's first historical eruption in 1979 followed a lengthy period of quiescence. A non-eruptive landslide in 1984 produced a debris avalanche and lahar that swept down valleys south and east of the volcano. Ascent of the 3063-m-high On-take is one of the major objects of religious pilgrimage in central Japan.

Information Contacts: *Volcanological Division*, Japan Meteorological Agency (JMA) (see Asama).

Karangetang

Sangihe Islands, Indonesia
2.78°N, 125.48°E; summit elev. 1,748 m

White gas emissions and glow were reported at Karangetang during October 2003 (*Bulletin* v. 28, no. 10). The Volcanological Survey of Indonesia (VSI) reported continuing activity over the period 26 October-30 November, with white gas plumes rising 350-400 m above the S crater rim and 50-150 m above the N crater. On 28 October an ash explosion produced a 2,000-m-high column with ashfall reaching the sea to the E and a lava avalanche toward the Batu Awang area, 750 m from the summit. Except for the week of 17-23 November, local seismicity decreased compared to the first half of October (table 2). The hazard status remained at Alert Level 2 (on a scale of 1-4).

Background. Karangetang (Api Siau) volcano lies at the northern end of the island of Siau, north of Sulawesi. The 1,784-m-high stratovolcano contains five summit craters 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/).

Date (2003)	Deep Volcanic	Shallow Volcanic	Multiphase	Emission	Tectonic
27 Oct-02 Nov	18	64	10	24	43
03 Nov-09 Nov	9	96	7	12	53
10 Nov-16 Nov	3	52	10	23	106
17 Nov-23 Nov	25	135	16	42	47
24 Nov-30 Nov	15	79	34	29	130

Table 2. Seismicity at Karangetang during 27 October-30 November 2003 One explosion and one avalanche also occurred during the week of 27 October-2 November. Courtesy of VSI.

Dukono

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

Ash explosions during 29 September-19 October rose 50-100 m above the crater. Some of the explosions were accompanied by blasting sounds, and ash fell to the E around the Tobelo area. White-gray ash eruptions continued during 27 October-30 November accompanied by booming sounds, a 100-m-high gray ash column, and more ashfall in the Tobelo area. The hazard status remained at Alert Level 2 (on a scale of 1-4) throughout this period.

The monitoring effort by the Volcanological Survey of Indonesia has been affected by the civil unrest on Halmahera. By 19 November the Dukono observatory had been completely destroyed by the recent "riots," with no idea when it might be rebuilt. Officially there is no longer a VSI officer there, but sometimes two staff check on the volcano. On 18 November they called Bandung with news that activity had increased, with larger, more frequent eruptions (every 5-15 minutes) generating higher plumes. Over the few weeks prior to 18 November eruptive activity has been tending towards bigger explosions, sometimes producing pyroclastic falls and lava flows down to the beach.

Ash plumes from Dukono have been identified in satellite imagery by the Darwin Volcanic Ash Advisory Centre almost every week since early June 2003. Plumes were usually reported rising to altitudes of 3-4.5 km and extending downwind 45-75 km from the summit. Longer plumes to distances of 80-130 km were reported after 18 August. Distinct visual plumes reaching distances of over 200 km were seen in November (figure 2), with a maximum of ~ 300 km during 12-18 November. Aviation notices continued to be issued through December, warning of almost continuous activity and plumes extending ~ 90 km from the volcano.

Paul Taylor provided the following account from Baptist missionary Charles W. Cole. He also noted that the Tobelo "o dukono" just means "(the) volcano," but that the word is now used as a proper name for the volcano on Halmahera. On 16 November 2003 Cole wrote: "The situation in Tobelo continues to be on edge as unknown parties continue to explode bombs. After the distribution of the food packets in Ternate, Kenneth and Oky accompanied the Tobelo pastors on a seven hour ride in a small van to Tobelo. When they arrived in Tobelo it looked like it had just snowed. The ground and all the buildings were covered with white ash. This past week it has rumbled and put out large clouds of white ash. Entire villages and neighborhoods have been destroyed (not by ash)."

Background. Reports from this remote volcano in northernmost Halmahera are rare, but Dukono has been one of Indonesia's most active volcanoes. 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

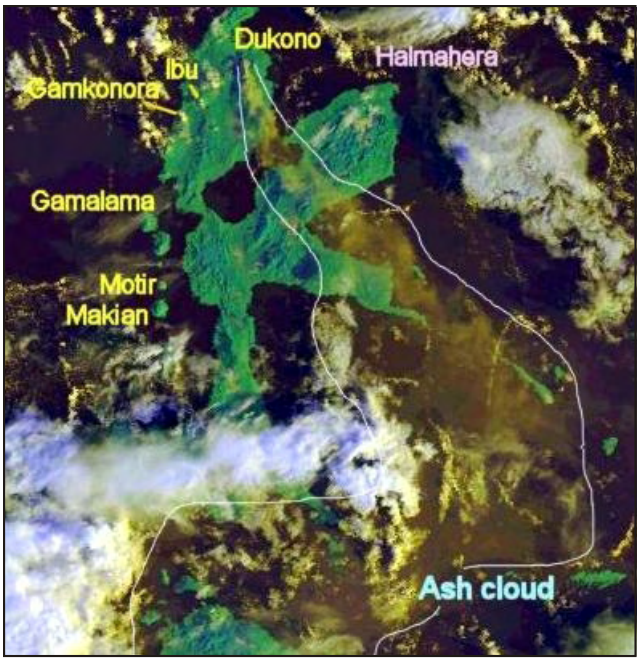

Figure 2. Satellite image showing an ash plume extending S and SE from Dukono on 17 November 2003. The volcano is located below the "D" in Dukono, and the approximate extent of the ash cloud has been outlined. Courtesy of Darwin VAAC.

north-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 Contacts: *Dali Ahmad*, *Hetty Triastuty*, *Nia Haerani*, and *Suswati*, Volcanological Survey of Indonesia (VSI) (see Karangetang); *Charles W. Cole*, Jakarta, Indonesia (Email: cbcole@emailworld.biz); *Paul W. Taylor*, Australian Volcanological Investigations, PO Box 291, Pymble, NSW 2073, Australia (Email: avitaylor@mpx.com.au); *Andrew Tupper*, Darwin Volcanic Ash Advisory Centre (VAAC), Commonwealth Bureau of Meteorology, Northern Territory Regional Office, PO Box 40050, Casuarina, NT 0811, Australia (URL: http://www.bom.gov.au/info/vaac/; Email: darwin.vaac@bom.gov.au).

Soputan

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

Seismic activity recorded at Soputan during November was dominated by avalanche earthquakes (table 3). Frequent ash explosions occurred during July and on 31 August, when a lava flow was also seen (*Bulletin* v. 28, no. 8). Only a white gas plume reaching heights of 25-50 m was observed during 27 October-30 November. The hazard status of the volcano remained at Alert Level 2 (on a scale of 1-4).

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 1,784 m and is located SW of Sempu volcano.

Date (2003)	Avalanche Earthquakes	Tectonic Earthquakes
27 Oct-02 Nov	51	5
03 Nov-09 Nov	35	18
10 Nov-16 Nov	24	17
17 Nov-23 Nov	37	7
24 Nov-30 Nov	66	10

Table 3. Seismicity at Soputan, 27 October-30 November 2003. Courtesy of VSI.

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).

Manam

Papua New Guinea
4.10°S, 145.061°E; summit elev. 1,807 m

Activity at Manam remained low during 10 November-14 December 2003. Occasional emissions of weak to moderate gray-brown ash clouds continued from Main Crater, at a lower level compared to late October-early November. An explosion on 11 November produced an ash plume that rose slowly to ~ 400 m above the summit crater, causing ashfall to the E. Occasional low rumbling and weak roaring noises were heard on 12 and 28-30 November. No night-time glow was observed during November. A forceful gas emission on 5 December sent an ash column ~ 500 m above Main Crater, and a steady glow was observed on the night of 10 December. Southern Crater gently released weak thin white vapor gently throughout the period. Small low-frequency volcanic earthquakes continued, with a slight increase in seismicity characterized by sub-continuous volcanic tremors after 1 December.

Background. The 10-km-wide island of Manam, lying 13 km off the northern coast of Papua New Guinea, is one of the country's most active volcanoes. Four large radial valleys extend from the unvegetated summit of the conical 1807-m-high stratovolcano to its lower flanks. These "avalanche valleys," regularly spaced 90 degrees apart, channel lava flows and pyroclastic avalanches that have sometimes reached the coast. Five small satellitic centers are located near the island's shoreline on the northern, southern and western sides. Two summit craters are present; both are active, although most historical eruptions have originated from the southern crater, concentrating eruptive products during the past century into the SE avalanche valley. Frequent historical eruptions have been recorded at Manam since 1616. A major eruption in 1919 produced pyroclastic flows that reached the coast, and in 1957-58 pyroclastic flows descended all four radial valleys. Lava flows reached the sea in 1946-47 and 1958.

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Ulawun

New Britain, Papua New Guinea
5.05°S, 151.33°E; summit elev. 2,334 m

The Darwin Volcanic Ash Advisory Centre reported that an ash plume from Ulawun was visible on satellite imagery on 22 September at an altitude of ~ 3.7 km extending NW. On 5 October a faint ash plume was identified on satellite imagery at ~ 4.3 km altitude, extending 55 km WSW of the summit. Another ash plume was seen reaching ~ 75 km WNW of the summit on satellite imagery on 10 October at an altitude around 3 km.

According to the Rabaul Volcano Observatory, the main summit crater at Ulawun released weak to moderate volumes of white-gray vapor emissions over the period 6 November-22 December 2003. The two north valley vents were quiet, with no emissions observed. The seismograph, restored on 31 October 2003; showed seismicity was low throughout this period, with small low frequency volcanic earthquakes and some high frequency volcano-tectonic events. The electronic tiltmeter, restored at the same time; recorded no significant changes.

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

Information Contact: *Ima Itikarai*, Rabaul Volcano Observatory (RVO) (see Manam); *Darwin Volcanic Ash Advisory Centre (VAAC)* (see Dukono).

Rabaul

New Britain, Papua New Guinea
4.271°S, 152.203°E; summit elev. 688 m

Emissions of light to pale ash clouds from Tavurvur characterized activity during November 2003. Between 10 and 20 November the ash emissions occurred frequently at irregular intervals. During 20-24 November Tavurvur produced only a handful of emissions at very long intervals, but after 24 November the emissions became frequent. Occasional moderate explosions through 14 December produced thick ash plumes that rose 1-2.5 km above the summit. Incandescent lava fragments from some explosions were visible at night and occasional roaring and rumbling noises were heard. After 16 November winds were consistently from the SE, blowing ash plumes N and NW. Ashfall resulted in downwind areas, including Rabaul Town and villages on Tavui Peninsula, Malagura and Matupit; accumulation was heaviest in the area of Rabaul Town. Fine ashfall also occurred to the W, SW, S, and SE.

Seismicity has been low, with some high-frequency earthquakes from the NE. Ground deformation in November remained low. The real-time GPS and electronic tilt site on Matupit Island, in the center of the caldera, continued to indicate a slow gradual uplift. This uplift is part of the long-term trend reported earlier (*Bulletin* v. 28, no. 3).

Background. The low-lying Rabaul caldera on the tip of the Gazelle Peninsula at NE end of New Britain forms a broad sheltered harbor utilized by what was the island's largest city prior to a major eruption in 1994. The outer flanks of the 688-m-high asymmetrical pyroclastic shield volcano are formed by thick pyroclastic-flow deposits. The 8 x 14 km caldera is widely breached on the east, where its floor is flooded by Blanche Bay. Two major Holocene caldera-forming eruptions at Rabaul took place about 7100 and 1400 years ago. Three small stratovolcanoes lie outside the northern and NE caldera rims. Post-caldera eruptions built basaltic-to-dacitic pyroclastic cones on the caldera floor near the NE and western caldera walls. Several of these, including Vulcan cone, which was formed during a large eruption in 1878, have produced major explosive activity during historical time. A powerful explosive eruption in 1994 occurred simultaneously from Vulcan and Tavurvur volcanoes and forced the temporary abandonment of Rabaul city.

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

Monowai Seamount

Kermadec Islands, Southern Pacific Ocean
25.888°S, 177.188°W; summit elev. -100 m (submarine)

Monowai is a frequently active submarine volcano that has had volcanic earthquake swarms recorded in May 2002 (*Bulletin* v. 27, no. 5), November 2002 (*Bulletin* v. 28, no. 2), and April-May 2003 (*Bulletin* v. 28, no. 5). Monowai exhibited increased activity for the first 11 months of 2003, during which more than 1,300 events were detected and located by the French Polynesian seismic network via hydro-acoustic waves (also called T-waves) generated by this submarine volcano. Each volcanic eruption, creating explosions and boiling water, generates hydro-acoustic waves that are able to propagate several thousands of kilometers through the ocean in a wave guide (a low velocity zone located at ~ 1,000 m depth called the SOFAR–Sound Fixing and Ranging–channel). Consequently, a major part of the volcanic activity can be monitored at great distances in the oceans (> 3,000 km) using the T-waves. The amplitudes of T-waves correlate with the strength or intensity of the eruptions.

Activity at Monowai during 2003 has been much greater than in 2002. From April through November 2003, 11 swarms have been detected (figure 3); about one swarm was detected every two weeks except in the months of June and September, when no T-waves were detected from Monowai. A volcanic swarm started suddenly on 10 April 2003 with an average rate of about 50-60 events per day

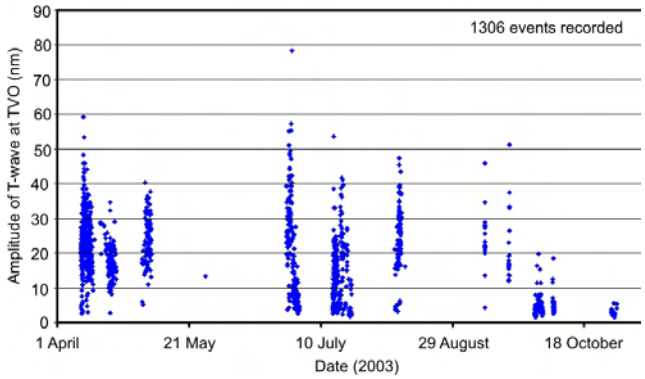

Figure 3. Amplitudes of T-waves from Monowai recorded at the TVO station on Tahiti during 1 April through early November 2003. Courtesy of Laboratoire de Geophysique, Tahiti.

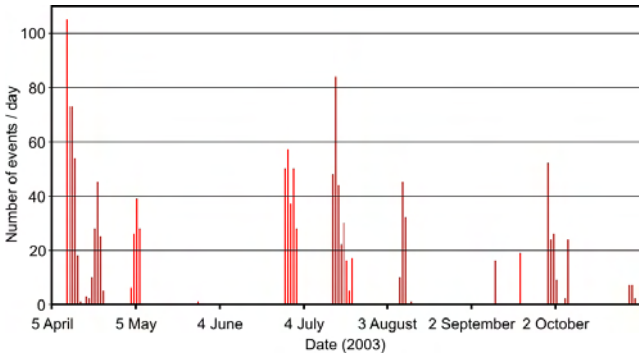

Figure 4. Number of daily seismic events at Monowai recorded by the Polynesian seismic network, RSP (Réseau Sismique Polynésien) during 5 April through early November 2003. These numbers are probably largely underestimated. Courtesy of Laboratoire de Geophysique, Tahiti.

(figure 4). The activity seemed to decrease smoothly in 2003 compared to abrupt halts in activity in 2002.

The observed swarms are composed of a lot of events over at least 30 minutes containing many tens of signals, producing a quasi-continuous and fluctuating noise. However, these types of signals are detected across the entire seismic network. If a particular wave (a maximum amplitude, or the beginning of a wave) visible in all the seismic records is selected, it is possible to locate the source by the inversion of the travel time. Sometimes strong amplitudes are recorded that can be correlated with the strength of the volcanic explosion.

Background. Monowai seamount, also known as Orion seamount, rises to within 100 m of the sea surface about halfway between the Kermadec and Tonga island groups. The volcano lies at the southern end of the Tonga Ridge and is slightly offset from the Kermadec volcanoes. Small parasitic cones occur on the north and west flanks of the submarine volcano, which rises from a depth of about 1,500 m and was named for one of the New Zealand Navy bathymetric survey ships that documented its morphology. Numerous eruptions have been detected from submarine acoustic signals since it was first recognized as a volcano in 1977. A shoal that had been reported in 1944 may have been a pumice raft or water disturbance due to degassing. Surface observations have included water discoloration, vigorous gas bubbling, and areas of upwelling water, sometimes accompanied by rumbling noises.

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