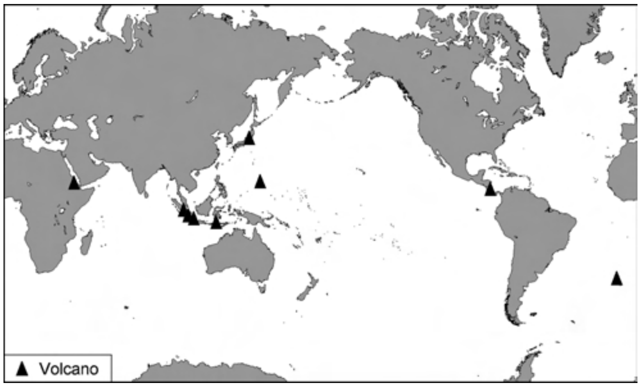
Bulletin of the Global Volcanism Network



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Tristan da Cunha

southern Atlantic Ocean, United Kingdom
37.092°S, 12.28°W; summit elev. 2,060 m

The Comprehensive Nuclear Test Ban Treaty Organisation (CTBTO) in Vienna operates a recently installed (July 2002) satellite-linked real-time hydroacoustic station on the island of Tristan da Cunha, with two elements (figure 1). These are designed to record T phases and use three-component short-period seismometers sampled at 100 samples per second. Roderick Stewart, a scientist with the CTBTO, reported that seismic activity, including several felt events, occurred in the vicinity of Tristan da Cunha in July and August 2004. This is the first time that seismicity near this volcano has been instrumentally recorded.

An intense swarm of seismic activity was recorded, and felt, on the night of 29-30 July. The activity lasted approximately six hours and peaked around 2100-2200 UTC on 29 July. There were a number of large earthquakes in the swarm; the largest, at approximately 2220 UTC on 29 July, had a body-wave magnitude of 4.2. The epicenter was in the vicinity of the island, but location uncertainties make it impossible to say whether the source was onshore or offshore. Seismic activity continued to be recorded, and occasionally felt, throughout August 2004, but was declining slowly (figure 2). No long-period earthquakes or tremor signals were positively identified although, according to Stewart, the temporal pattern of the swarm appeared to be volcanic. A pseudo-RSAM plot of the data from one of the stations showed that the activity grew gradually to a peak over a period of two or three hours and that the larger events occurred after this peak.

Stewart described the earthquakes as follows. “All the earthquake signals were impulsive with well-developed P and S phases, typical of volcano-tectonic activity. With only two stations, it is not possible to determine individual hypocentres with any confidence and the locations of the earthquakes can only be inferred from general observations made on the data. First-motion analysis of the P waves was made difficult because the arrivals were very small on the horizontal components. However, it was possible to determine that the P wave was always arriving from the SE at both stations and that the angle of incidence of the arriving P wave was very steep, within 10 degrees of vertical. S-P times were between 4 and 5 seconds at both stations, with H09N1 typically a fraction of a second longer than H09W1. Depending on the velocities assumed, these S-P times indicate that the earthquakes were between 20 and 30 km from the stations. The simplest interpretation of both the above observations is that the earthquakes occurred at depth directly below the volcano. However, an offshore location to the SE cannot be ruled out. What is certain is that these events occurred close to the volcano.”

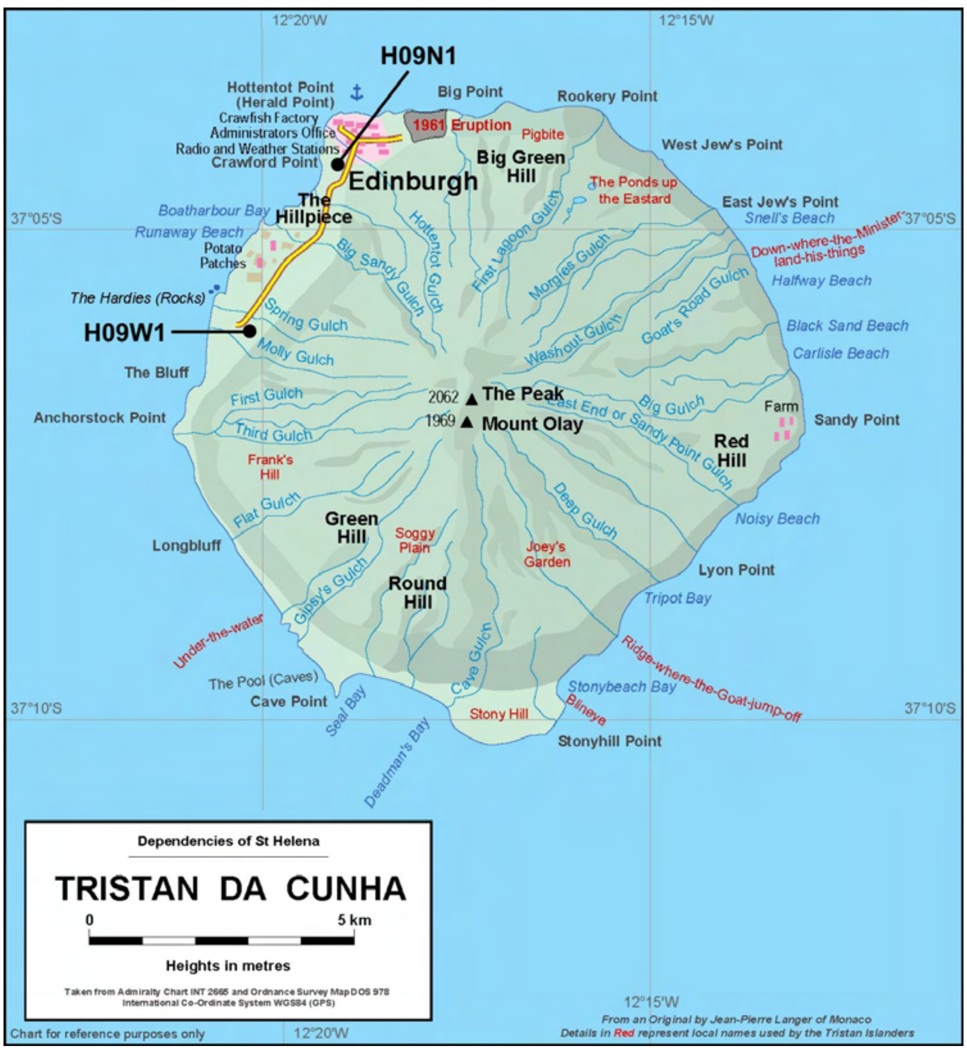

Figure 1. Map of the island of Tristan da Cunha showing the locations of the two CTBTO hydroacoustic stations. Station locations courtesy of R. Stewart, CTBTO.

Reports from the island of rocks floating in the water in the days following the seismic activity, along with an initial offshore estimate of the location of the largest earthquake (which had large uncertainties), led to speculation of an underwater eruption. One newspaper account from the Tristan Times on 6 August described “angular and not round” rocks seen by fishermen floating “all around the Island.” In a 14 September BBC World Service interview, Island Administrator Mike Hentley stated that fishermen found “huge lumps of [pumice], up to 10 or 12 kg floating on the surface to the south/west of the Island.” He further described the pumice as “a very crumbly, light grey stone.” Samples of this pumice collected by James Glass (figure 3) are being sent to the Global Volcanism Program.

The Tristan Times also reported on 30 September that volcanologist Victoria Hards from the British Geological Survey (BGS) arrived on the island on 10

September to assess the potential threat of the recent seismic activity. She reportedly determined that the 29-30 July event was caused by rising magma 25 km SE of the island.

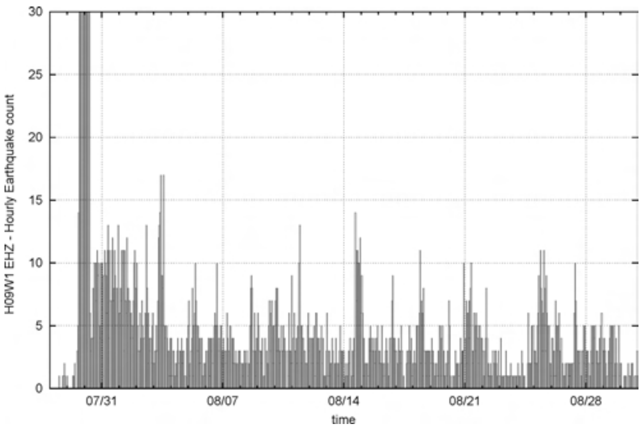

Figure 2. Hourly count of earthquakes at Tristan da Cunha from 27 July to 31 August 2004. Events were counted manually on constant gain plots. The counts of earthquakes during the initial swarm were more than 100 per hour. Courtesy of R. Stewart, CTBTO.

Figure 3. Photographs of pumice collected near Tristan da Cunha, August 2004. No scale or size description was provided with the photos, but the top photo of the single sample appears to have been taken on a window ledge and the bottom photo of multiple samples on a bench `seat cushion. Courtesy of James Glass, Tristan Times.

She also noted that there was no sign of activity at the 1961 eruption site, and no eruption was imminent so there was no threat to the settlement. The BGS planned to monitor the seismic data over the next four months to assess any longer-term implications.

Background. Tristan da Cunha is a 13-km-wide island volcano lying about 500-km east of the crest of the Mid-Atlantic Ridge just south of the latitudes of Buenos Aires and Cape Town. The conical stratovolcano is bounded on most sides by high cliffs. Its steep upper flanks, composed primarily of pyroclastic materials, rise above a low-angle base consisting principally of lava flows. Eruptions have occurred from the 300-m-wide summit crater, Queen Mary's Peak, which contains a small lake, and from numerous flank vents. Radial dike swarms are prominently exposed on all sides of the island. Numerous strombolian cinder cones occur on the flanks of the volcano along both concentric ring structures and NNW- and ENE-trending radial fissures. The only historical eruption of Tristan da Cunha occurred during 1961 from a north-shore vent and forced the evacuation of the island's only settlement.

Information Contacts: *David Booth*, British Geological Survey, Murchison House, Edinburgh EH9 3LA, UK (Email: dcb@bgs.ac.uk); *Roderick Stewart*, Preparatory Commission for the Comprehensive Nuclear Test Ban Treaty Organisation (CTBTO), Vienna International Centre, PO Box 1200, A-1400 Vienna, Austria (Email: roderick.stewart@ctbto.org); *Juanita Brock* and *James Glass*, Tristan Times (URL: http://www.tristantimes.com); *BBC World Service* (URL: http://www.bbc.co.uk/worldservice/).

Erta Ale

Ethiopia
13.60°N, 40.67°E; summit elev. 613 m

Field expeditions during November 2003 and February 2004 found that the molten-surfaced lave lake at Erta Ale had almost disappeared (*Bulletin* v. 29, no. 2). HIGP MODIS Thermal Alerts satellite observations of infrared emissions from the volcano during January 2001-March 2004 confirmed the declining activity levels. MODIS acquires an image of subaerially active volcanoes such as Erta Ale an average of four times in each 48-hour period, twice by day and twice by night. Elevated levels of thermal emission (e.g. active lava flows) are detected by the MODVOLC algorithm, and collated (at http://modis.higp.hawaii.edu).

The level of radiative power output from the summit of Erta Ale (figure 4) averaged 75 MW during 2001 and 2002, dropped significantly during the first five months of 2003, and even further between June and November 2003 to a level beneath the detection limit of the algorithm (~ 10 MW). With the exception of one isolated thermal spike in December 2003, this decline in thermal output continued up to the time of the MODIS report (March 2004). Between December 2002 and March 2004, the average rate of power loss fell to approximately 30 MW. The field-expedition reports corroborated the MODIS observations that a substantial decline in the level of lava-lake activity at Erta Ale occurred since January 2003.

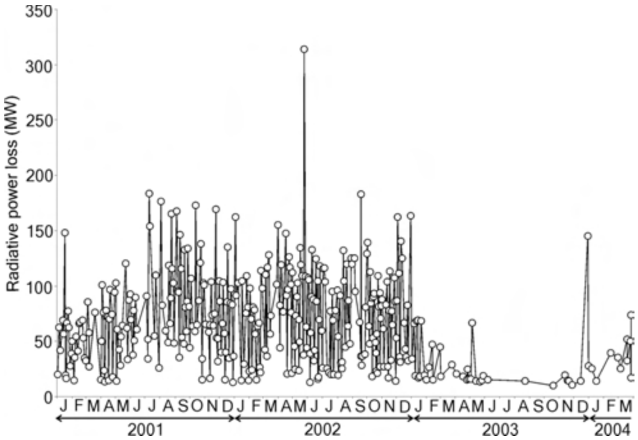

Figure 4. Level of radiative power output from the summit of Erta Ale, January 2001-March 2004. Data courtesy HIGP MODIS thermal alert system.

Observations during November-December 2003. Between 22 November and 6 December 2003, Joshua Jones and Roberto Carniel recorded continuous seismic, thermal, and acoustic data during fieldwork at the volcano. During this time they took several digital photographs showing a small but active lava lake in the southern crater of the summit caldera, and overflows were observed into the southern crater floor. The lava lake was approximately 20 m across.

Background. Erta Ale is an isolated basaltic shield volcano that is the most active volcano in Ethiopia. The broad, 50-km-wide volcano rises more than 600 m from below sea level in the barren Danakil depression. Erta Ale is the namesake and most prominent feature of the Erta Ale Range. The 613-m-high volcano contains a 0.7 x 1.6 km, elliptical summit crater housing steep-sided pit craters. Another larger 1.8 x 3.1 km wide depression elongated parallel to the trend of the Erta Ale range is located to the SE of the summit and is bounded by curvilinear fault scarps on the SE side. Fresh-looking basaltic lava flows from these fissures have poured into the caldera and locally overflowed its rim. The summit caldera is renowned for one, or sometimes two long-term lava lakes that have been active since at least 1967, or possibly since 1906. Recent fissure eruptions have occurred on the northern flank of Erta Ale.

References: Wright, R., and Flynn, L.P., 2004, Space-based estimate of the volcanic heat flux into the atmosphere during 2001 and 2002: Geology, v. 32, p. 189-192.

Information Contacts: *Rob Wright and the HIGP MODIS Thermal Alerts Team*, Hawaii Institute of Geophysics and Planetology, University of Hawaii, 2525 Correa Road, Honolulu, HI 96822, USA (URL: http://modis.hgip.hawaii.edu/; Email: wright@higp.hawaii.edu); *Joshua Jones*, Department of Earth & Space Sciences, Box 351310, Seattle, WA 98195-1310, USA (Email: josh@ess.washington.edu); *Roberto Carniel*, Dipartimento di Georisorse e Territorio, University of Udine - via Cotonificio, 114 - 33100 Udine, Italy (Email: rcarniel@dgt.uniud.it).

Kerinci

Sumatra, Indonesia
1.814°S, 101.264°E; summit elev. 3,800 m

Although frequently active, the most recent eruptive period at Kerinci had ended by late 2002 (*Bulletin* v. 27, nos. 8 and 12). A new eruptive episode was reported by the Directorate of Volcanology and Geological Hazard Mitigation (DVGHM) starting in late July. However, the Darwin Volcanic Ash Advisory Centre (VAAC) issued an advisory on 22 June after receiving a report of ash from Kerinci at ~ 3.8 km altitude (summit level) drifting W; no ash was visible on satellite imagery.

During 24-31 July 2004 observers reported seeing a "white, thick blackish" plume rising 100-600 m above the crater rim and drifting WSW. Ashfall deposits as thick as 1 cm were identified at distances of 3 km from the summit. The number of volcanic earthquakes recorded rose during this week and remained high through the week ending on 8 August (table 1). Another eruption on the morning of 6 August sent a gray ash plume 600 m above the summit. Based on the increased activity, DVGHM raised the hazard status to Alert Level II (yellow).

Volcanic earthquakes decreased during 9-15 August, although continuous emission signals were still being recorded and thin white plumes were seen rising 50-300 m above the summit. Similar activity continued the following week. A thick gray plume rising 50 m was reported the week of 23-29 August, but there was no change in seismicity.

Background. The 3800 m high Gunung Kerinci in central Sumatra forms Indonesia's highest volcano and is one of the most active in Sumatra. Kerinci is capped by an unvegetated young summit cone that was constructed NE of an older crater remnant. The volcano contains a deep 600 m wide summit crater often partially filled by a small crater lake that lies on the NE crater floor opposite the SW- rim summit of Kerinci. The massive 13 x 25 km wide volcano towers 2400 to 3300 m above surrounding plains and is elongated in a N-S direction. The frequently active Gunung Kerinci has been the source of numerous moderate explosive eruptions since its first recorded eruption in 1838.

Information Contacts: *Dali Ahmad*, *Hetty Triastuty*, *Nia Haerani*, and *Sri Kisyati*, Directorate of Volcanology and Geological Hazard Mitigation, Jalan Diponegoro No. 57, Bandung 40122, Indonesia (Email: dali@vsi.esdm.go.id); URL: http://www.vsi.esdm.go.id/); *Darwin Volcanic Ash Advisory Centre (VAAC)*, Bureau of Meteorology, Northern Territory Regional Office, PO Box 40050, Casua-

Date (2004)	Volcanic A	Volcanic B	Local Tectonic	Emission
12 Jul-18 Jul	2	1	—	continuous
19 Jul-25 Jul	5	3	2	continuous
26 Jul-01 Aug	6	3	1	continuous
02 Aug-08 Aug	5	2	2	continuous
09 Aug-15 Aug	1	1	—	continuous
16 Aug-22 Aug	2	2	—	continuous
23 Aug-29 Aug	—	1	—	continuous

Table 1. Seismicity at Kerinci, 12 July-29 August 2004. Courtesy of DVGHM.

rina, NT 0811, Australia (URL: http://www.bom.gov.au/info/vaac/).

Krakatau

Sunda Strait, Indonesia
6.10°S, l05.42°E; summit elev. 813 m

Intense activity occurred at Anak Krakatau beginning on 4 July 2004, when gas and steam emissions increased. The number of volcanic earthquakes also increased on 5 July to between 1 and 4 events per day, then abruptly rose to as high as 58 events/days during the week of 12-18 July before dropping again to 2-17 daily events (table 2). Based on the increased activity, the hazard status was upgraded to Alert Level II (yellow) on 16 July; visitors were not allowed to approach the summit or crater. Seismicity recorded at the Kalianda station after 18 July through 15 August was variable, but did not exhibit the high numbers recorded in the first half of July.

Date (2004)	Volcanic A	Volcanic B	Local Tectonic
04 Jul-11 Jul	77	56	3
12 Jul-18 Jul	113	51	8
19 Jul-25 Jul	22	5	4
26 Jul-01 Aug	36	12	21
02 Aug-08 Aug	45	42	65
09 Aug-15 Aug	10	14	8

Table 2. Seismicity at Krakatau, 4 July-15 August 2004. Courtesy of DVGHM.

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

Information Contacts: *Dali Ahmad*, *Hetty Triastuty*, *Nia Haerani*, and *Sri Kisyati*, Directorate of Volcanology and Geological Hazard Mitigation, Jalan Diponegoro No. 57, Bandung 40122, Indonesia (Email: dali@vsi.esdm.go.id); URL: http://www.vsi.esdm.go.id/).

Papandayan

Java, Indonesia
7.32ºS, 107.73ºE; summit elev. 2,665 m

Volcanic activity increased at Papandayan beginning 17 July 2004. On 13 July, volcanic earthquakes increased from a range of between 1-3 events per day to 7-9 events per day and increased to 57 events on 16 July (table 3). The temperature on Baru Crater I increased from 84 to 88.5ºC, and at Baru Crater II the temperature increased from 89 to 102ºC. A visible thin white plume rose 25-100 m. This activity prompted a rise in the hazard status to Alert Level II. During the following week volcanic and local tectonic earthquakes increased, but there were no emissions. A white thin plume rose to 50-150 m above the summit. After 26 July seismicity declined and remained low through at least mid-August. The thin white plume was observed throughout this time, but its maximum height decreased each week until it was only 25-75 m above the summit during 9-15 August.

Background. Papandayan is a complex stratovolcano with four large summit craters, the youngest of which was breached to the NE by collapse during a brief eruption in 1772 and contains active fumarole fields. The broad 1. 1-km-wide, flat-floored Alun-Alun crater truncates the summit of Papandayan, and Gunung Puntang to the north gives the volcano a twin-peaked appearance. Several episodes of collapse have given the volcano an irregular profile and produced debris avalanches that have impacted lowland areas beyond the volcano. A sulfur-encrusted fumarole field occupies historically active Kawah Mas ("Golden Crater"). After its first historical eruption in 1772, in which collapse of the NE flank produced a catastrophic debris avalanche that destroyed 40 villages and killed nearly 3000 persons, only small phreatic eruptions had occurred prior to an explosive eruption that began in November 2002.

Information Contacts: *Dali Ahmad*, *Hetty Triastuty*, *Nia Haerani*, *Suswati*, and *Sri Kisyati*, Directorate of Volcanology and Geological Hazard Mitigation, Jalan Diponegoro No. 57, Bandung 40122, Indonesia (Email: dali@vsi.esdm.go.id); URL: http://www.vsi.esdm.go.id/).

Date (2004)	Volcanic A	Volcanic B	Local Tectonic	Emission
05 Jul-11 Jul	—	21	—	—
12 Jul-18 Jul	20	101	4	2
19 Jul-25 Jul	65	129	10	—
26 Jul-01 Aug	8	44	8	—
02 Aug-08 Aug	4	32	3	—
09 Aug-15 Aug	1	46	4	—

Table 3. Seismicity at Papandayan, 5 July-15 August 2004. Courtesy of DVGHM.

Egon

Flores Island, Indonesia
122.45° E 8.67° N; summit elev. 1,703 m
All times are local (= UTC - 6 hours)

Volcanic activity began at Egon in late January when ash explosions caused local ashfall (*Bulletin* v. 29, no. 3). Activity subsequently decreased, and evacuated residents returned home. Reports from the Directorate of Volcanology and Geological Hazard Mitigation (DVGHM) indicated that in May 2004 only ten A-type volcanic earthquakes were detected. These types of events increased to 19 during June, when three shallow B-type volcanic earthquakes were also registered (table 4).

Volcanism resumed at 1930 on 3 July 2004 when small explosions along with rumbling sounds and a white- gray ash plume rose 100 m and caused ashfall to the SE. Ash from a second small explosion that began with increasing A-type volcanic earthquakes on 6 July at 0100 again drifted SE. Maximum amplitudes (peak-to-peak) of the explosion earthquakes were 1 mm and lasted 60 seconds. White plumes rising to ~ 75 m above the summit were then observed during 5-18 July. Continuous emission earthquakes were recorded during the week of 5-12 July with 2 mm amplitude. After 11 July a PS-2 telemetered seismograph was operational.

A significant ash explosion accompanied by rumbling sounds at 2240 on 25 July 2004 sent a plume ~ 1,000-1,500 m above the summit. A thick black ash column drifted NW and the smell of sulfur gas was very strong. Seismic data indicated that the eruptions lasted about 2 hours and 30 minutes; tremor amplitude was 30-35 mm. Ashfall affected the Egon (3 km NW) and Nangatobong (7.5 km NNW) villages, and 339 families evacuated to Waigete. Daily seismic events increased from 14 to 36 prior to the eruption. Ash explosions continued through 1600 the next day, sending plumes ~ 250 m above the summit at intervals of about a minute. Additional evacuations occurred from Egon, Nangatobong, and Itoper villages. Another explosion at 2200 on 28 July sent volcanic material to a height of 750 m; ash drifted WSW. Recorded tremor emission showed maximum amplitudes decreasing from 5 mm to 2 mm.

By the week of 9-15 August observers were only reporting a thin white plume to ~ 100 m above the summit, although tremor was still being recorded. Similar activity continued through 22 August. On 27 August two eruptions ejected ash plumes more than 250 m high. Shallow volcanic earthquakes increased significantly during the week of 23-29 August.

Date (2004)	Volcanic A	Volcanic B	Tremor	Tectonic
20 Jun-27 Jun	7	2	—	23
28 Jun-04 Jul	9	3	—	24
05 Jul-11 Jul	9	2	continuous	2
12 Jul-18 Jul	22	139	2	35
19 Jul-25 Jul	17	109	—	54
26 Jul-01 Aug	5	37	—	28
02 Aug-08 Aug	3	38	34	28
09 Aug-15 Aug	2	49	49	16
16 Aug-22 Aug	1	70	51	16
23 Aug-29 Aug	4	90	42	17

Table 4. Seismicity at Egon during 20 June-29 August 2004. Courtesy of DVGHM.

Background. Gunung Egon volcano sits astride the narrow waist of eastern Flores Island. The barren, sparsely vegetated summit region has a 350-m-wide, 200-m-deep crater that sometimes contains a lake. Other small crater lakes occur on the flanks of the 1703-m-high volcano. A lava dome forms the southern 1671-m-high summit. Solfataric activity occurs on the crater wall and rim and on the upper southern flank. Reports of historical eruptive activity are inconclusive. A column of "smoke" was often observed above the summit during 1888-1891 and in 1892.

Information Contacts: *Dali Ahmad*, *Hetty Triastuty*, *Nia Haerani*, *Suswati*, and *Sri Kisyati*, Directorate of Volcanology and Geological Hazard Mitigation, Jalan Diponegoro No. 57, Bandung 40122, Indonesia (Email: dali@vsi.esdm.go.id); URL: http://www.vsi.esdm.go.id/).

Anatahan

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

The current eruption began after increased seismicity on 31 March 2004 (*Bulletin* v. 29, nos. 4 and 5). Lava was noted in the crater on 15 April and may have extruded for a few weeks thereafter. The most energetic phase occurred during 24-28 April, when a ash clouds rose ~ 1,000 m. This report summarizes activity from mid-June through September 2004.

During June, seismicity was higher as a result of more frequent small explosions every few tens of seconds, and a 100-km-long, light-colored plume of steam and ash was occasionally visible. A cone active since at least 10 June produced continuous Strombolian explosions that ejected material as high as 100 m every few tens of seconds to minutes, filling the inner crater by about 10 July. The seismicity level was generally significantly lower during 14-16 June, after which it returned to earlier levels. On 27 June a tropical storm knocked out the last seismic station on the island.

The last time the weather was clear enough to see well, on 3 July, the Washington VAAC reported a 31-km-long ash plume well below 3 km altitude. During a few days in mid-July, prolonged periods, 10-15 minutes long, of continuous ash emission began to occur and became more frequent. A plume of light ash and steam trailed tens of kilometers WSW at altitudes less than 3 km.

Seismicity increased on 23 July to approximately double the level of the previous day, approaching the previous high of late April. The seismic signals indicated somewhat larger and longer periods of ash emission. Strombolian explosions continued to occur very frequently. The explosions threw mostly coarse material upward a hundred meters or so at intervals of tens of seconds to a few minutes. A plume of light ash and steam trailed a few tens of kilometers downwind, generally W, at altitudes below 1.8 km. An Air Force Weather Advisory on 24 July reported that their satellite could see the source as a hot spot. The Commonwealth of the Northern Mariana Islands Emergency Management Office (CNMI/EMO) reported a plume of light ash trailing a few tens of kilometers WSW at altitudes below ~ 3 km.

Joe Kaipat (EMO) visited the island on 25 July with personnel from Fish and Wildlife and reported observing an ash plume probably a few tens of kilometers long moving NE. This plume persisted until 3 August, less than a few kilometers long and below 600 m. After 26 July seismicity decreased to a very low level, with the signals indicating that the frequent individual explosions of several days before had decreased significantly in size and number and finally ceased by 31 July. Instead, ash and gas were being ejected almost continuously. Seismicity remained very low and frequent individual explosions ceased through August and September 2004.

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.

Information Contacts: *Juan Takai Camacho* and *Ramon Chong*, CNMI/EMO, Saipan, MP 96950, USA (URL: http://www.cnimemo.org; Email: juantcamacho@hotmail.com and rcchongemo@hotmail.com); *Frank Trusdell*, Hawaii Volcano Observatory, U.S. Geological Survey (HVO/USGS), Hawaii National Park, HI 96718, USA (URL: http://hvo.wr.usgs.gov/cnmi/; Email: trusdell@usgs.gov); *Washington Volcanic Ash Advisory Center (VAAC)*, Satellite Analysis Branch, NOAA/NESDIS E/SP23, NOAA Science Center Room 401, 5200 Auth Road, Camp Springs, MD 20746 USA (URL: http://www.ssd.noaa.gov/).

Asama

Honshu, Japan
36.40°N, 138.53°E; summit elev. 2,560 m
All times are local (= UTC + 9 hours)

An explosive eruption occurred from the summit crater of Asama at 2002 on 1 September 2004. Most of the initial reporting was in Japanese, although many of those reports had segments in English. Setsuya Nakada and Yukio Hayakawa provided links to initially available reports. According to the Geological Survey of Japan's website (managed by N. Geshi) and an article there summarizing contributions from many organizations and authors, the 1 September eruption was a single Vulcanian explosion.

According to the preliminary report of JMA, red-hot blocks spread several kilometers from the summit and caused many wildfires. Video images showed an extraordinary amount of incandescence at height, as well as bright zones on the ground surface. Some of the burns remained limited to the area of contact between the hot bombs and alpine vegetation.

On 3 September Yukio Hayakawa (Gunma University) visited parts of Asama's upland areas where wildfires had occurred (figure 5). There he found bombs up to a meter in diameter. Because of their greater size, the larger bombs cooled more slowly and had the greatest thermal impact. At least one large bomb had cracked and fragmented on impact, delivering relatively hot material over a wide area. This process accounted for the largest burned area he inspected. Hayakawa photographed an impressive impact crater associated with a large volcanic bomb from the 1 September eruption (figure 6). Along the impact crater's rim, the network of low-lying alpine vegetation was torn loose and lay folded back and upside-down.

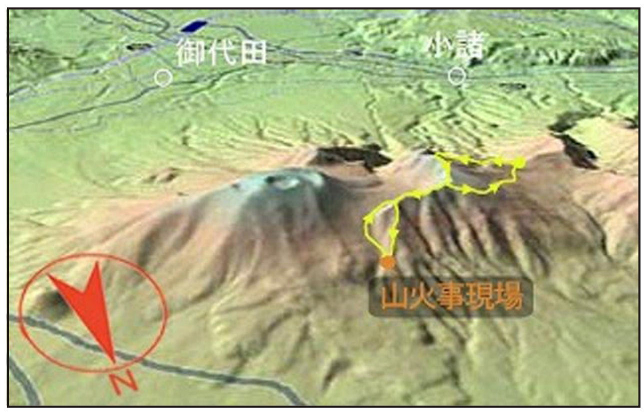

Figure 5. An image depicting Asama's topography with the route hiked (yellow) to investigate the eruption-induced wildfires (orange dot is the fire site investigated, at ~ 2,000 m elevation). Two urban areas indicated in Japanese on the map are Miyota town and Komoro city (white circles on left and right, respectively); the two sit ~ 7 km apart. Courtesy of Yukio Hayakawa, Gunma University.

Figure 6. A fresh impact crater formed by a large bomb from the 1 September 2004 Asama eruption. Crater diameter at the plane of the undisturbed land surface was ~ 6 m, crater depth was ~ 1 m, and the rim of disturbed material stood up to ~ 0.5 m high. The impactor is visible at the NW wall of the crater (~ 0.8 m). Courtesy of Yukio Hayakawa, Gunma University.

After the eruption, a helicopter flight around the volcano also confirmed that many ballistic blocks had landed on the volcano's upper flanks (figure 7). Asia Air Survey (Ltd.) also compiled a comprehensive set of post-eruption aerial stereophotos of Asama and surroundings. Ones taken of the crater on 3 September showed the principal crater immersed in a circular bank of dense white volcanic gases. A thin white plume blew NE. Impact scars were also visible on these photos, scattered over the upper flanks.

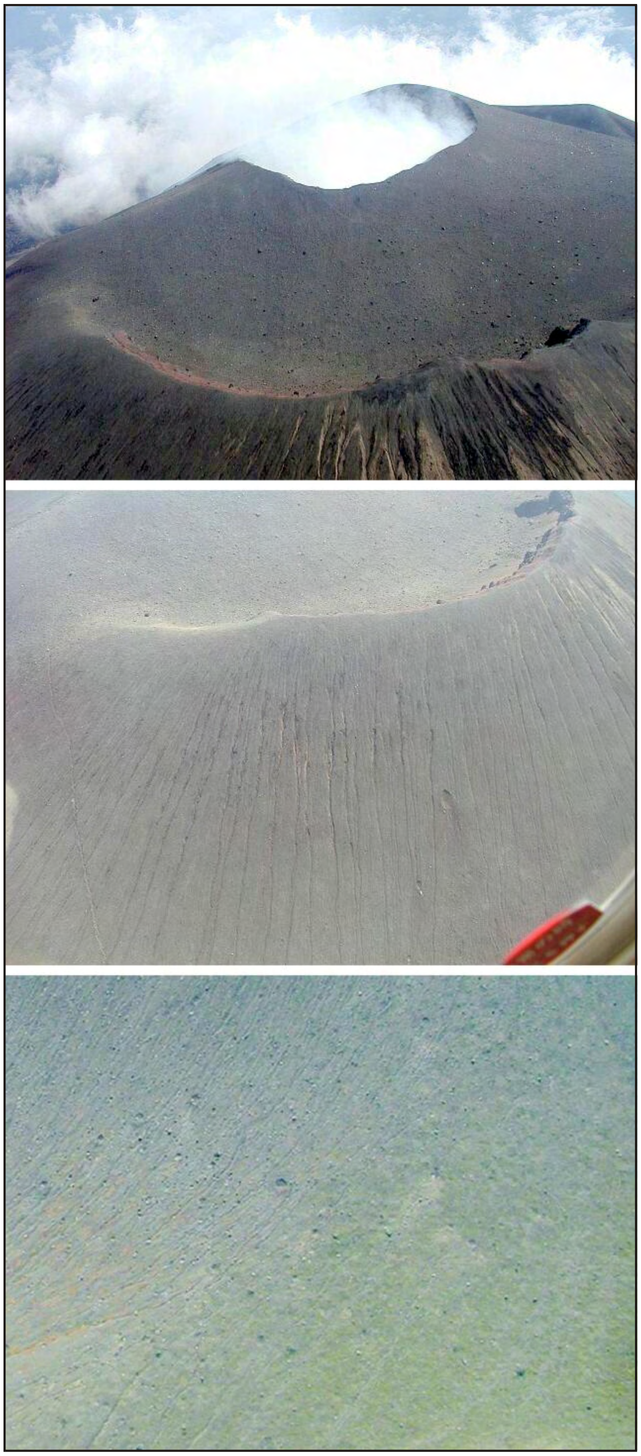

Figure 7. The Asama summit crater as seen in a series of shots taken from a helicopter two days after the 1 September 2004 eruption: (top) The main crater engulfed in white fumes with a thin plume blowing NE; (center) a closer view of the outer W flank and adjacent moat area, ~ 1 km from the crater; (bottom) a still closer view depicting a conspicuously cratered surface on the summit's NW flank. The center photo also shows two big craters in the center right; a trail following the outer crater rim is largely tephra covered but segments remain recognizable. Courtesy of the Geological Survey of Japan (captions and photos by H. Hoshizumi, GSJ).

Tephra sampling and distribution. Strong winds blew the eruption cloud NE. Ashfall occurred ~ 250 km from the volcano and reached to the Pacific Ocean (with ash reported at the coastal locations of Soma and Haranomachi cities in Fukushima Prefecture). The ash-fall deposit covered a narrow and elongated area, forming a classic cigar-shaped pattern. Field work was begun to establish the mass and distribution of the tephra blanket (figure 8). The Earthquake Research Institute (ERI) noted that 5-cm-diameter cinders appeared up to ~ 5 km from the crater. In some cases rainfall occurred during or after the ashfall; in some cases it washed away fine-grained portions of the ash-fall deposit. In preliminary ERI and Geological Survey of Japan (GSJ) reports and personal communication, workers calculated tentative estimates of eruptive products on the order of 40,000-230,000 metric tons. The initial estimate by Hayakawa was 200,000 metric tons.

Geophysical and geochemical observations. Investigators at ERI Tokyo plotted the time-series of deformation recorded by four 3-component GPS stations within a few kilometers of the summit over January to early September 2004. Of these, only one station, ASM4, ~ 4 km S of the summit, showed any clear and consistent variation. Its changes were only clear in one component: it moved to the S on the order of 5-10 mm, motion that became most apparent after June 2004 (figure 9). Other groups also maintained GPS (and tilt?) stations on Asama and may have seen more diagnostic ground displacement associated with the eruption.

ERI briefly discussed seismic signals received at the station for Asama, which arrived at about 2002 on 1 September 2004. The first extensive seismic signal was of elevated amplitude and persisted for about a minute. Another plot suggested that the entire set of 1 September eruptive signals spanned about 30 minutes. SO_2 measurements used the differential optical absorption spectrometer (DOAS) technique. Ground-based traverses on 3 September measured an average of 1,475 metric tons/day, with respective measured lows and highs of 1,168 and 1,738 tons/day.

Satellite data. The TOMS Volcanic Emissions Group used the Atmospheric Infrared Sounder (AIRS) to detect emissions from Asama's 1 September eruption. AIRS is a hyperspectral imager on the EOS/Aqua satellite. It provides higher spatial resolution than TOMS, and as an infrared sensor it produces nighttime images of volcanic clouds. AIRS volcanic cloud studies are a collaborative effort between the TOMS group and the Atmospheric Spectroscopy Laboratory in the Department of Physics at UMBC.

A sub-circular cloud was associated with the eruption on 1 September (figure 10). When detected at 1554 UTC the cloud was well out over the Pacific Ocean, ~ 640 km from Asama. Travel time for the cloud was 4 hours and 52 minutes, which implies a (straight line) mean velocity for the cloud's center of ~ 130 km/hour. Even though there was no quantitative estimate of aerosol and gas, there was a strong volcanic signal. The AIRS image is presented as a bias difference (in Kelvin, K; the scale at the right). The larger the bias difference, the stronger the volcanic signal. In this case, a significant area reached a difference of over 10 K.

Background. Asama, Honshu Island'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 E 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 shield volcano 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 E flank. Maekake-yama, capped by the Kama-yama pyroclastic cone that forms the present summit of the volcano, is probably only a few thousand years old and has an historical record dating back at least to the 11th century AD. Maekake-yama has had several major plinian eruptions, the last two of which occurred in 1108 and 1783 AD.

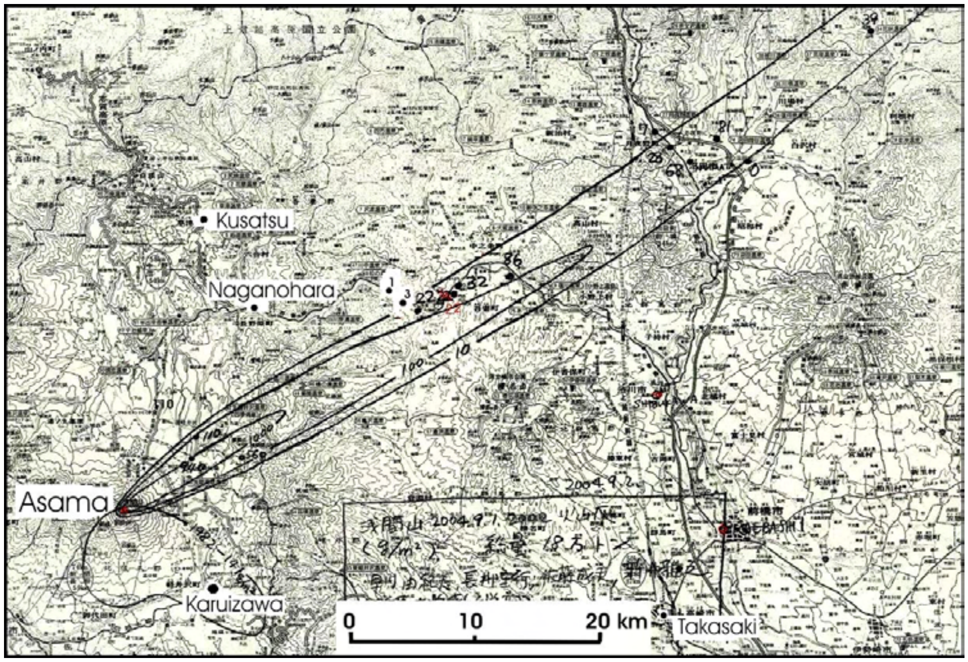

Figure 8. One preliminary (working) map of Asama's 1 September 2004 tephra mass (out to ~ 70 km from the source) showing data points used to constrain the isomass contours (in units of grams per meter squared). For comparison, one S- to SE-directed isomass contour (141 g/m^2) was also included from a 1982 eruption. The base map is in Japanese but English names have been added to selected urban areas. Courtesy of Yukio Hayakawa, Gunma University.

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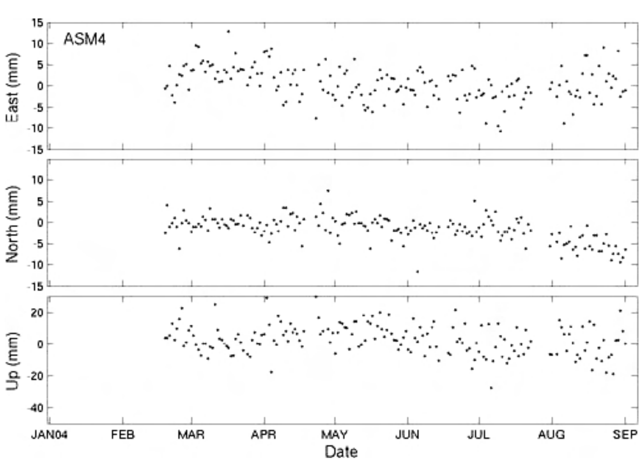

Figure 9. Time-series deformation of Asama recorded at GPS station ASM4, January-September 2004. The three orthogonal components are shown as follows: Upper row is in the E-W direction, middle row is in the N-S direction, and bottom row is in the up-down direction. The GPS reference frame was ITRF2000. These data were posted on the web on 6 September 2004 by the Volcano Research Center, University of Tokyo.

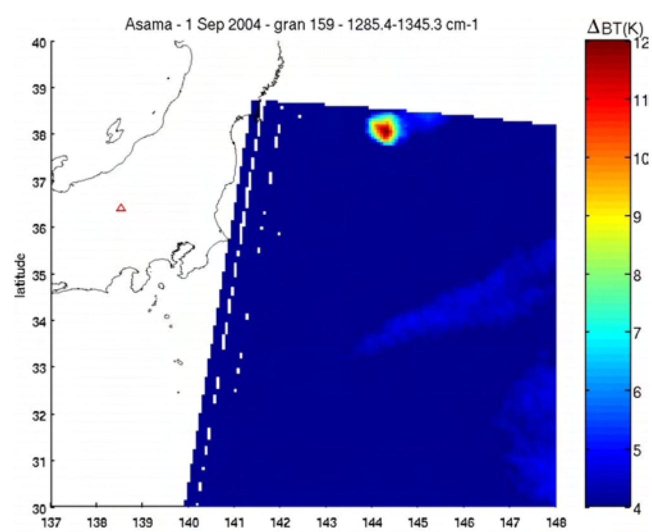

Figure 10. Asama's 1 September 2004 eruption generated a cloud that persisted and was imaged ~ 640 km ENE. The local time of this image was 0054 on 2 September (1554 UTC 1 September). Courtesy of Simon Carn and L. Larrabee Strow, UMBC.

Arenal

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

A sequence of pyroclastic flows moved down the N and NE flanks in September 2003 (*Bulletin* v. 28, no. 9). In general, Arenal's behavior during October 2003-March 2004 was similar to past years, with Crater C exhibiting ongoing gas emissions, lava flows, and sporadic Strombolian eruptions, and Crater D emitting fumarolic gases. The month with the highest number of inferred eruption earthquakes and the longest duration of tremor was March 2004 (table 5); long-period earthquakes spiked in May 2004.

Typical NE-flank lava flows persisted on 11 October 2003; in addition, some lava flows began to descend the SE flank, but they ceased by month's end. November 2003 reports noted NE-flank lava flows reaching 8 km NE of the edifice. There were a few October eruptions that produced columns of ash more than 500 m above Crater C's rim. During November lava flows persisted on the NE; some extended 8 km. During December 2003, tephra fell on both Crater C's NE and SE sides; acid rain was also noted.

On 12 March 2004 a hot avalanche occurred at the lava front progressing toward Arenal's NE side; the avalanche cascaded downslope and stopped at 850 m elevation. Near the crater's N edge some blocks fell and portions of that mass-wasting event reached vegetation. Eruptive activity declined but crevasses continue to widen. Small cold avalanches were also seen.

Pyroclastic flows on 6 July 2004. At 1319 on 6 July a series of pyroclastic flows descended the NE flank; other pyroclastic flows may have occurred later. Several medium-size pulses affected some patches of vegetation in the lower areas of the cone, ~ 900 m below the summit. The hot avalanches and airborne materials formed a plume of ash and dust blown SW. The pyroclastic flows resulted from the collapse of the upper areas of a lava flow, and impacted an area affected by flows during 1999-2003, but also invaded other areas. This type of phenomena has been common, particularly in recent years, to the N and NE. Figure 11 shows the distal portion of the area of pyroclastic-flow. Deposits included both abundant fine-grained materials and substantial blocks. Direct observations were hampered by the pyroclastic flows as well as cloud cover. Authorities temporarily closed routes around the volcano, but the area was within the National Park in a zone excluding visitors.

Month	Eruption earthquakes	Tremor (hours)	Long-period earthquakes
Oct 2003	997	521	16
Nov 2003	724	468	—
Dec 2003	—	—	—
Jan 2004	910	610	10
Feb 2004	896	639	8
Mar 2004	1169	661	18
Apr 2004	957	604	4
May 2004	901	405	53
Jun 2004	974	401	—

Table 5. Seismic activity registered at Arenal's station VACR, October 2003-June 2004. From 24 June onward, the seismic station was out of service. Courtesy of OVSICORI-UNA.

Background. Conical Volcán Arenal is the youngest stratovolcano in Costa Rica and one of its most active. The 1,657-m-high andesitic volcano towers above Lake Arenal, which has been enlarged by a hydroelectric project. Arenal lies along a volcanic chain that has migrated to the NW from the late-Pleistocene Los Perdidos lava domes through the Pleistocene-to-Holocene Chato volcano, which contains a 500-m-wide, lake-filled summit crater. The earliest known eruptions of Arenal took place about 7,000 years ago. Growth of Arenal has been characterized by periodic major explosive eruptions at several-hundred-year intervals and periods of lava effusion that armor the cone. Arenal's most recent eruptive period began with a major explosive eruption in 1968. Continuous explosive activity accompanied by slow lava effusion and the occasional emission of pyroclastic flows has occurred since then from vents at the summit and on the upper western flank.

Information Contact: *Observatorio Vulcanológico y Sismológico de Costa Rica*, Universidad Nacional (OVSICORI-UNA), Apartado 86-3000, Heredia, Costa Rica. (URL: http://www.ovsicori.una.ac.cr).

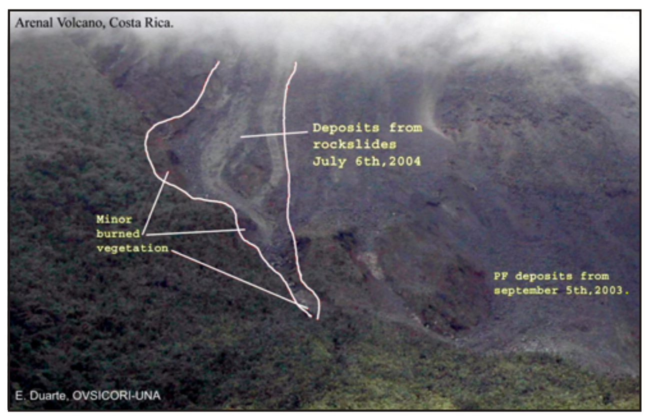

Figure 11. The lower portions of Arenal's 6 July 2004 pyroclastic-flow deposit, as outlined by OVSICORI-UNA scientists. Eliecer Duarte provided a rough estimate of distance from the middle left to the lower right side of the area (the 'heel to the tip of the toe') as 250 m. Locations of some of the burned and singed vegetation are indicated. Loose mass-wasted materials (labeled as deposits from rockslides) also accompanied the pyroclastic flows. Courtesy of OVSICORI-UNA.

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