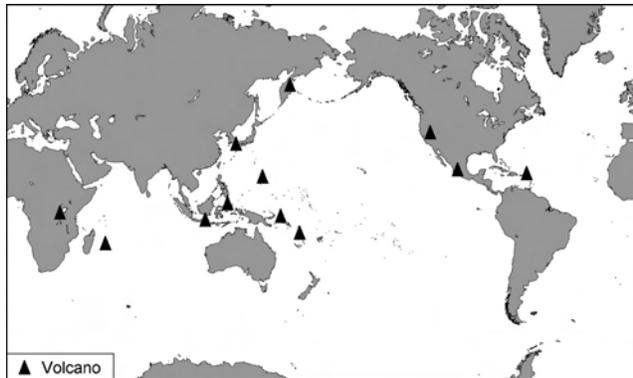


Bulletin of the Global Volcanism Network

Volume 29, Number 5, May 2004



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Awu

Sangihe Islands, Indonesia
 3.67°N, 125.50°E; summit elev. 1,320 m
 All times are local (= UTC + 8 hours)

A dome-extruding eruption occurred in the previously lake-bearing summit crater of Mount (Gunung) Awu, a stratovolcano in Northern Indonesia off the N end of the island of Sulawesi (Celebes). Details of the eruption are still emerging, but an early dome had clearly extruded by 2 June 2004 (figure 1).



Figure 1. A close up of Awu's new dome as it appeared amid loose tephra and through a steam-laden atmosphere on 2 June 2004, soon after emplacement began. Courtesy Penduduk.

Prior to the eruption the crater contained a green lake. Before 1992, water volume was $35,000 \times 10^3 \text{ m}^3$, but it decreased continuously, and in 2003, only $50 \times 10^3 \text{ m}^3$ remained. Research carried out in 1993-1995 attributed the water loss to active faulting beneath the crater. Water inside the crater was of great concern because of its potential to produce lahars that could threaten settlements around Awu. Prior to the eruption, thick vegetation covered the crater's inner and outer rims.

Awu's previous eruption took place 12 August 1966. It took 39 lives, injured more than 1,000, and forced ~11,000 evacuations.

Signs of Awu threatening to erupt became clear mid-May 2004. They included a 15 May (felt, I MMI) tectonic earthquake, followed by two volcanic earthquakes. On 16 May, there were 12 volcanic earthquakes recorded, events interpreted as a signs of fluid moving up, and supported by the appearance of tremor with peak-to-peak amplitude of 8 mm. A gas plume rose 75 m above the crater's rim. On 17 May there were 4 volcanic earthquakes; peak-to-peak tremor amplitudes had dropped to 5 mm. This pattern continued through 18 May, with the number of volcanic earthquakes typically standing at ~6 and tremor amplitudes at 5 mm. The S minus P (S - P) times dropped from 2.0-1.75 sec to 0.5 sec, suggesting a shallower earthquake source, a possible indication of stress moving towards the surface.

In addition to the above observations, VSI scientists regarded the shortest historical repose time at Awu volcano as 25 years, an interval that had passed since the last

eruption, and this became an additional reason for raising the alert level on 18 May.

Figure 1, a photo from the VSI website shows a close-up of a dome on 2 June 2004 with intense steam escaping, indicating that at least portions of a dome had emerged by that time. In figure 1, the dome and surrounding tephra predominantly appear as gray, darker-colored spines and angular blocks and fragments, but occasional clasts of large white fragments, presumably pumice, lie sprinkled across the surface.

Seismicity increased on 4-5 June during 2330-0130 when more than 30 shallow volcanic (Type A) earthquakes occurred. In contrast, typical May seismicity only included one earthquake per day. On 5 June during 1000-1300, instruments recorded 85 earthquakes. On 6 June during 0200-0430, they recorded 50; and during 0900-1010, they recorded 2-3 earthquakes per minute. Tremor followed, with maximum peak-to-peak amplitude of 24 mm. The hazards status quickly increased to its highest level ('IV,' WITA).

At 1230 on 6 June, explosion earthquakes of small size occurred, followed by a rain of thin ash, which fell to the N. Visible white ash reached 500-750 m above the summit. An explosion sent ash 1 km above the crater rim, and the ash fell around the summit. Tremor prevailed until 2000, with maximum amplitude of 5 mm. At this point, 20,000 residents had already been evacuated.

Seismicity increased on 7 June; during the period 0000 to 0800 hours seismometers recorded 165 deep volcanic earthquakes, 18 shallow volcanic earthquakes, and continuous volcanic tremor—amplitude maxima exceeded 46 mm.

At 1117 on 7 June, an eruption began at 1800 hours, with ash plumes rising 1 km above the summit. After the eruption on 7 June, seismic signals similar to tremor occurred (at 1807), with continuous, peak-to-peak amplitudes of about 12-45 mm (maximum).

During 7-8 June from 2000 to 0600, visual observers noted that 500- to 700-m-high ash clouds still hung over the summit. For the interval 0600-0600 8-9 June, VSI reported, "All day long there were many explosions." In addition, five major explosions were noted, at 1510, 1630, and 1730 on 8 June, and at 0606 and 0910 on 9 June. Presumably due to each of those larger outbursts, dark gray ash plumes rose up 1-2 km above the summit.



Figure 2. Ash plume at Mount Awu at 0529 on 10 June 2004. Courtesy of Wittiri, VSI, Directorate of Volcanology and Geological Hazard Mitigation.



Figure 3. Recent tephra deposited below the Mount Awu lava dome, 12 June 2004. For scale, note the backpack-clad person standing on fresh tephra and amid stripped vegetation in the right-central foreground. Courtesy of A. Solihin, VSI, Directorate of Volcanology and Geological Hazard Mitigation (DVMBG).

Ash thickness at Tahuna was about 0.5-1.5 mm. Beginning on 8 June 2004 at 0800, Tahuna airport was closed. VSI noted that the ash rain could have reached Tabukan Utara and part of Kendahe, caused by the wind to the SW.

At 0529 on 10 June, Awu began a sustained eruption, described as the climax, lasting 34 minutes (figure 2). That event sent a column of gray to black ash to 3 km above the summit. The outburst was accompanied by low rumbling sounds and tephra.

By 11 June, explosions and seismicity decreased drastically, with tremor amplitudes of only 2-3 mm. Until 13 June VSI recorded no deep volcanic earthquakes. At 0600 on 13 June authorities reduced the hazard status and some W- and ESE-flank residents returned home.

Figure 3 documents fresh deposits, the presumably new dome, and denuded vegetation. Ash generally fell to the ESE. During the first eruption, ash fell on Tahuna city and its vicinity with a thickness of 0.5-1 mm. Surrounding villages received ash deposits as follows: Lenganeng, 2 mm; Naha, 2 mm; Bahang, 1.5 mm; Kalakuhe, 1.5 mm; and Mala, 1.5 mm.

Inspection of the crater at an undisclosed time revealed a lava dome 300 x 250 m in plan view and 40 m in height. It is uncertain whether these values represent an early dome (figure 1) or larger, later dome (figure 3).

On 14 June, observers saw a thin white plume rising 50 – 100 m above the crater. Beginning 17 June, the hazard status dropped to level II (Waspada). Following 18 June, seismicity declined, and instruments no longer recorded tremor. The latest Awu report, which discussed the interval 28 June-4 July, noted level II hazard status, plumes 50-200 m tall, and the observation of incandescent material, suggesting continued dome growth.

UN Reports. According to an 8 June report from the UN Office for the Coordination of Humanitarian Affairs, the

evacuation process triggered by Awu's eruption started on the evening of 6 June and continued through at least 8 June. The total number of people expected to be evacuated was ~27,000 (12,065 from Tahuna, 5,690 from Kendahe, and 9,248 from Tabukan Utara). As of 8 June, 17,326 people had been evacuated. These displaced people were accommodated in government buildings, schools, and houses of prayer. The Directorate of Volcanology strongly advised the temporary halting of flights from Manado (at the N end of Sulawesi Island) to Sangihe Island.

Background. The massive Gunung Awu stratovolcano occupies the northern end of Great Sangihe Island, the largest island of the Sangihe arc. Deep valleys that form passageways for lahars dissect the flanks of the 1,320-m-high volcano, which was constructed within a 4.5-km-wide caldera.

Awu is one of Indonesia's deadliest volcanoes; powerful explosive eruptions in 1711, 1812, 1856, 1892, and 1966 produced devastating pyroclastic flows and lahars that caused more than 8,000 fatalities. In 1992 Awu contained a summit crater lake that was 1 km wide and 172 m deep in 1922, but was largely ejected during the 1966 eruption.

Information Contacts: Dali Ahmad, Volcanological Survey of Indonesia (VSI), Directorate of Volcanology and Geological Hazard Mitigation, Jalan Diponegoro 57, Bandung 40122, Indonesia (Email: dali@vsi.dpe.go.id; URL: www.vsi.dpe.go.id); Office for the Coordination of Humanitarian Affairs (OCHA), United Nations, New York, NY 10017 USA.

Tengger Caldera

east Java, Indonesia

7.94°S, 112.95°E; summit elev. 2,329 m

All times are local (= UTC + 7 hours)

Reports of the Volcanological Survey of Indonesia (VSI) stated that Mount Bromo produced a phreatic eruption at 1526 on 8 June 2004. The eruption killed two people and injured several others. The Bromo cone is the youngest and most active volcano within the larger Tengger caldera complex. Bromo also resides within an inner caldera (Sandsea caldera).

The eruption, which vented at the crater, had a duration of ~ 20 minutes. Ash rose up to 3 km above the crater rim (figure 4) and was blown to the WNW and detected at the Mount (Gunung) Kelud observatory (~ 75 km away). Lapilli and ash spread out over a radius of ~ 300 m from the crater's center.

Bromo was closed to the public until further notice. Its hazard status was set to the elevated state of 'Alert Level III' (on a scale with a maximum of IV). Search and rescue teams were advised to stay away from the volcano until declaration of safe approach.

John Seach reported that many buildings in the nearby towns of Malang and Probolinggo were covered by a light coating of ash 2 hours after the eruption. The neighboring towns of Lumajang and Pasuruan were also affected by the eruption.

From 0600 on 9 June to 0600 on 10 June, visual observations disclosed a thin white and slightly red cloud about 25-50 m above the crater, moving W. Seismic records were dominated by tremor with peak-to-peak amplitudes ranging from ~ 1-4 mm. Seismometers also registered 123 emission earthquakes and 15 type-A volcanic earthquakes.

During 1800 on 10 June through 0600 on 11 June, the activity of Bromo was dominated by 'smoke emissions' of low-to-medium intensity reaching heights of ~ 25-100 m. Shallow volcanic earthquakes increased, and continuous tremor occurred with a peak-to-peak amplitude of 6.0 mm. Four volcanic earthquakes were detected within about 8-15 minutes, followed by tremor for 18 minutes, after which came 8 volcanic earthquakes. Despite all of the tremor and earthquakes, however, no explosion followed. When the weather was clear, VSI scientists could see white, thick 'smoke' emissions and smelled sulfur.

At 0819 on 14 June 2004, there was an ash explosion, accompanied by a plume that rose to 100 m. Pre-explosion spectrometer measurements suggested SO₂ fluxes of 200 tons/day. During 13-14 June the seismic record contained emission and tectonic earthquakes, as well as a half hour of continuous tremor with a peak-to-peak amplitude of 6.0 mm. Deformation measurement using electronic distance meters (EDM) and global positioning systems (GPS) implied deflations of about 2-6 mm and 2-15 mm, respectively.

By 0630 on 15 June 2004, activity at Bromo had generally decreased, and the Alert Level was reduced to Level II. During that day emissions of white thin smoke rose ~ 25-150 m above the summit and the seismograph recorded 24 emission earthquakes and 1 tectonic earthquake. Deformation measured by EDM and GPS implied respective deflations of 1.0-5.0 mm and 0.2-6.2 mm.

Background. The 16-km-wide Tengger caldera complex sits at the end of a volcanic massif extending N from Semeru volcano. The Tengger volcanic complex dates back to about 820,000 years ago and contains five overlapping stratovolcanoes, each truncated by a caldera. Lava domes, pyroclastic cones, and a maar occupy the flanks of the massif. The Ngadisari caldera at the NE end of the complex



Figure 4. Bromo's 8 June 2004 eruption as seen 2.2 km away, looking from the N. The photographer, K. Nishi, was in the seismic station and saw evidence of the eruption on the seismic system. He ran to the adjacent crater rim and took a series of shots. This one was taken 9 minutes after the eruption began. The prominent cone on the right is Batok. Courtesy of K. Nishi.

formed about 150,000 years ago and is now drained through the Sapikerep valley.

The most recent of the Tengger calderas is the 9 x 10 km wide Sandsea caldera at the SW end of the complex, which formed incrementally during the late Pleistocene and early Holocene. A cluster of overlapping, post-caldera cones was constructed on the floor of the Sandsea caldera within the past several thousand years. The youngest of these is Bromo, one of Java's most active and most frequently visited volcanoes.

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Bagana

Bougainville Island, Papua New Guinea
6.14°S, 155.19°E; summit elev. 1,750 m
All times are local (= UTC + 10 hours)

The Rabaul Volcano Observatory (RVO) received a report on 28 April from a pilot of the Hevi Lift helicopter company stating that new lava had come from Bagana volcano the day before. RVO has had no monitoring equip-

ment at Bagana since 1989. Although they hope to again install monitoring instruments in the future, they could not confirm the visual observations instrumentally.

Bagana has been in long-term eruption since 1972, although reports ceased in 1995 because of political and eco-



Figure 5. An overview of the scene on the SW region surrounding Bagana illustrating a potentially threatened hamlet and the erupting volcano and block-lava flow in the background. Courtesy of Ima Itikarai, RVO.



Figure 6. Bagana summit and upper flanks as seen in April 2004 showing the active block-lava flow on the SW side (steaming, at left center). A second block-lava flow path may have begun to descend the leveed banks on the right (note abundant steam on upper right-hand slopes). Copyrighted photo by Peter Mildner provided courtesy of Ima Itikarai, RVO.

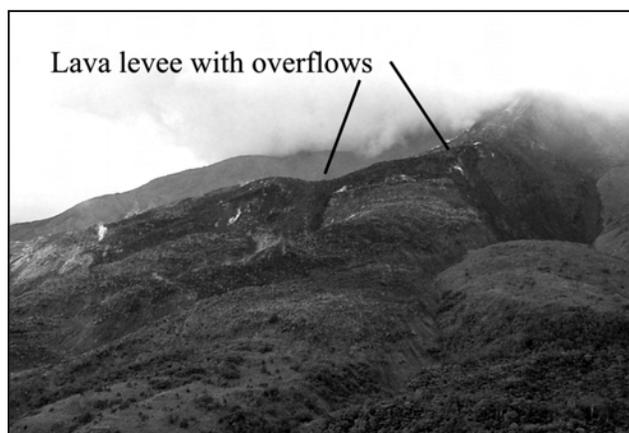


Figure 7. Closer view of the block-lava flow down Bagana's SW flank taken in April or May 2004, on a day with considerable low clouds. The initially confined lava flow followed the leveed path and then began to escape at several places. The fresh block lava's darker color stands in mild contrast to sparsely vegetated, older levee banks, which have a speckled appearance. Courtesy of Ima Itikarai, RVO.

nomie unrest. MODIS satellite observations began in 2000, and almost monthly thermal alerts have been recorded since September 2000.

According to a news article, on 2 May local volcanologists and a team of provincial disaster delegates conducted an aerial inspection of the area around Bagana. At that time, the team concluded that the lava flows were not an immediate threat to the safety of villagers near the volcano. According to news reports a spokesperson for Papua New Guinea's national Disaster Center said the aerial inspection team noted a continual effusion of lava flowing in a south-westerly direction, but there was a great deal of vegetation in the area which acted as a buffer.

A later news article also noted that in the long term the lava flows could expose local hamlets to danger. The hamlets were constructed in the 1990s by people displaced by civil unrest.

RVO staff sent a series of photos and brief notes regarding their visit. Ima Itikarai commented that during his trip clouds affected the quality of the photos. Figure 5 shows a hamlet, which sits 3 km from the active block-lava flow front and 6.5 km from the summit, well within reach of pyroclastic flows similar to those in 1952, 1960, and 1966.

At about the same time but in clearer weather, another photographer, Peter Mildner, took the photo in figure 6. It shows Bagana's summit and the active block-lava flow at a point where the levees had become 'bank full.' Figure 7 shows the lava flow pouring over the levees at various points. The lava flow's toe was also being overridden.

Background. Bagana volcano, occupying a remote portion of central Bougainville Island, is one of Melanesia's youngest and most active volcanoes. Bagana is a massive symmetrical lava cone largely constructed by an accumulation of viscous andesitic block-lava

flows. The entire lava cone could have been constructed in about 300 years at its present rate of lava production. Eruptive activity at Bagana is characterized by non-explosive effusion of viscous block-lava that maintains a small lava dome in the summit crater, although explosive activity occasionally producing pyroclastic flows also occurs. Block-lava flows form dramatic, freshly preserved tongue-shaped lobes up to 50-m-thick with prominent levees that descend the volcano's flanks on all sides.

Information Contacts: *Ima Itikarai* and *Herman Patia*, Rabaul Volcano Observatory (RVO), P.O. Box 386, Rabaul, Papua New Guinea (Email: hguria@global.net.pg); *Papua New Guinea Post-Courier*; *The National*; *The Australian*.

Ambrym

Vanuatu

165.25°S, 168.12°E; summit elev. 1,334 m

Ambrym (last reported in *Bulletin* v. 29, no. 3) exhibited high levels of activity in March and April 2004. During March, an active lava lake was present in Mbwelesu crater, one of the active summit craters. As of 27 March, there were reports that the people of Craig Cove in West Ambrym were suffering from the effects of the ongoing volcanic eruption on the island. Gas and acidic rainfall from the active vents on the volcano were threatening to destroy the local food gardens. The island was still recovering from the effects of Cyclone Ivy, which caused widespread damage two weeks earlier; the added affects of the eruption prompted Vanuatu's leaders to request emergency relief assistance from national and local authorities.

As of 3 April, reports confirmed by the Darwin VAAC and J. Seach described continuing lava lake activity at Ambrym. On 27 April, a large ash plume was recorded drifting 150 km NW of the volcano, passing the northern tip of Malekula Island and almost reaching Malo Island. Eruptions were still continuing up to 2 May.

NASA's Earth Observatory posted two images of Ambrym and its plume as they appeared on 27 April 2004 (figure 8). The pair of images came from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Terra satellite. A large plume of volcanic ash blew westward from the volcano, which appears at the center right edge of Figure 8 (top). The plume was mixing with clouds, and was more apparent as a bright, reddish orange color in the false-color image (below). Figure 8 (bottom) shows a wider area at the same spatial resolution.

Background. Ambrym, a large basaltic volcano with a 12-km-wide caldera, is one of the most active volcanoes of the New Hebrides arc. A thick, almost exclusively pyroclastic sequence, initially dacitic, then basaltic, overlies lava flows of a pre-caldera shield volcano. The caldera was formed during a major plinian eruption with dacitic pyroclastic flows about 1900 years ago. Post-caldera eruptions, primarily from Marum and Benbow cones, have partially filled the caldera floor and produced lava flows that ponded on the caldera floor or overflowed through gaps in the caldera rim. Post-caldera eruptions have also formed a series of scoria cones and maars along a fissure system oriented ENE-WSW. Eruptions have apparently occurred al-

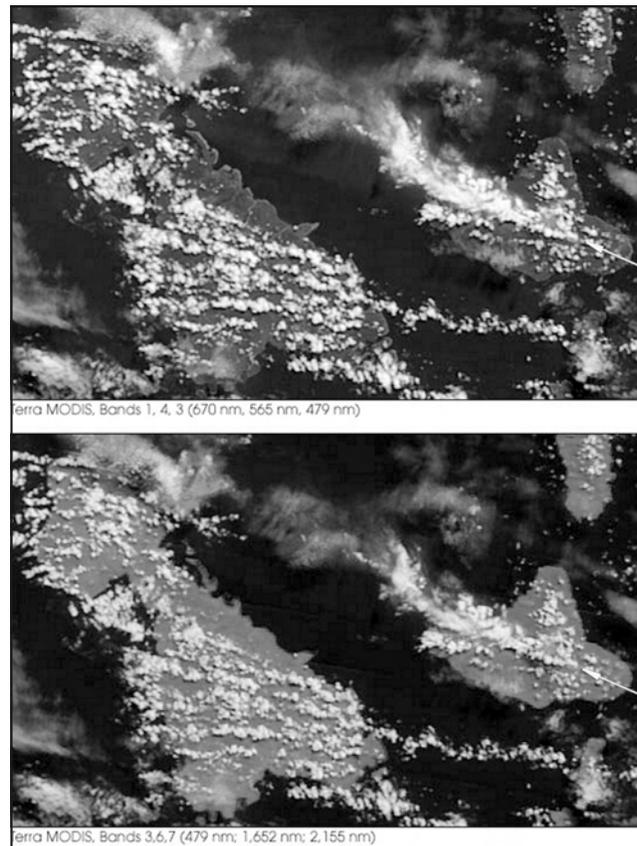


Figure 8. Ambrym volcano in two MODIS images (top and bottom). See text for discussion. Image courtesy Jeff Schmaltz, MODIS Rapid Response Team, NASA-GSFC.

most yearly during historical time from cones within the caldera or from flank vents. However, from 1850 to 1950, reporting was mostly limited to extra-caldera eruptions that would have affected local populations.

Information Contact: *John Seach*, PO Box 4025, Port Vila, Vanuatu (Email: john@volcanolive.com, URL: <http://www.volcanolive.com/>); *Darwin VAAC* (URL: <http://www.bom.gov.au/info/vaac/>); *Jeff Schmaltz*, MODIS Rapid Response Team, NASA-GSFC (Email: Jeff.Schmaltz@gsfc.nasa.gov); *Holli Riebeek*, NASA's Earth Observatory (URL: <http://naturalhazards.nasa.gov/>, <http://earthobservatory.nasa.gov/>; Email: nh-contact@eodomo.gsfc.nasa.gov).

Correction: *Bulletin* v. 29, no. 3 incorrectly listed Rabaul Volcano Observatory as an Ambrym information source. A more relevant source would have been Département de la Géologie, des Mines et des Ressources, Vanuatu.

Anatahan

Mariana Islands, central Pacific Ocean
16.35°N, 145.67°E; summit elev. 788 m
All times are local (= UTC + 10 hours)

The first recorded historical eruption at Anatahan Island began on 10 May 2003 (*Bulletin* v. 28, nos. 4, 5, 6, and 9). More volcanism accompanied increased seismicity beginning 30 March 2004 (*Bulletin* v. 29, no. 4). Lava was noted

in the crater on 15 April. During an overflight on 24 April scientists reported fresh lava within the inner crater. Seismic activity increased abruptly at 1052 on 24 April, escalating to levels higher than recorded since summer 2003, and a moderate eruption initially produced a light ash cloud that rose to altitudes below 2 km. The cloud persisted for only a day or so.

The seismicity level increased further on 24 and 25 April. On 26 April, a flat-shaped dome was observed within the inner crater. On the evening of April 28, the seismicity level peaked, then decreased slowly to about 40% of its peak value by 29 May. That seismicity resulted from strombolian bursts every minute or so that ejected material some hundreds of meters out of the crater, and steam and ash to several hundred meters. After a two-day-long decrease, the seismicity surged on 30-31 May to double the value of the previous few days, resulting from more frequent small explosions (occurring every few tens of seconds) as well as increased tremor.

On 7 and 8 June a 100-km-long, light-colored plume of steam and ash blew W. This was reported by the U.S. Air Force Weather Agency based on Defense Meteorological Satellite Program (DMSP) satellite images (figure 9).

Juan Camacho of the Commonwealth of the Northern Mariana Islands Emergency Management Office (CNMI/EMO) visited the island on 10 June and reported an active spatter cone, from which continuous strombolian explosions threw material as high as 100 m every 10 seconds to one minute. By 15 June, the amplitude and number of discrete events appeared to have decreased slightly.

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

flows on Anatahan indicated that they were of Holocene age, but the first historical eruption of Anatahan did not occur until May 2003, when a large explosive eruption took place forming a new crater inside the eastern caldera.

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Sakura-jima

Kyushu, Japan

31.585°N, 130.657°E; summit elev. 1,117 m

All times are local (= UTC + 9 hours)

Based on information from the Japanese Meteorological Agency (JMA), the Tokyo Volcanic Ash Advisory Center (VAAC) reported that on 3 December 2003 at 2025 ash was emitted from Sakura-jima, rose to ~2.5 km a.s.l., and extended to the S. An eruption on 12 January 2004 at ~1430 produced an ash cloud that rose higher than 2 km altitude. On 19 and 20 February, explosions produced ash clouds that rose to unknown heights. No ash was visible on satellite imagery. Based on JMA information, the Tokyo VAAC reported that explosions on 26 March at 1715 and 27 March at 0607 produced plumes that extended S and rose to ~2.5 km and ~2 km altitude, respectively.

An eruption on 17 April produced a gas-and-ash plume that rose to ~3 km altitude and extended W. Another eruption on 25 April produced an ash plume that rose to ~2.4 km altitude, and extended N. The Tokyo VAAC reported, based on information from the JMA, that an eruption occurred on 28 April at 1820. It produced a plume that rose to ~2.4 km altitude and drifted SE. No ash was visible on satellite imagery.

According to the Har-Tass news agency, JMA reported a powerful ash-bearing discharge on 15 May at 1107. Specialists stated that the activity was the most intensive in four years. There were no reports of damage or injuries. The explosion registered as 'large' on the JMA's scale for both the sound and the strength of the tremor it caused, according to a quoted official at the local agency office in Kagoshima.

The Tokyo VAAC said the ash plume rose to more than 1.8 km altitude. An explosion occurred on 17 May at 1946, sending an ash plume to a height of 2.1 km altitude. On 18 May a pilot reported ash at a height of ~1.2 km altitude and ~23 km S of the Amori region. During 19-24 May, several explosions produced ash clouds. The highest reported ash cloud reached ~2.4 km altitude on 24 May. An explosion on 20 June at 1523 produced an ash cloud that rose to an unknown height.

Background. Sakura-jima, one of Japan's most active volcanoes, is a post-caldera cone of the Aira caldera at the northern half of Kagoshima Bay. Eruption of the volumi-

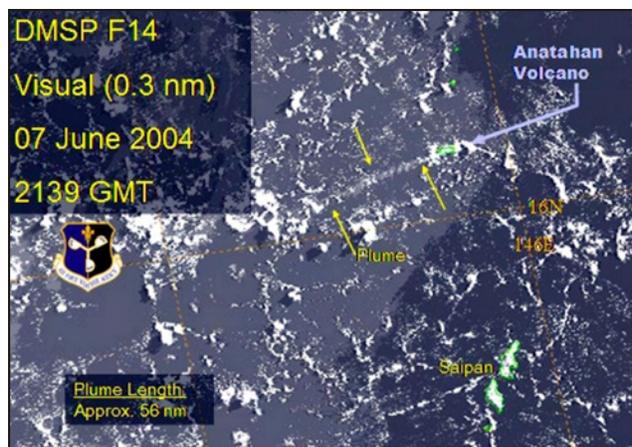


Figure 9. Visual (0.3 nm) image of plume from Anatahan volcano taken from Defense Meteorological Satellite Program satellite on 7 June 2004 at 2139 hours GMT (8 June 2004 at 0739 hours local time). Note that the plume length at this time, measured by the U.S. Air Force Weather Agency, was ~104 km (~56 nautical miles). Courtesy of Charles R. Holliday, U.S. Air Force Weather Agency.

nous Ito pyroclastic flow accompanied formation of the 17 x 23 km wide Aira caldera about 22,000 years ago. The smaller Wakamiko caldera was formed during the early Holocene in the NE corner of the Aira caldera, along with several post-caldera cones. The construction of Sakura-jima began about 13,000 years ago on the southern rim of Aira caldera and built an island that was finally joined to the Osumi Peninsula during the major explosive and effusive eruption of 1914. Activity at the Kita-dake summit cone ended about 4,850 years ago, after which eruptions took place at Minami-dake. Frequent historical eruptions, recorded since the 8th century, have deposited ash on Kagoshima, one of Kyushu's largest cities, located across Kagoshima Bay only 8 km from the summit. The largest historical eruption took place during 1471-76.

Information Contacts: Naokuni Uchida, Japan Meteorological Agency (JMA), Fukuoka, Japan (URL: <http://www.jma.go.jp/>; Email: nuchida@redcfk.kishou.go.jp); Tokyo Volcanic Ash Advisory Center (VAAC) (URL: http://www.jma.go.jp/JMA_HP/jma/jma-eng/jma-center/vaac/; Email: vaac@eqvol.kishou.go.jp).

Bezymianny

Kamchatka Peninsula, Russia

55.98°N, 160.59°E; summit elev. 2,882 m

All times are local (= UTC + 12 hours) [or +13 hours in March-June]

Eruptions associated with extrusion of viscous lavas continued at Bezymianny into June 2004. Since observers last reported on Bezymianny (*Bulletin* v. 29, no. 3) they noted substantial ash plumes occurring in June 2004 (table 1). The summary below chiefly comes from weekly reports made by Kamchatkan Volcanic Eruptions Response Team (KVERT) and disseminated through the Alaska Volcano Observatory (AVO).

This report concerns the most recent eruption of Bezymianny which occurred on 19 June 2004. Increased activity on the volcano began during 11 to 14 June, when seismicity rose above background level and 2-3 shallow earthquakes occurred daily.

By 16 June, KVERT elevated Bezymianny's hazard status, raising the Concern Color Code from Yellow to Orange (table 2), signifying that an eruption could occur at any

| Date | Time | Characteristics of Eruption |
|----------------|------|-----------------------------------------------------------------------------------------------------------------------|
| 26-27 Dec 2002 | 0715 | Ash cloud to 5 km altitude, depositing ash 55 km NW of volcano |
| 26 Jul 2003 | 2057 | Ash plume to 8-11 km altitude, extending 192 km, 217 km and ~250-300 km W of the vent |
| 14 Jan 2004 | 1053 | Ash plume to 6-8 km altitude, extending ~190 km; pyroclastic flow |
| 19 Jun 2004 | 0840 | Ash plume to ~8-10 km altitude (estimated from seismic signature); plume ultimately sighted over 1,000 km from source |

Table 1. A synopsis of some recent eruptions distinguished at Bezymianny (the first three were previously discussed, *Bulletin* v. 28, no. 10 and 29, no. 3). Taken from KVERT reports.

| Color | Status |
|--------|-------------------------------------------------------------------------------|
| Green | Volcano is dormant; normal seismicity and fumarolic activity. |
| Yellow | Volcano is restless; eruption may occur. |
| Orange | Volcano is in eruption or eruption may occur at any time. |
| Red | Significant eruption is occurring or explosive eruption expected at any time. |

Table 2. The significance of various hazard status categories on the KVERT Concern Color Code Key. This key is regularly posted with their reports.

time. On 19 June, the Code was raised to Red, the highest level.

Explosive activity began at 0840 on 19 June, and according to seismic data, it produced an ash plume that rose ~8-10 km altitude. Satellite imagery revealed that by 1319, the plume had extended ~200 km. The more concentrated portion of the plume was in the zone of ~167-189 km from the volcano. At 1439, a large local ash cloud moved to the NNE towards Bering Island. Later in the day, the seismicity level decreased, and KVERT reduced the Concern Color Code to Orange. During 18 to 19 June, an ash cloud extended over 1,000 km E and SE of the volcano, and "possible ash deposits" were inferred 190 km SE of the lava dome. The last time an ash cloud was noted near Korovin Island was on 20 June.

Around this time KVERT noted viscous lava flows at the lava dome. They documented weak, 1- to 4-pixel thermal anomalies over the dome. In the wake of the eruption KVERT reported gas-steam plumes extending ~3.5 km S, NE, and ESE. Following that, they reported no other activity as recently as 25 June.

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 4,700 years ago over a late-Pleistocene lava-dome complex and an ancestral volcano that was built between about 11,000-7,000 years ago. Three periods of intensified activity have occurred during the past 3,000 years. The latest period, which was preceded by a 1,000-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 A. 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).

Shiveluch

Kamchatka Peninsula, Russia
 56.653°N, 161.360°E; summit elev. 3,283 m
 All times are local (= UTC + 12 hours [or 13 hours
 March-June])

With the exception of strong ash explosions and related seismic activity on 9-10 May (described below), unrest at Shiveluch during 9 April–27 May 2004 was similar to that described in our last report (*Bulletin*, v. 2903, no. 3).

In effect, observers noted above-background seismicity, lava dome growth, and associated pyroclastic flows. Steam plumes rising as high as 3.5 km altitude, and ash plumes rising 4-7 km altitude, were seen frequently. Earthquakes occurred at depths of 0-5 km and had local magnitudes (M_l) of 1.25 - 2.25 while spasmodic tremor varied between 0.1-0.9 $\mu\text{m}/\text{sec}$.

During the period, U.S. and Russian satellites repeatedly detected 1- to 9-pixel thermal anomalies. According to ground-based observers, the volcano was obscured by clouds throughout much of the report period.

Less than ten strong earthquakes were recorded each week in April. However, activity increased during the week ending 6 May when 35 strong earthquakes were recorded. According to seismic data, from 0210 to 0730 on 10 May, a series of strong ash explosions occurred at the lava dome. Continuous tremor at 14.8 $\mu\text{m}/\text{sec}$ occurred during that time, decreasing to 0.3 $\mu\text{m}/\text{sec}$ by 0940. Seismic activity increased again during 2150-2325, and tremor was 5-6 $\mu\text{m}/\text{sec}$. According to video and visual observation, explosions sent ash to altitudes of 8-11 km. American and Russian satellite data recorded a 9-pixel thermal anomaly over the lava dome at 2336 on 9 May and a 6-pixel anomaly at 0642 on 10 May. Around this time, authorities temporarily raised the level of concern from orange to red.

From 0725 through 1502 on 10 May an ash plume extended over 450 km to the SE and ash deposits were observed on 11 May over a wide sector to the SE at distances over 100 km. At 0914, pyroclastic- and mud-flow deposits were observed on the SE slopes of the volcano extending to distances of ~7-8 km.

At Ust-Kamchatsk (coastal settlements ~100 km ENE of Bezymianny), the thickness of orange-brown ash deposits on 10-11 May was ~1-2 mm. On 10 May, the airport at Ust-Kamchatsk was closed and the road and the dam in the area of the Bekesh River were destroyed by mud flows.

On 10 May seismic activity continued with 27 and 21 strong earthquakes recorded, respectively, during the subsequent two weeks. The number of thermal anomalies reported from satellite observations also increased to as many as 36 during the week ending 13 May.

By 27 May, activity had returned to levels typical of April (and earlier). On 21 May, the lava dome and pyroclastic-flow deposits were observed from a helicopter

and from the ground. A part of the dome had been destroyed. Deposits were gas-rich, high-temperature juvenile pyroclastic flows in the central sector of the S slope of the volcano. The temperature of the main flow was ~300°C at a depth of 15 cm. According to satellite data, 1-20 pixel thermal anomalies were observed over the lava dome during the week.

Background. The high, isolated massif of Shiveluch volcano (also spelled Sheveluch) rises above the lowlands NNE of the Kliuchevskaya volcano group. The 1,300-km³ 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.

Information Contacts: Olga Girina, Kamchatka Volcanic Eruptions Response Team (KVERT) (see Bezymianny).

Long Valley

California, USA
 37.70°N, 118.87°W, summit elev. 3,390 m
 All time are local (= UTC - 8 hours)

The following is a summary of Hill (2004) and Sorey, Hill, and McConnell (2000), reports that collectively concluded that with the close of 2003, Long Valley Caldera had sustained nearly five years of relative quiescence. This marked the longest such interval since the onset of unrest in 1978. A summary of 2001-2002 activity was published in March 2003 (*Bulletin* v. 28, no. 3).

The slow inflation of the resurgent dome at a rate of ~1 cm/year that persisted through most of 2002 leveled off in early 2003 with essentially no change through the end of the year. At the end of 2003, the center of the resurgent dome stood only about 0.5 cm higher than in early 1999. It remained roughly 80 cm higher than in the late 1970s.

Seismic activity within the caldera remained low through 2003 as it has for the previous four years, averaging fewer than five earthquakes per day large enough to be located by the realtime computer system (M 0.5 and above). As in the past, most of these earthquakes were confined to the S moat and the S margin of the resurgent dome. The largest intra-caldera earthquake during the year was a M 2.4 event on 19 September 2003 at 0751, associated with a cluster of smaller events in the S moat beneath the E margin of Mammoth Lakes. An earthquake sequence of comparable intensity was centered beneath the SE margin of the resurgent dome on 8 November. This sequence included three $M > 2$ earthquakes, the largest of which was a M 2.2 earthquake at 2102.

Most of the earthquake activity in the Sierra Nevada block S of the caldera continued to be concentrated in the N-NE lineation of epicenters that represents the aftershock zone of the three $M > 5$ earthquakes of June and July 1998 and May 1999 (figure 10). A notable exception was the M 4.0 earthquake of 8 March (0735) that was located 1 km S of Laurel Mountain (~5 km S of the caldera boundary and 11 km ESE of Mammoth Lakes). This earthquake was felt in the Mammoth Lakes area and was accompanied by over 50 smaller earthquakes, the largest of which was a M 3.2 event. The Grinnell Lake area near the S end of the seismicity lineation in the Sierra Nevada was one of the more persistently active areas through the year. It produced M 3.2 earthquakes on 15 June and 18 August as well as a host of smaller earthquakes.

Occasional M 3 earthquakes elsewhere in the region included: a M 3.2 earthquake on 23 January 3 km E of Red Slate Mountain (midway along the seismicity lineation in figure 10), a M 3.0 earthquake on 18 March located beneath the Volcanic Tableland 10 km E of Crowley Lake, a M 3.1 earthquake on 31 August located 2 km E of Lake Dorothy in the Sierra Nevada, a M 3.0 earthquake on 26 October located 20 km W of Bishop, and a M 3.5 earthquake on November 10 in Round Valley. Altogether, ten earthquakes of M 3 or greater occurred in the area during 2003, the largest being the M 4.0 event on 8 March near Laurel Mountain. The mid-crustal (10- to 25-km-deep) long period (LP) volcanic earthquakes, which began during the 1989 Mammoth Mountain earthquake swarm, continued beneath the SW margin of Mammoth Mountain but at a much-reduced rate with respect to the activity levels during the first half of 1997. LP activity for 2003 was limited to the first and last quarters of the year with no LP earthquakes detected from April through September.

The carbon dioxide (CO_2) emissions from the tree-kill areas around the flanks of Mammoth Mountain remained similar over the last several years. In particular, data from the CO_2 sensors at Horseshoe Lake were relatively flat and uneventful for 2003 except for the normal winter excursions due to snow accumulation. A soil CO_2 efflux survey of Horseshoe Lake in August gave an emission rate of 135 tons/day, which is slightly higher than the rate for 2002. However, the emission rate trend from 1995 through 2003 based on linear regression was relatively flat at ~100 tons/day, suggesting continued CO_2 emissions. The Horseshoe Lake tree-kill area produces roughly one third of the total CO_2 flux from the flanks of Mammoth Mountain.

Intra-caldera sites contained dead vegetation, elevated soil temperatures, and CO_2 concentrations consistent with ongoing geothermal activity. The areas that produced the greatest CO_2 emissions were in the vicinity of the geothermal plant and have been known for some time. Initially the formation of these areas likely occurred as a result of superficial changes

linked to increases in geothermal fluid production in the late 1980s and early 1990s. Some recently identified sites displayed elevated soil temperatures on the resurgent dome above Fumarole Canyon; these may reflect a delayed response to the 1997 earthquake swarm activity in the area. Total CO_2 emissions at these sites are marginally above background levels.

Hydrologic monitoring data show that declining fluid pressures in key monitoring wells over the past several years continued through 2003. Fluid pressures in four of five key monitoring wells during 2003 were at the lowest values since 1995 and for three of these wells the pressures were the lowest since the late 1980s. The data also show a sharp decline in thermal-water discharge from springs in Hot Creek Gorge, an event that began in August 2003 and persisted to the end of 2003. The decline in discharge was ~18% of the long-term mean discharge.

The decline in thermal-water discharge from Hot Creek Gorge springs was consistent with the low fluid pressures recorded in wells CW3 and CH10B, both of which tapped the S-moat hydrothermal system. The reason for this decline was unclear. Geothermal production from the Casa Diablo power plant has not changed significantly over the past year and the caldera has shown no significant unrest.

New instrumentation and an interdisciplinary workshop. During the week of 2 August 2003, a team of scientists and drilling experts from the oil industry successfully installed a 30-m-long geophysical instrument string at a depth ~2.4 km in the Long Valley Exploratory Well (LVEW). The instrument string includes two three-component seismometers (4 Hz natural frequency, one at 2592 m and the other at 2264 m depths), a dilatometer (at 2254 m depth), a 48-m-long vertical-axis optical-fiber strainmeter (centered at 2150 m depth), and pass-through tubes designed to track pore pressure in the open hole beneath the instrument package. As signals from the remaining components of the LVEW deep borehole observatory come on line over the next few months, they will greatly enhance the power of the LVO network as both a monitoring and research tool.

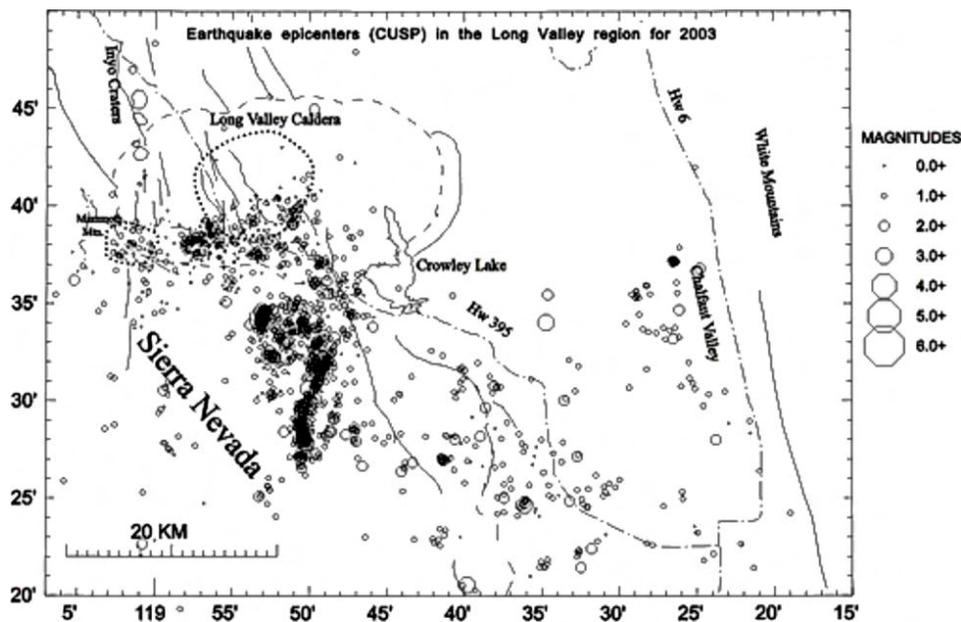


Figure 10. Earthquake epicenters in the Long Valley region for 2003 (from Hill, 2003).

Instrumentation of LVEW as a deep-borehole observatory represents the final stage of a major drilling project that began in the mid-1980s with multi-agency support (Sorey and others, 2000).

A four-day workshop was held 8-12 October 2003. The title was "Understanding a Large Silicic Volcanic System: An Interdisciplinary Workshop on Volcanic Process in Long Valley Caldera-Mono Craters."

Background. The large 17 x 32 km Long Valley caldera east of the central Sierra Nevada Range formed as a result of the voluminous Bishop Tuff eruption about 730,000 years ago. Resurgent doming in the central part of the caldera occurred shortly afterwards, followed by rhyolitic eruptions from the caldera moat and the eruption of rhyodacite from outer ring-fracture vents, ending about 50,000 years ago. During early resurgent doming the caldera was filled with a large lake that left strandlines on the caldera walls and the resurgent dome island; the lake eventually drained through the Owens River Gorge. The caldera remains thermally active, with many hot springs and fumaroles, and has had significant deformation, seismicity, and other unrest in recent years. The late-Pleistocene to Holocene Inyo Craters cut the NW rim of the caldera, but are chemically and tectonically distinct from the Long Valley system.

References: Hill, D.P., 2003, Long Valley Observatory quarterly report October-December 2003 and annual summary for 2003: Long Valley Observatory, U.S. Geological Survey, Menlo Park, CA (URL: http://lvo.wr.usgs.gov/Quarterly/qrt_rpt_4-03.htm).

Sorey, M.L., Hill, D.P., and McConnell, V.S., 2000, Scientific drilling in Long Valley Caldera, California—an update, in *California Geology*, California Geological Survey, v. 53, pp. 4-11; URL: http://www.consrv.ca.gov/cgs/information/publications/california_geology_magazine.htm.

Information Contacts: David P. Hill, Long Valley Observatory, Volcano Hazards Program, U.S. Geological Survey, 345 Middlefield Rd., MS 977, Menlo Park, CA 94025, USA (Email: hill@usgs.gov; URL: <http://lvo.wr.usgs.gov/>); Deborah Bergfeld, Jim Howle, Chris Farrar, and William Evans, U. S. Geological Survey, Menlo Park, and Carnelian Bay, CA.

Colima

western México

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

A March 2004 observatory report noted that one year of explosive activity had passed, an interval that began in February 2003 after the termination of lava emission (*Bulletin*, v. 28, no. 6). During March-May 2003 there was an increase in the number of small explosions. During the year, seismometers recorded ~ 1,500 small explosions (figure 11). After that, the frequency of explosions became stable, with 3-5 daily explosions (figures 12 and 13). Four relatively significant explosions occurred during 2003 on 17 July, on 2 and 28 August (*Bulletin*, v. 28, no. 8), and on 15 November, although there was no change in the daily number of events.

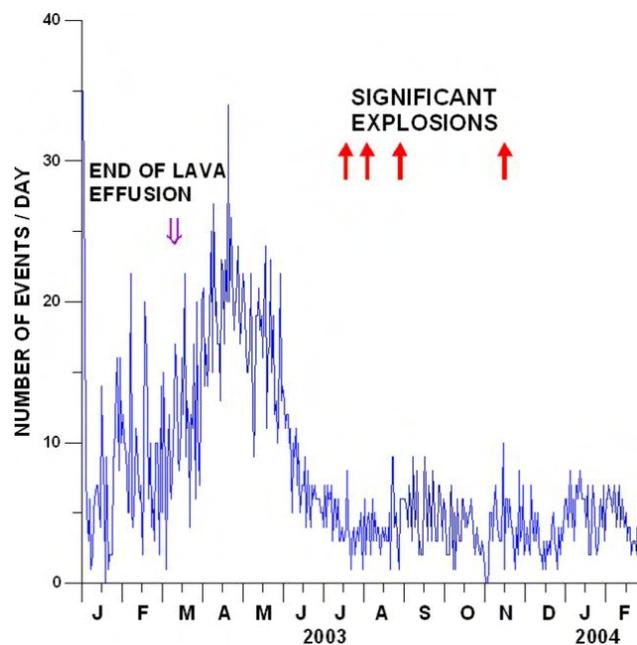


Figure 11. Daily variations in the number of small explosions recorded by the seismic network Red Sismica de Colima (RESCO) of Colima University from January 2003 to February 2004. The termination of the effusive stage is shown by the open arrow; four significant explosions are shown by filled arrows. Courtesy of Colima Volcano Observatory.

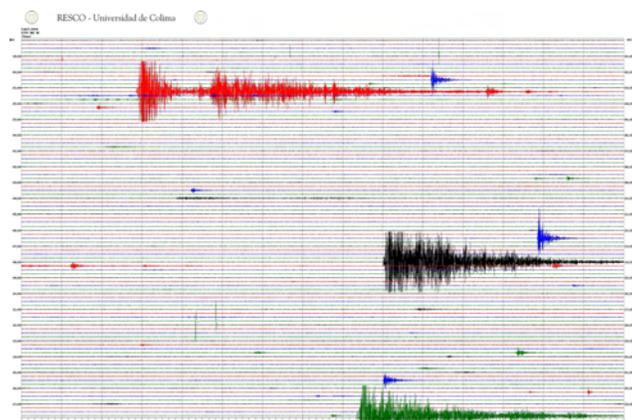


Figure 12. A typical daily seismogram with the records of small explosions (27 February 2004). RESCO seismic station Soma, at a distance of about 1.7 km from the crater. Courtesy of Colima Volcano Observatory.



Figure 13. A typical view of a small explosion at Colima. Photo was taken on 1 February 2004. Courtesy of Colima Volcano Observatory.



Figure 14. A view of Colima's crater floor from the S, taken on 27 February 2004. Courtesy of Colima Volcano Observatory.

The sequence of explosions destroyed the former lava dome. Although the depth of the crater floor increased slightly as a result, the crater's dimensions changed little (figure 14).

A later observatory report also noted that a significant explosion took place at 1228 on 12 June 2004. During preceding days, the volcano continued to show low-intensity activity, with an average of under 3 ash explosions per day. The heights of the columns did not exceed 2,000 m above the crater; they blew mainly to the W.

The exclusionary zone for both States adjoining Colima volcano remained 6.5 km from the summit. Also, the alert radius covered distances of up to 11.5 km from the summit, in order to include residents of Causentla, Cofradia de Tonila, Atenguillo, El Saucillo, El Fresnal, and El Embudo. Warnings to avoid lingering were also applied to the valleys of La Lumbre, El Cordobán, San Antonio and Monte Grande, El Muerto, La Tuna, Santa Ana, El Cafecito, La Arena, and Beltrán-Duranzno.

The Washington Volcanic Ash Advisory Center (VAAC) for aviation safety issued many reports ("Volcanic Ash Advisories") for Colima during 2003 and 2004, including over 30 during 2004. The bulk of the 2004 reports came out in February, March, April, and as recently as 14 May; no reports were issued since then to the late June date of this *Bulletin*. A sampling of the 2004 VAAC reports and associated graphics indicated several plumes to over 6 km altitude had been seen via satellite.

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 Volcan 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.

Volcan de Colima (also known as Volcan 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 Contacts: *Observatorio Vulcanológico de la Universidad de Colima*, Colima, Col., 28045, México (Email: ovc@cgcic.ucol.mx); *Washington Volcanic Ash Advisory Center (VAAC)*, NOAA-NESDES, Satellite Analysis Branch, 5200 Auth Road, Camp Springs, Maryland 20746 USA.

El Chichón

México

17.360°N, 93.228°W; summit elev. 1,150? m

The *Bulletin* staff received numerous photographs of currently non-eruptive El Chichón from amateur photographer King Freeland; a few are included below. Some of Freeland's photos are wide-angle montages compiled from multiple photos using image-processing software. The photograph in figure 15 was taken in April 2004 and shows the warm, bright green, acidic crater lake. Figure 16 illustrates the central crater as it looked in May 2004 from the SE side of the volcano looking towards the WSW.

Figure 17 depicts a sequence of what resemble stair steps developed on the pyroclastic deposits. Yuri Taran estimated the approximate height of these "steps" as 0.5-1 m, but the photographer Freeland suggested a height of up to 3 m. Taran and Freeland both offered that the features may result from the work of water, and Taran also suggested wind as a possibility.

Taran lamented the lack of people studying these features, even though they appeared quite spectacular, stating "We need a team of geographers to study this type of erosion, soil formation..." Many of Freeland's other photos in our archives also depict fumarolic and hydrothermal features.

Yuri Taran from the Institute of Geophysics, Universidad Nacional Autonoma de Mexico (UNAM), has been studying El Chichón volcano and its hydrothermal activity for almost 10 years (see Capaccioni and others, 2004). Taran noted that three groups of hot springs exist on the slopes of the volcano: Agua Caliente, S of the volcano with a maximum temperature of 74°C; Agua Salada, at the base of the dome, SSW from the crater, with a maximum temperature of 55°C; and Agua Tibia, NW of the crater with an estimated maximum temperature of ~ 51°C. The crater lake has variable shape and size, depending on the flow rate of a boiling spring in the crater that feeds the lake. When this spring sometimes disappears, the lake becomes smaller until an equilibrium develops between precipitation, evaporation, and seepage through the lake bottom. This 'equilibrium' lake size is quite small. Taran noted that during the period of his study the lake was smallest in November 1998 (at the end of the rainy season), and it was very shallow, ~1.3 m deep.

References: Capaccioni, B., Taran, Y., Tassi, F., Vaselli, O., Mangani, G., and Macias, J.L., 2004, Source conditions and degradation processes of light hydrocarbons in volcanic gases: an example from El Chichón volcano (Chiapas State, Mexico), *Chemical Geology*, v. 206, n.p. 1-2, p.81-96.



Figure 15. Photograph taken in April 2004 from the SW crater rim of El Chichón showing the crater lake. Courtesy of King Freeland.



Figure 16. The S side of El Chichón's inner crater, May 2004, looking toward WSW. Courtesy of King Freeland.



Figure 17. Broken 'stair-stepped' surface developed on pyroclastic deposits at El Chichón. The inset at upper right is a blow-up of a representative area in the photo's center. The photo was taken in 2004. Courtesy of King Freeland.

Background. El Chichón is a small, but powerful andesitic tuff cone and lava dome complex that occupies an isolated part of the Chiapas region in SE México far from other Holocene volcanoes. Prior to 1982, this relatively unknown volcano was heavily forested and of no greater height than adjacent nonvolcanic peaks. The largest dome, the former summit of the volcano, was constructed within a 1.6 x 2 km summit crater created about 220,000 years ago. Two other large craters are located on the SW and SE flanks; a lava dome fills the SW crater, and an older dome is located on the NW flank. More than ten large explosive eruptions have occurred since the mid-Holocene. The powerful 1982 explosive eruptions of high-sulfur, anhydrite-bearing magma destroyed the summit lava dome and were accompanied by pyroclastic flows and surges that devastated an area extending about 8 km around the volcano. The eruptions created a new 1-km-wide, 300-m-deep crater that now contains an acidic crater lake.

Information Contacts: King Freeland, Distrito Reynosa 157, Fracc. Pages Llergo, Villahermose, Tabasco, CP86125, México (Email: king.freeland@stsrental.com or kfreeland@prodigy.net); Yuri Taran, Instituto de

Geofísica, Universidad Nacional Autónoma de México (UNAM), Ciudad Universitaria, Coyoacan 04510, México D.F., México (URL: <http://tepetl.igeofcu.unam.mx>; Email: taran@tonatiuh.igeofcu.unam.mx).

Soufrière Hills

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

Although seismicity and volcanism were generally low during this reporting interval, mid-January to early June 2004, several episodes of elevated activity occurred. Weekly summaries for the early part of 2004 are presented in tables 3 and 4. The tables include a summary of seismicity, SO₂ emissions, and forward-looking infrared (FLIR) measurements of the HCl/SO₂ ratio.

On 18 January a low-amplitude swarm of long-period (LP) earthquakes comprised of 1000 separate events began and continued for ~36 hours. A similar swarm occurred on

30 January, lasting for ~30 hours. On 21 February a period of low-level tremor, including many small LP earthquakes, began at ~0600 and continued for ~36 hours.

A period of low-level tremor began on 2 March and continued until 1444 on 3 March when seismic activity increased significantly and an explosion and collapse event occurred. According to the Washington Volcanic Ash Advisory Center (VAAC), the ash clouds associated with the explosion reached an altitude of ~7 km. During 1445-1500 pyroclastic flows were observed in the Tar River, reaching the sea at the Tar River fan on at least two occasions. Seismicity returned to near background levels by 1525, but vigorous ash venting continued until ~0700 on 4 March. Visual observations reported that the explosion removed the small dome that had grown in the collapse scar in late July 2003, as well as a portion of the NW remnant of the 1995-1998 dome.

Episodes of tremor and ash venting continued until 7 May. During this period, tremor amplitude varied from low to moderate, and tremor duration varied from several days (continuous background) to a few seconds. Tremor peak frequencies were in the 1-10 Hz range. Subsequently, the activity level was low (table 3). The SO₂ flux level dropped to 146 metric tons/day on 13 May (table 4), the lowest value recorded since before the collapse event of 12-15 July 2003. For the remainder of the report period, activity remained at a low level. The seismic network recorded several hybrid earthquakes but also a number of 'mixed' events, characterized by emergent onsets and relatively short durations (~30 seconds) with broad frequency spectra (1-10 Hz), peaking at ~10 Hz.

Background. The complex andesitic Soufrière Hills volcano occupies the southern half of the island of Montserrat. The summit area consists primarily of a series of lava domes emplaced along an ESE-trending zone. Prior to 1995, the youngest dome was Castle Peak, which was located in English's Crater, a 1-km-wide crater breached widely to the east. Block-and-ash flow and surge deposits

| Date (2004) | SO ₂ (metric tons/day) | HCl/SO ₂ ratio |
|---------------|-----------------------------------|---------------------------|
| 16 Jan-23 Jan | 440 | 0.36-0.41 |
| 23 Jan-30 Jan | 500-700 | 0.33-0.37 |
| 30 Jan-06 Feb | 439-726 | — |
| 06 Feb-13 Feb | 350-450 | 0.32 |
| 13 Feb-20 Feb | — | — |
| 20 Feb-27 Feb | 496-920 | — |
| 27 Feb-05 Mar | 480-820 | — |
| 05 Mar-12 Mar | 330-1250 | 0.47 |
| 12 Mar-19 Mar | 470-755 | — |
| 19 Mar-26 Mar | 370-550 | 0.53-0.66 |
| 26 Mar-02 Apr | 440-480 | — |
| 02 Apr-09 Apr | 150-720 | — |
| 09 Apr-16 Apr | 540-870 | — |
| 16 Apr-23 Apr | 1030 | — |
| 23 Apr-30 Apr | 155-290 | 0.49 |
| 30 Apr-07 May | 200-672 | 0.30 |
| 07 May-14 May | 146-695 | — |
| 14 May-21 May | 182-428 | — |
| 21 May-28 May | 255-922 | 0.60 |
| 28 May-04 Jun | 179-496 | — |

Table 4. Summary of SO₂ emissions and the HCl/SO₂ ratio recorded at Soufrière Hills, 16 January to 4 June 2004. Courtesy of Montserrat Volcano Observatory.

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 later 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.

| Date (2004) | Activity level | Rockfall events | LP earthquakes | Hybrid earthquakes | VT earthquakes |
|---------------|-----------------|-----------------|----------------|--------------------|----------------|
| 16 Jan-23 Jan | Low | 1 | 38 | 9 | 1 |
| 23 Jan-30 Jan | Very low | 8 | 1 | 10 | 1 |
| 30 Jan-06 Feb | Low | 15 | 7 | 9 | 1 |
| 06 Feb-13 Feb | Low | — | — | 3 | 1 |
| 13 Feb-20 Feb | Low | 1 | — | 3 | — |
| 20 Feb-27 Feb | Low | 3 | 2 | 5 | — |
| 27 Feb-05 Mar | Increased | 4 | 1 | 38 | — |
| 05 Mar-12 Mar | Low | — | 1 | 15 | — |
| 12 Mar-19 Mar | Increased | 1 | 4 | 6 | 6 |
| 19 Mar-26 Mar | Elevated | — | 4 | 7 | — |
| 26 Mar-02 Apr | Moderate | 1 | 1 | 1 | — |
| 02 Apr-09 Apr | Low to moderate | 5 | 1 | — | — |
| 09 Apr-16 Apr | Low | 1 | 1 | — | — |
| 16 Apr-23 Apr | Low | — | 5 | 14 | — |
| 23 Apr-30 Apr | Low | — | 3 | 5 | — |
| 30 Apr-07 May | Low | — | — | 1 | — |
| 07 May-14 May | Low | — | — | 1 | — |
| 14 May-21 May | Low | — | — | 1 | — |
| 21 May-28 May | Low | — | — | 7 (and 44 'mixed') | — |
| 28 May-04 Jun | Low | — | — | 4 (and 16 'mixed') | — |

Table 3. Summary of seismicity recorded at Soufrière Hills, 16 January to 4 June 2004. Courtesy of Montserrat Volcano Observatory.

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

Nyamuragira

Democratic Republic of Congo, central Africa
1.408°S, 29.20°E; summit elev. 3,058 m
All times are local (= UTC + 2 hours)

When last reported (*Bulletin* v. 29, no. 4), Nyamuragira was in the midst of an eruption that had begun on 8 May 2004 and continued through 12 May. The Toulouse Volcanic Ash Advisory Center (VAAC) reported that satellite imagery showed a weak ash eruption on 25 May and that from 26 May to 1 June there were weak but steady emissions from Nyamuragira and neighboring Nyiragongo (~13 km SE of Nyamuragira). The Goma volcano observatory confirmed that ash fell within a radius of 60 km of both volcanoes. VAAC reports on 1 June said that satellite imagery indicated the eruptions at Nyamuragira had ceased.

Background. Africa's most active volcano, Nyamuragira is a massive basaltic shield volcano that rises about 25 km north of Lake Kivu across a broad valley NW of Nyiragongo volcano. Nyamuragira, also known as Nyamulagira, has a volume of 500 km³, and extensive lava flows from the volcano blanket 1,500 km² of the East African Rift. The broad low-angle shield volcano contrasts dramatically with its steep-sided neighbor Nyiragongo. The 3,058-m-high summit of Nyamuragira is truncated by a small 2 x 2.3 km caldera that has walls up to about 100 m high. Historical eruptions have occurred within the summit caldera, frequently modifying the morphology of the caldera floor, as well as from the numerous fissures and cinder cones on the volcano's flanks. A lava lake in the summit crater, active since at least 1921, drained in 1938, at the time of a major flank eruption. Historical lava flows extend down the flanks more than 30 km from the summit, reaching as far as Lake Kivu.

Information Contacts: Baluku Bajope and Kasereka Mahinda, Observatoire Volcanologique de Goma, Département de Géophysique, Centre de Recherche en Sciences Naturelles, Lwiro, D.S. Bukavu, DR Congo (Email: ocha.volcan@wfp.org); Toulouse Volcanic Ash Advisory Center (VAAC), Météo-France, 42 Avenue Gaspard Coriolis, F-31057 Toulouse cedex, France (Email: vaac@meteo.fr; URL: <http://www.meteo.fr/aeroweb/info/vaac/>); TOMS Volcanic Emissions Group (URL: <http://skye.gsfc.nasa.gov/>).

Piton de la Fournaise

Réunion Island, Indian Ocean
21.229°S, 55.713°E, summit elev. 2,631 m
All times are local (= UTC + 4 hours)

After the eruption of December 2003 (*Bulletin* v. 29, no. 3), Piton de la Fournaise underwent a month of high seismic activity in April 2004. The activity consisted of 10-30 earthquakes per day with two minor seismic crises, and was

accompanied by continuous inflation of the summit. On 2 May a new seismic crisis started at 1903. At 1936 eruption tremor appeared. The high intensity of tremor near the Bory crater (2,632 m) indicated that eruption had most likely started within or very close to the crater.

No activity was visible in the crater on 3 May. An overflight planned by the Observatoire Volcanologique du Piton de la Fournaise (OVPF) with the help of local police militia was unable to take place due to bad weather and rain on the volcano. The initial assessments of the observatory indicated the opening of eruptive cracks in the higher of the two craters. A long crack on the SW side extended from 2,500 m to at least 2,300 m elevation. During an observational visit by OVPF volcanologists on 4 May, a fissure was observed to have opened between 2,800 m and 2,200 m elevation. The fissure was inactive at the time of observation but much lava ejecta covered the surrounding area. A second fissure, opened during the night between Sunday and Monday, was active. As of 4 May, activity continued from three eruptive vents located between Chateau-Fort crater and Piton Bert. Tremor remained stable. During the night of 11-12 May, the single remaining active fissure projected lava ejecta onto the slopes of the cone in the SW area of the crater. The eruption continued on 15 May but moved from the summit of the volcano toward its lower slopes. Flows accumulated within the crater, and a large flow with an estimated length of 300 m was seen coming from a ~ 2.5 km-long tunnel, originating at the floor of the Enclos Fouqué caldera and issuing at the surface near the Nez du Tremblet and in the Grandes Pentes area. Further downslope, burning vegetation was observed, indicating the presence of lava flows far from the point of emission. The larger flow reached an elevation of 1,150 m, putting it 4 km from National Route (NR) 2. At 1200, the lava flow was 2.5 km from NR 2. Scientists at the observatory expected the flow's advance to slow due to the shallowing of the slope starting at 900 m elevation, and because the eruptive tremor, though it had increased slightly the day before, remained at a moderate level.

On 16 May, the lava flow stopped 1.8 km from NR 2 at 460 m elevation. A second fissure produced a second lava flow parallel to the first. Tremor increased in the crater, indicating a renewal of activity, and lava ejecta were erupted from the two cones. The OVPF reported on 17 May that the eruption was still continuing. Lava fountains from the main eruptive cone rose several tens of meters above the vent. That evening, lava flows were visible on the upper part of the Grandes Pentes. Pélés's hair had fallen in the town of St. Rose. Seismicity remained on a moderate level. At about 1500 on 18 May, the OVPF's network recorded a progressive increase in the tremor over a twenty-minute period; then at 1552, the tremor decreased dramatically. By 1615, any trace of tremor had disappeared from the recordings. On 21 May at 1500, a lava front was observed flowing at 1150 m elevation, within ~4 km of National Route 2. Volcanic tremor increased slightly, but remained at a moderate level.

Background. The massive Piton de la Fournaise basaltic shield volcano on the French island of Réunion in the western Indian Ocean is one of the world's most active volcanoes. Much of its >530,000 year history overlapped with eruptions of the deeply dissected Piton des Neiges shield volcano to the NW. Three calderas formed at about 250,000, 65,000, and less than 5,000 years ago by progres-

sive eastward slumping of the volcano. Numerous pyroclastic cones dot the floor of the calderas and their outer flanks. Most historical eruptions have originated from the summit and flanks of Dolomieu, a 400-m-high lava shield that has grown within the youngest caldera, which is 8 km wide and breached to below sea level on the eastern side. More than 150 eruptions, most of which have produced fluid basaltic lava flows, have occurred since the 17th century. Only six eruptions, in 1708, 1774, 1776, 1800, 1977, and 1986, have originated from fissures on the

outer flanks of the caldera. The Piton de la Fournaise Volcano Observatory, one of several operated by the Institut de Physique du Globe de Paris, monitors this very active volcano.

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