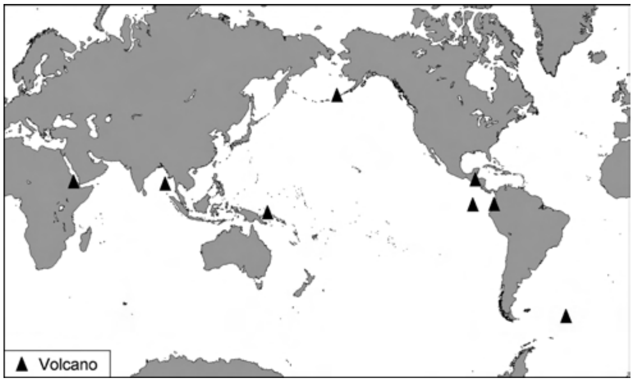
Bulletin of the Global Volcanism Network



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Dabbahu

Ethiopia
12.60°N, 40.48°E; summit elev. 1,442 m
All times are local (= UTC + 3 hours)

An eruption began on 26 September 2005 in the Afar triangle region of NW Ethiopia, near the Afar's W topographic margin, a spot ~ 330 km E of Lake Tan'a (the source of the Blue Nile river) and ~ 320 km NNW of the city of Djibouti. The venting took place on the flanks of Dabbahu (Boina), a volcano without previous historical eruptions. What follows is a brief synopsis of seismicity available from the USGS and some field observations from Gezahegn Yirgu, Dereje Ayalew, Asfawossen Asrat, and Atalay Ayele of Addis Ababa University (AAU). Shortly after the *Bulletin* editors received the AAU report, normal lines of communication were temporarily halted due to civil unrest. Consequently, this report was reviewed and augmented by Anthony Philpotts of the University of Connecticut, who had flown to Erta Ale and Dabbahu with them and other scientists on 16 October 2005.

Dabbahu, a stratovolcano, also goes by several other names, including Mount Dabbahu, Boina, Moina, and Boyna. The eruption occurred at least 5 km NE of Dabbahu's summit area, at a flat spot referred to by the names Da'Ure and Teru Boyna. The profusion of names and spellings for this region of Africa partly stems from widely dissimilar alphabets; the one used in the region has over 100 letters, complicating conversion into languages having only 26.

The Dabbahu eruption has been confusing. Initial news reports shed little light on the eruption's source, size, or impact. Several news reports stated that nearby earthquakes had caused an eruption at Erta Ale, which is 113 km N of Dabbahu, but that was not the critical eruption in this region during late September. (Seismicity, however, did appear associated with an elevated level of unrest at Erta Ale in October-see report in this issue.) The confusion propagated into the *Smithsonian-USGS Weekly Report* of 5-11 October 2005, which incorrectly attributed some details of the Dabbahu eruption to Erta Ale. A correction was issued and the report was withdrawn. Official sources and news reports also seem to have initially overstated the impact (e.g., statements like 50,000 nomads evacuated, almost 500 goats killed, etc.).

In a later, more measured report, *The Ethiopian Herald* posted a 6 October article on the web that noted the following.

"... the [Disaster Prevention and Preparedness Commission] has sent relief aid, household utensils and a tanker truck to areas affected by the natural disaster. A regional committee set up in charge of studying the magnitude of the disaster has already sent its report to the commission. According to the report, 1,215 quintals [121,500 kg] of food aid has been dispatched to 6,384 citizens displaced from Boya and Debawo ... and resettled in Debabo locality, 20 km from Teru. Some 18,234 various household utensils, 1,280 blankets as well as 119 roles of plastic sheets were being transported to the area."

According to faculty at Addis Ababa University, prior to the eruption and in addition to the earthquake swarm there was also volcanic tremor, as well as faulting, fracturing, and possible local landslides.

Earthquake swarm. During September-4 October 2005, an earthquake swarm consisting of 131 events occurred at and immediately surrounding Dabbahu (figure 1 and table 1). The swarm was sudden and comparatively intense, with magnitudes ranging from body-wave magnitude (mb) 3.9 to 5.2. Instruments registered earthquakes of both the highest number and magnitude during 24-26 September, just prior to the 26 September eruption. Seismicity in the area declined sharply on 27 September and stopped on 4 October. According to another data set, earthquakes occurred in the region during the 5 years prior to this swarm at an average rate of ~ 12 per year.

First-hand observations. Gezahegn Yirgu of AAU submitted a preliminary description of the eruption. He reported that people in the area noted that on 26 September at about 1300 a very strong earthquake occurred. That was followed by a dark column of "smoke" that rose high into the atmosphere and spread out to form an umbrella-shaped cloud. Emissions darkened the area for 3 days and 3 nights. On their first visit, provoked by the abnormal seismicity,

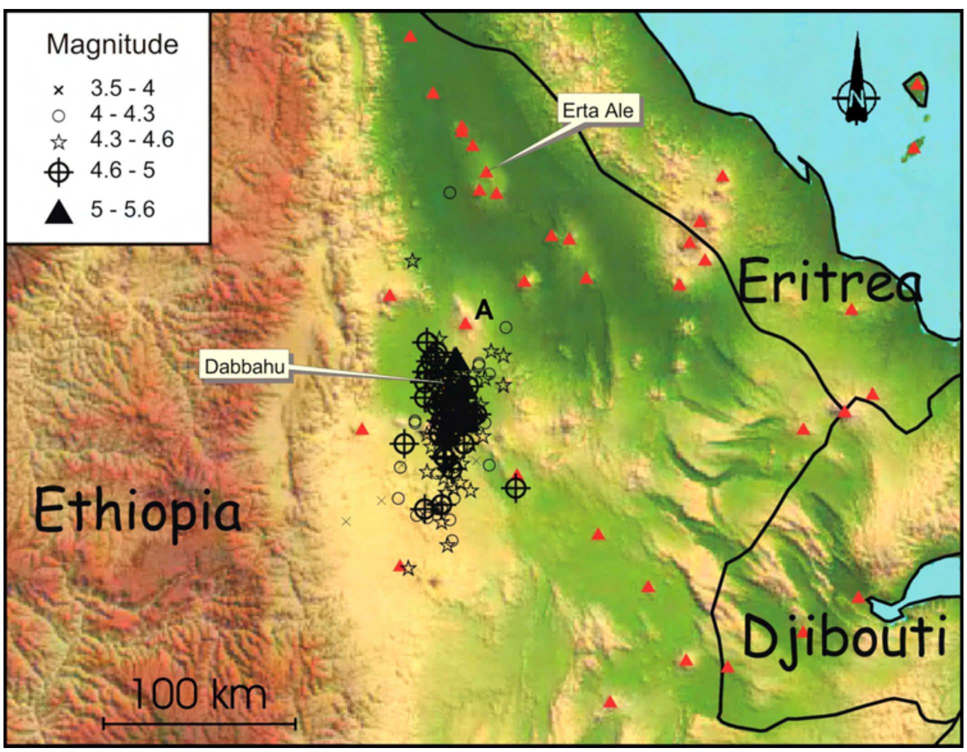

Figure 1. A map showing Dabbahu volcano in the Afar triangle, along with epicenters from the earthquake swarm of 14 September to 4 October 2005 The solid triangles indicate Holocene volcanoes, although the one for Dabbahu is swamped by the pattern of epicenters. The Alayta shield volcano (labeled "A") sits 32.7 km NNE of Dabbahu's summit and erupted several times in the early 1900's. Epicenters were compiled from the U.S. Geological Survey (USGS) National Earthquake Information Center website.

Date	Events	Maximum Magnitude
14 Sep 2005	1	4.6 mb
20 Sep 2005	2	5.5 Mw
21 Sep 2005	16	4.9 mb
22 Sep 2005	12	4.9 mb
23 Sep 2005	9	4.8 mb
24 Sep 2005	29	5.6 Mw
25 Sep 2005	42	5.2 mb
26 Sep 2005	9	5.2 mb
27 Sep 2005	1	4.5 mb
28 Sep 2005	5	5.1 mb
29 Sep 2005	2	4.8 mb
01 Oct 2005	1	4.5 mb
02 Oct 2005	1	5.0 mb
04 Oct 2005	1	4.5 mb

Table 1. Daily number and maximum magnitude of earthquakes located in the Dabbahu region during 14 September-4 October 2005 (up to 42 per day, with a total of 131 earthquakes). Mw stands for moment magnitude; mb stands for body-wave magnitude. Data courtesy of National Earthquake Information Center, USGS.

his team departed the site just two hours before the 26 September eruption. He went back to Dabbahu for several more visits, some of which included geologists from overseas.

The visitors found that a minor explosive eruption had taken place from a fissure-vent system, producing a light-colored ash layer that extended over 500 m from the vent (figure 2). The eruption threw out pre-existing near-surface pyroclastic deposits (sediments) and felsic lavas, and redeposited them near the vent (figure 3). Some of the rocks that were thrown 20 m from the vent measured 2-3 m across. Fine white ash fell in the surrounding region as far as Teru village, 40 km SW of the eruption site.

Roughly two-thirds of the way from the S end of the fissure vent, a 30-m-diameter pumice dome formed. From within the fractures in this dome, the team heard a sound from below resembling the sound of a helicopter engine or a boiling liquid.

The bulk of Yirgu's report on the second visit to the eruption site, on 4-5 October, follows.

"A team of three geologists and one geophysicist (Gezahegn Yirgu, Dereje Ayalew, Asfawossen Asrat, and Atalay Ayele) revisited the Da'Ure locality (at approximately 120° 43' 37" N, 40° 32' 55" E) immediately adjacent to the NE flank of the Quaternary Boina felsic complex. This locality is the southwestern extension of the area we visited a week earlier and where we observed a number of newly opened parallel fissures and a major reactivated normal fault.

"We first investigated the area where a volcanic eruption had been reported. Here we observed the presence of a wide and elongate fissure more than 500 m long and about 60 m deep [(figures 2 and 3)]. The elongate fissure attains a maximum width of about 100 m where a semi-circular pit has formed and from where the explosive eruption appears to have taken place. This elongate vent is oriented almost N-S [trending N10W] and has bro-

Figure 2. An aerial view of the fissure vent at Da'Ure (Dabbahu) taken around 4-5 October 2005, showing the post-eruptive scene captured by a camera that was aimed down and toward the NW. The fissure vent, which extends ~500 m and trends nearly N-S, cuts across the photo diagonally (for sense of scale, see people in figure 4). The deepest part, ~100 m below the surface, lies along the vent's base at its widest point. It exposes dark material at the bottom (see figure 3). N of that wide segment lies a cauliflower-shaped pumice dome, a feature ~30 m in diameter. What appears as a short, narrow segment of the fissure vent continuing in the distance behind (to the N of) the dome is actually longer and more prominent than it appears, owing to foreshortening due to camera angle, surface topography, and perspective to the more distant location. This northernmost segment of the vent is roughly one-third as long as the segment in front of the dome. Photo taken by Asfawossen Asrat.

Figure 3. An aerial view of the fissure vent at Da'Ure (Dabbahu) taken around 4-5 October 2005, showing the post-eruptive scene captured by a camera aimed down and approximately NE. This image presents enlarged views of both the pumice dome and the fissure vent's lower portions. (For sense of scale, see figure 4). Photo taken by Asfawossen Asrat.

ken through felsic pyroclastic deposits and lavas. Two smaller pits were also observed farther N along the fissure [situated] to the N of the major pit. A very fine and light grey ash has been deposited on both sides of the elongate fissure with the ash cover extending more than 500 m away from the vent. Beneath the ash deposit lies a sequence of loose layers consisting of mixed volcanic ash and ejecta from pre-existing fissure wall rocks. These layers have a total thickness of about 20 m near the large pit."

At the pumice dome Yirgu noted "... intense degassing is occurring with the production of SO_2 as evidenced by its smell as far as 500 m away. Degassing is also visible along the length of the vent as well as through nearby fissures. The local people have reported that on 26 September 2005 at about 1300 local time a very strong earthquake shook the area. This was followed by a dark column of 'smoke' that rose high into the atmosphere and spread out to form a cloud, which darkened the area for three days and three nights. Our field observations were consistent with . . . [a minor ejection] of volcanic ash from a small vent or vents along the opened fissure."

"In the same locality, we also studied the newly formed second-order fractures and fissures, most of which were located on the eastern side of the main eruptive fissure/vent. Here, the [roughly N- to S-trending] fractures and fissures were all parallel to each other .... They were better developed on unconsolidated pyroclastic deposits and sediments; they affected an area nearly 700 m away from the main eruptive vent/fissure; spacing is commonly between 10 and 20 m; some extend discontinuously along strike for over 500 m, as observed from the helicopter; open fissures in the pyroclastic deposits measure up to 20 cm wide with common elliptical pits or collapse structures between fissures up to 4 m wide and up to 4 m deep.

Figure 5. Curving fractures in the top of the new Da'Ure (Dabbahu) pumice dome; view looking N. Two people are visible in the photo, one immediately behind the large central fracture. It was from these fractures the boiling noise had been heard the previous week. No sound was heard during the visit on 16 October. Courtesy of Anthony Philpotts.

"We have also observed a major reactivation on a N- to S-trending normal fault located some 500 m to the E of the elongate eruptive vent/opening. This fault breaks through felsic lavas and unwelded pyroclastic deposits and has a reactivated displacement (down thrown to the W) reaching half a meter in places. This reactivated fault extends . . . discontinuously for at least three kilometers as observed from the helicopter. Degassing is occurring along some parts of this fault."

Figure 4. A view taken from Da'Ure's (Dabbahu's) new pumice dome looking S down the fissure vent on 16 October 2005, with people for scale. Part of the outer flank of Dabbahu is visible on the right side of the photo; Dabbahu's central area lies farther to the right off the margin of the photo. Courtesy of Anthony Philpotts.

Yirgu also said that, according to the AAU Geophysical Observatory, seismicity continued in early October in the area affected by the eruption, faulting, and fissuring.

Other data from a 16 October visit. Anthony Philpotts accompanied a team who, along with AAU colleagues, were helicoptered to the eruption site, which had completely ceased by this time. At the eruption site and on the helicopter trip to and from it, he saw no dead nor injured livestock. The team also visited a refugee camp for displaced nomads.

In discussions with AAU colleagues who saw the fissure vent during multiple visits, and in

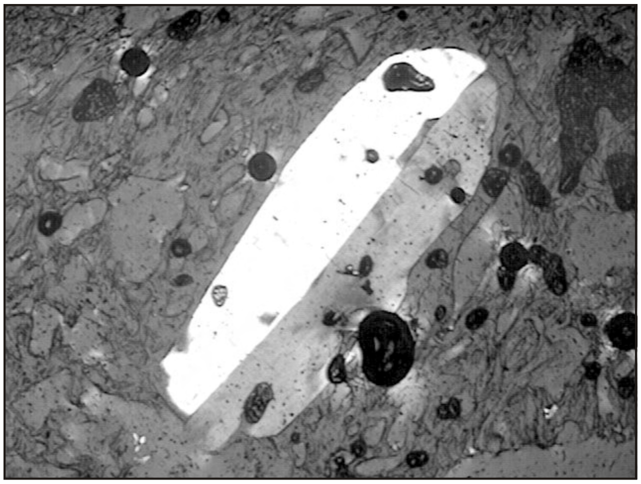

Figure 6. A rounded, twinned phenocryst of sanidine feldspar in pumice from the Da'Ure (Dabbahu) dome in the center of the vent. Dark circles are air bubbles trapped during preparation of the thin section. The photo was taken with partly crossed polarizing filters; the width of the entire field is 1.62 mm. Courtesy of Anthony Philpotts.

comparing photographs, it appeared that material exposed at depth in the wall of the vent changed to a lighter color. Presumably, these color changes were linked to water, initially present but that had evaporated in the intense heat of the Afar day. Philpotts suggested that if the vent did provide a window into the water table, groundwater may have added to the explosive activity.

Philpotts said that when they arrived, on 16 October, the pumice dome (shown in close-up in figure 5) still yielded temperatures of 400°C in cracks. The pumice dome lacked any deposits on top of its upper surfaces, and thus clearly represented the last volcanic feature to form. Some post-eruptive faulting was noticed with offsets on the order of 10 m.

Philpotts made several thin sections of pumice dome samples, and found it to be almost totally aphyric. It contains a very few rounded (resorbed) sanidine phenocrysts (figure 6) and needle-shaped microlites with high refractive index (pyroxene?). He noted that "The microlites undoubtedly formed during emplacement of the dome, but the resorption of the sanidine phenocrysts must have occurred at depth prior to eruption and probably indicates heating of the source magma chamber with an influx of hotter (basaltic?) magma."

Background. Dabbahu, also known as Boina or Moina, is a Holocene volcanic massif forming an axial range of the Afar depression SSW of the Alayta massif. Pantelleritic obsidian flows, lava domes, and pumice cones form the summit and upper flanks of the volcano, which rises above the Teru Plain and was built over a base of basaltic-to-trachytic lava flows of a shield volcano. Late-stage basaltic fissure eruptions occurred at the NW base of the volcano. Abundant fumaroles are located along the crest of the volcano and extend NE towards Alayta.

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Erta Ale

Ethiopia
13.60°N, 40.67°E; summit elev. 613 m
All times are local (= UTC + 3 hours)

In conjunction with their investigation of eruptive activity related to a swarm of earthquakes at Dabbahu/Boina, a team of geologists from Addis Ababa University (AAU) also undertook field observations at Erta Ale, with the aid of a military helicopter (see map in this issue of *BGVN*, the report on Dabbahu/Boina). What follows is their report combined with other information they gathered.

Between 21 and 24 September 2005, the local people saw, from a distance, red and glowing light shooting and rising into the air above Erta Ale. This was an indication that a Strombolian eruption probably occurred, emitting a significant volume of fresh magma within and possibly out of the pit.

The AAU team surveyed Erta Ale's craters at about 0930 on 26 September from the helicopter, as landing was not possible. Within the small southern pit crater of the main crater, they observed a new cone-shaped construct and the presence of an actively convecting lava lake in the center of the new cone. The lava lake occupied the entire lower/inner pit with hot red lava visibly overturning at the edges of the pit. Molten lava was breaking through the lake's solidified black crust. In the northern pit crater, there was a conspicuous solidified lava bulge with dark emissions along the crater walls. No incandescent lava was visible in this pit.

In addition to their direct observations, the AAU team studied videos taken by Walta Information Center of the southern pit on November 2004 and 26 September 2005. The comparison revealed significant changes, particularly in the morphology and activity of the southern pit crater. In the later videos the main crater/pit had widened significantly, with portions of the earlier crater walls having collapsed into the lava lake. There was a new cone-shaped construct within the crater in place of the previous platform that existed between the rim of the outer crater/pit and the lower pit. The new cone was estimated to be some 20 to 30 m from the top of the crater rim. The new cone apparently contained layers of basaltic scoria covered by fresh lava flows. The combined thickness of tephra and lava was estimated to be 20 to 30 m. The lava lake occupied the entire width of the inner crater/pit and was then bounded by steep sides. The lake's surface stood 20 to 30 m below the cone's top.

Anthony Philpotts accompanied Gezahegn Yirgu and colleagues from Addis Ababa University faculty on a helicopter visit to Erta Ale on 15 October. They found the lava lake incredibly active, much more so than when filmed by earlier visitors in March 2005.

A brief review of satellite thermal anomaly data from MODIS/MODVOLC revealed an absence of thermal activity between 12 October 2004 and 31 March 2005, with a renewal beginning on 31 March 2005, increasing substantially in mid-2005 and continuing vigorously through at least 2 November 2005.

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.

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Barren Island

Andaman Islands, Indian Ocean
12.278°N, 93.858°E; summit elev. 354 m

The latest eruption of Barren Island began about 28 May 2005 (*BGVN* 30:05 and 30:07). The following additional information regarding this eruption was provided by Dhanapati Haldar (Presidency College). A photograph (figure 7) taken on 21 July by the Indian Coast Guard indicated that the lava pouring from the main crater had cascaded down to arrive at two points on the W shore. The seawater boiled profusely.

On 28 August, a senior geologist with the Central Ground Water Board (CGWB), A. Kar, made observations from a ship (figure 8). Kar noted that Strombolian eruptive activity had increased, and was both explosive and effusive in nature. The main crater and a newly created vent on the N flank were active. Streams of hot lava flowed down the slope of the cinder cone at the main crater. This cinder cone was built during the eruption in 1787-1832 and modified during subsequent eruptive pulses in 1991, in 1994-95, and (the current episode) in 2005. Kar's observations on 28 August 2005 noted that the descending lava flows traveled to the W shore, entering the sea near the lone preexisting landing site and ~ 250 m S of it. The latter was where the lava stream had met the sea during the 1994-95 eruption. Gas columns rose to more than 2 km, and fire fountains attained a height of around 300 m.

Kar visited the island again on 2 September and noted that eruptive activity was continuing unabated. As before, a thick gas plume hovered over the N part of the island, and hot lava still flowed down into the sea. The lava coming in contact with sea water was immediately broken into fine particles that were forcefully thrown into the air to a height of nearly 100 m. Accompanying steam rose to a height of about 300-400 m before being drawn away by the prevailing wind. The eruption column's top formed a spectacular mushroom of gas and smoke, blowing to the N. Subsequent reports received from the Indian Coast Guard indicated that the eruption was continuous until at least 25 Septembe.

All the active vents so far observed during 2005 eruption, including the S footwall vent, lie in a zone trending almost N-S. This zone conforms with a pre-existing surficial fracture. This alignment of the active vents had been noted during the 1991 and 1994-95 eruptions, and, as previously mentioned, the lava streams of the current eruption retraced the 1991 and 1994-95 lava routes.

Figure 7. Photo taken on 21 July 2005 showing the Barren Island eruption continuing unabated. Lava cascaded down and into the sea along the island's W shore. It entered the sea at two points following the pre-existing lava routes of the 1991 and 1994-95 eruptions. Courtesy of the Indian Coast Guard.

Figure 8. Photo taken 26 August 2005 showing Barren Island in Strombolian eruption. The main crater was active, and both explosive and effusive activity had shifted N. Hot lava (seen as incandescent strips) was flowing down the slope of the cinder cone. As before, lava entered the sea at two points on the W shore. Courtesy of A. Kar.

According to Haldar, recent lava samples show large (to 5 mm) megacrysts and phenocrysts of plagioclase (An 93-57), olivine (Fo 85-70), and diopside (Mg 47-44, Fe 16-10). The samples also included a groundmass of glass charged with microlites of plagioclase (An 50-45), augite, olivine, titanomagnetite, and rare orthopyroxene. The 2005 lavas contain relatively few olivine megacrysts, but are rich in plagioclase megacrysts, similar to the 1994-95 lavas.

The bulk chemical composition of the lava falls within the basalt field (table 2), which was comparable with the compositions of the 1994-95 lava. In comparison, the 2005 lava is slightly richer in both MgO and Na_2O and slightly lower in SiO_2.

As this issue went to press Haldar noted that Barren Island continued to vigorously spew lava, gas, and ash at least as late as 10 November 2005. The eruption was unabated since the last week of May 2005.

Background. Barren Island, a possession of India in the Andaman Sea about 135 km NE of Port Blair in the Andaman Islands, is the only historically active volcano along the N-S-trending volcanic arc extending between Sumatra and Burma (Myanmar). The 354-m-high island is the emergent summit of a volcano that rises from a depth of about 2250 m. The small, uninhabited 3-km-wide island contains a roughly 2-km-wide caldera with walls 250-350 m high. The caldera, which is open to the sea on the west, was created during a major explosive eruption in the late Pleistocene that produced pyroclastic-flow and -surge deposits. The morphology of a fresh pyroclastic cone that was constructed in the center of the caldera has varied during the course of historical eruptions. Lava flows fill much of the caldera floor and have reached the sea along the western coast during historical eruptions.

Information Contacts: *Dhanapati Haldar*, Presidency College, Kolkata, 4/3K/2 Ho-Chi-Min Sarani, Shakuntala Park, Biren Roy Road (West), Kolkata-700 061, India (Email: haldar2115@yahoo.co.uk); *Geological Survey of India*, 27 Jawaharlal Nehru road, Kolkata 700 016, India (URL: http://www.gsi.gov.in/barren.htm); *Indian Coast Guard*, National Stadium Complex, New Delhi 110 001, India (URL: http://indiancoastguard.nic.in/indiancoastguard/).

Analyzed Oxide	Bulk composition (%)	Groundmass glass composition (EMPA) (%)
SiO_2	49.80	58.31
TiO_2	0.82	0.69
Al_2O_3	21.04	19.38
Fe_2O_3 (total)	8.45	—
FeO (total)	—	6.16
MnO	0.14	0.02
MgO	4.23	1.30
CaO	10.91	7.13
Na_2O	3.47	5.26
K_2O	0.39	0.71
P_2O_5	0.10	0.18

Table 2. Analysis of one lava sample (number B1/05) erupted in June 2005 from Barren Island volcano. EMPA stands for electron microprobe analysis. Courtesy of Dhanapati Haldar.

Pago

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

During the observation interval 12-18 September 2005, Pago continued to be quiet. Very small volumes of thin white vapor were released from all vents. No noises were heard and no glow was observed. Seismic activity was low, with some small, high frequency earthquakes being recorded. The highest number of high frequency events on any given day was 3, recorded on 18 September.

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

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Ulawun

New Britain, Papua New Guinea
5.05°S, 151.33°E; summit elev. 2334 m
All times are local (= UTC + 10 hours)

During the week of 22-28 August 2005, Ulawun often remained quiet but also displayed continued restlessness. People from Tauke, on the S side of the volcano reported occasional low roaring, rumbling, and booming noises on 21-22 and 26-28 August. Emissions from the summit crater consisted of moderate volumes of thick grayish vapor released forcefully. Some traces of blue vapor were also visible, but no glow was observed. Seismicity fluctuated between low and moderate, marked by small low-frequency earthquakes and small sporadic volcanic tremors. Only one high-frequency earthquake was recorded. An earthquake was felt on 22 August by people from Tauke. Apparently the earthquake was not reported by the observer at Ulamona, NW of the volcano, suggesting it was local and focused on the S side of the volcano.

Ulawun remained quiet through mid-September 2005, with the summit crater releasing weak to moderate volumes of thick white vapor.

Background. The symmetrical basaltic-to-andesitic Ulawun stratovolcano is the highest volcano of the Bismarck arc, and one of Papua New Guinea's most frequently active. Ulawun volcano, also known as the North Son, rises above the N coast of the island of New Britain across a low saddle NE of Bamus volcano, the South Son. The upper 1,000 m of the 2,334-m-high Ulawun volcano is unvegetated. A prominent E-trending escarpment on the S may be the result of large-scale slumping. Satellitic cones occupy the NW and eastern flanks. A steep-walled valley cuts the NW side of Ulawun volcano, and a flank lava-flow complex lies to the S of this valley. Historical eruptions date back to the beginning of the 18th century. Twentieth-century eruptions were mildly explosive until 1967, but after 1970 several larger eruptions produced lava flows and basaltic pyroclastic flows, greatly modifying the summit crater.

Information Contacts: *Rabaul Volcano Observatory* (see Pago).

Montagu Island

South Sandwich Islands, Antarctica
58.42°S, 26.33°W; summit elev. 1,370 m

The first recorded eruption of Mt. Belinda volcano (Montagu Island), which began around 20 October 2001, continued (as reported in *BGVN* 28:02, 29:01, 29:09, 29:10) until at least the latter part of 2005. Information for the following report was prepared and submitted by Matt Patrick of the Hawai'i Institute of Geophysics and Planetology (HIGP) and John Smelie of the British Antarctic Survey, with the assistance of the HIGP Thermal Alerts Team.

This eruption was detected by the MODVOLC automated satellite detection system, which scans for anomalous thermal activity in MODIS (Moderate Resolution Imaging Spectroradiometer) satellite data over the entire Earth approximately twice per day (Wright and others, 2004). Investigators acquired a recent, 23 Sept 2005, cloud-free ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) image (15-30 m pixel size), which provided valuable information on a new phase of activity. It revealed a larger effusive eruption than previously identified in satellite imagery of Montagu Island (figure 9).

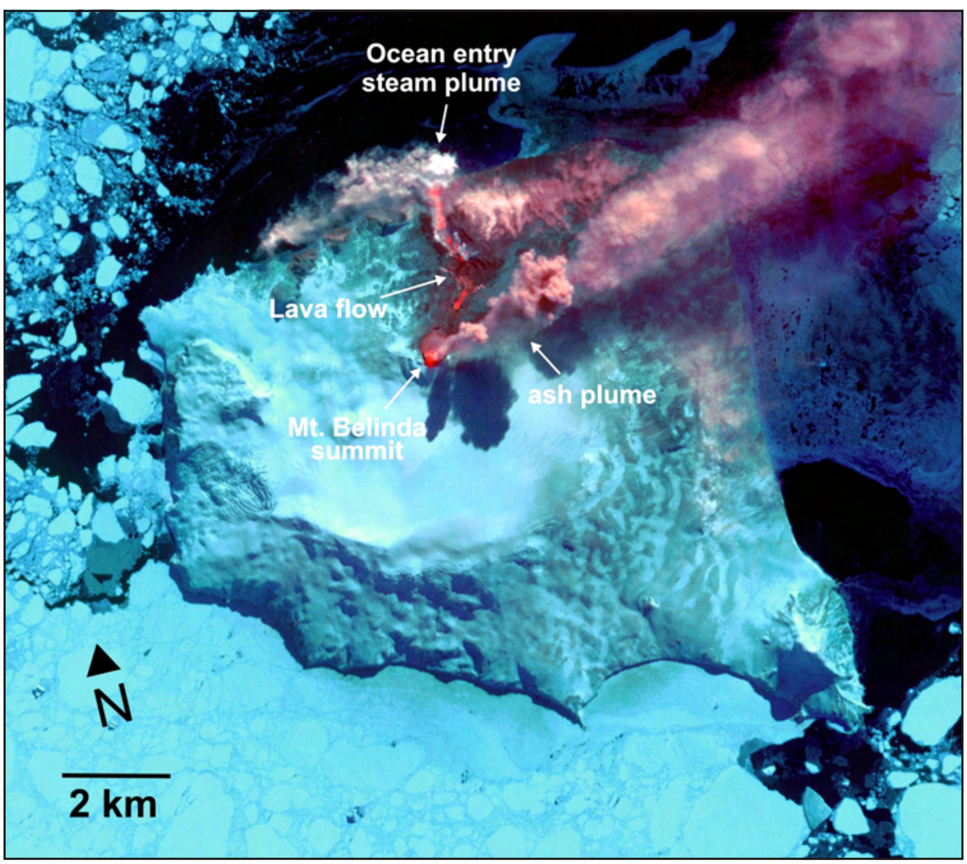

Figure 9. ASTER image showing Montagu Island's Mount Belinda on 23 September 2005. Courtesy of HIGP Thermal Alerts Team.

Based on frequent MODVOLC alerts (figure 10) and occasional high-resolution satellite data (ASTER, IKONOS, and Quickbird), Mount Belinda has maintained persistent activity since the start of the eruption. Activity has consisted of continuous steaming and low-intensity explosive events at the summit (presumably Strombolian), producing low-level ash plumes and ubiquitous tephra deposits on the island's ice cover, and at least three distinct effusive events. Several satellite images were posted by HIGP on the National Aeronautics and Space Administration (NASA) Earth Observer website, 13 October 2004 and 19 October 2005.

Scientists noted an intense shortwave-IR anomaly at the summit of Mt. Belinda in all cloud-free ASTER images acquired throughout the eruption. This suggested the presence of a lava lake in the summit crater (see Patrick and others, 2005, for more detailed information on the eruption).

Far from slowing down, the activity throughout 2005 marked the highest levels yet registered by MODVOLC (figure 10a). For the first time in 2005, radiant heat output exceeded 150 MW (see Wright and Flynn, 2004, and Wright and others, 2005, for calculation details).

By plotting the position of each anomalous MODVOLC pixel relative to the central vent (figure 10b) one can see that most pixels are within 1 km of the vent. This reflects the approximate scale of MODIS pixels and thus the inherent level of location ambiguity (note, however, these results fail to show the 2-km-long lava flow emplaced in mid-2003–see *BGVN* 29:01).

For the first time during this eruption, anomalous pixels began appearing more than 2 km away from the central vent on the satellite image for 0100 UTC on 15 September 2005, some up to 3.3 km away (figure 10b). This suggested the presence of a ~ 3 km long lava flow. Corroborating this was the ASTER image from 23 September 2005 (figure 9), which indicated heightened activity and a 3.5-km long lava flow extending from the summit cone of Mt. Belinda into the sea. A steam plume originated in the vicinity of the ocean entry. Note that the steam plume appears to drift W from its origin (where the plume is whitest), while the ash plume from the summit of Mt. Belinda

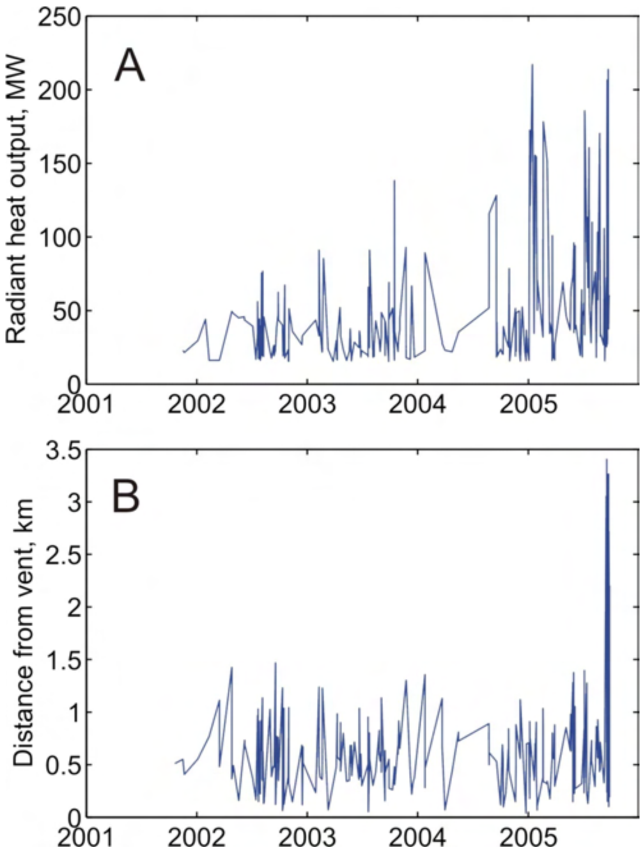

Figure 10. (A) Chronological graph of radiant heat output from Mount Belinda measured from satellite sensors. The date range depicted along the x-axis of this graph is from late 2001 to September 2005. (B) A plot showing the distance of satellite-measured thermal anomaly pixels from the Mount Belinda vent during the period 2001 to September 2005. Courtesy of HIGP Thermal Alerts Team.

(1,370 m elev.) drifts E, indicating varying wind directions at different elevations.

The lava flow initially traveled NE from the vent, but farther on it ran into a rocky arete, which diverted its path to due N. A 90-m-wide lava channel is visible at a distance of 1 km from the summit. The flow appears to be covered (perhaps entering a tube) within its first kilometer, where no anomalous shortwave IR pixels exist. It is unlikely that the flow is subglacial in this first kilometer, as its path is coincident with emplacement of the previously mentioned lava flow of mid-2003, which was 2 km long and had already melted ice along this route.

At the request of the British Antarctic Survey, the Royal Air Force sent an airplane from the Falkland Islands on 11 October 2005. The plane encountered cloudy conditions but those on board recognized steam rising from the sea. This flight took place prior to study of the 23 September ASTER image and thus it marked the first observation that lava reached the sea.

References: Patrick, M., Smellie, J.L., Harris, A.J.L., Wright, R., Dean, K., Izbekov, P., Garbeil, H., and Pilger, E., 2005, First recorded eruption of Mount Belinda volcano (Montagu Island), South Sandwich Islands: Bulletin of Volcanology, v. 67, p. 415-422.

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

Wright, R., Flynn, L.P., Garbeil, H., Harris, A.J.L., and Pilger, E., 2004, MODVOLC: near-real-time thermal monitoring of global volcanism: Journal of Volcanology and Geothermal Research, v. 135, p. 29-49.

Wright, R., Carn, S., and Flynn, L.P., 2005, A satellite chronology of the May-June 2003 eruption of Anatahan volcano: Journal of Volcanology and Geothermal Research, v. 146, p. 102-116.

Background. The largest of the South Sandwich Islands, Montagu consists of one or more stratovolcanoes with parasitic cones and/or domes. The summit of the 10 x 12 km wide, polygonal-shaped island rises about 3,000 m from the sea floor between Bristol and Saunders Islands. Around 90% of the island is ice-covered; glaciers extend to the sea over much of the island, forming vertical ice cliffs. The name Mount Belinda has been applied both to the high point at the southern end of a 6-km-wide ice-filled summit caldera and to the young central cone. Mount Oceanite, an isolated 900-m-high peak, lies at the SE tip of the island and was the source of lava flows exposed at Mathias Point and Allen Point. There was no record of Holocene or historical eruptive activity at Montagu until MODIS satellite data, beginning in late 2001, revealed thermal anomalies consistent with lava lake activity that has been persistent since then. Apparent plumes and single anomalous pixels were observed intermittently on AVHRR images during the period March 1995 to February 1998, possibly indicating earlier unconfirmed and more sporadic volcanic activity.

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Galeras

Colombia
1.22°N, 77.37°W; summit elev. 4,276 m

In a meeting abstract Gomez and others (2004) wrote, "Following 11 years of relatively low activity, Galeras . . . produced a sequence of ash eruptions in July and August 2004. . .. Initial evidence of the activity transition appeared in the gas measurements [of] early June, followed by a strong increase in the shallow seismic activity below the active cone on 27 June. As in many cases at other volcanoes, the most clear evidence for the transition came in the form of seismic swarms and tremor. The current activity has culminated in two brief episodes of ash emission, on 16 July and 21 July, followed by two longer episodes, [during] 27 July-8 August and 11-19 August. This last episode began with a large explosion and released more ash than any individual episode from 1989 to 1993. Sudden deformation, as well as changes in the electric and magnetic [EM] fields at the crater EM station, and [in] gas parameters such as CO_2 concentration and fumarole temperature accompanied the [16 and 21 July] ash emissions. Unfortunately, the EM and gas instruments were lost to ashfall shortly afterward."

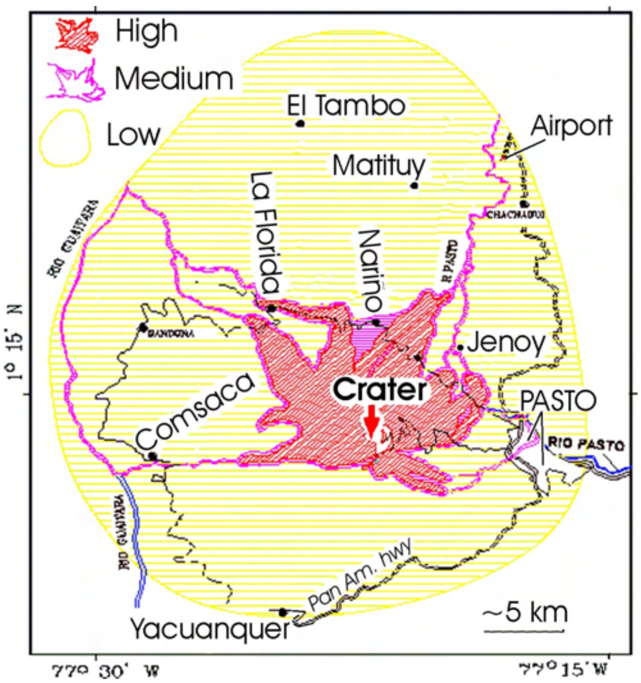

Figure 11. A hazards map prepared for Galeras. The key (upper left) shows symbols for risk zones (high, medium, and low). The settlement Genoy is also spelled Jenoy. This map is slightly modified from one by Observatorio Vulcanológico y Sismológico de Pasto, INGEOMINAS.

The same abstract also noted that "Starting in March 1996, a multiparameter real-time monitoring system was installed at Galeras, as a part of a cooperative program between INGEOMINAS [Instituto Colombiano de Geología y Minería] (Colombia) and the BGR [Bundesanstalt für Geowissenschaften und Rohstoffe] (Germany). Broadband seismometers were installed first, with electromagnetic (EM) sensors, sensors for the chemistry and physics of the fumarole gases, and a weather station following later. The data from these instruments augment the short-period seismic network and tiltmeters of Observatorio Vulcanológico de Pasto (OVP). Additional spot measurements [relied upon] visual inspection from the ground or helicopter, a thermal camera[,] and regular geological forays onto Galeras' slopes."

Our previous report covered events through late July 2004 (*BGVN* 29:07); this report discusses events through mid-October 2005. Besides the eruptions of July through August 2004, another month with vigorous activity was November 2004. A sudden explosion on 21 November drove a plume to 9-10 km altitude. The latter portion of this report interval (June to mid-October 2005) typically involved ongoing though diminished intensity of volcanism and seismicity.

In response to the crisis, authorities produced engaging graphics, reminiscent of landscape paintings, but also containing risk assessments (figures 11 and 12), in the originals as color-coded lines. These graphics accompanied explanatory text. The authorities also produced a colorful poster. In addition, articles on Galeras hazards appeared in local papers, many along with clear graphics. The distance from the summit to central Pasto is only ~ 9 km.

July-December 2004. INGEOMINAS noted that the July 2004 emissions came from El Pinta crater and from Deformes fumarolic field. Field observations on 19 July disclosed ash freshly vented from El Pinta crater, forming a deposit that ranged in thickness from 3 mm at the base of the cone to ~ 20 cm near the point of emission.

During the latter half of July 2004 INGEOMINAS noted that emissions rose ~ 600 m above the volcano's summit. Ash was not then visible on satellite imagery. On 21 July 2004 a seismic signal corresponded with a visible plume rising ~ 500 m above the volcano and seen from Pasto. According to a news report, a wide area around the

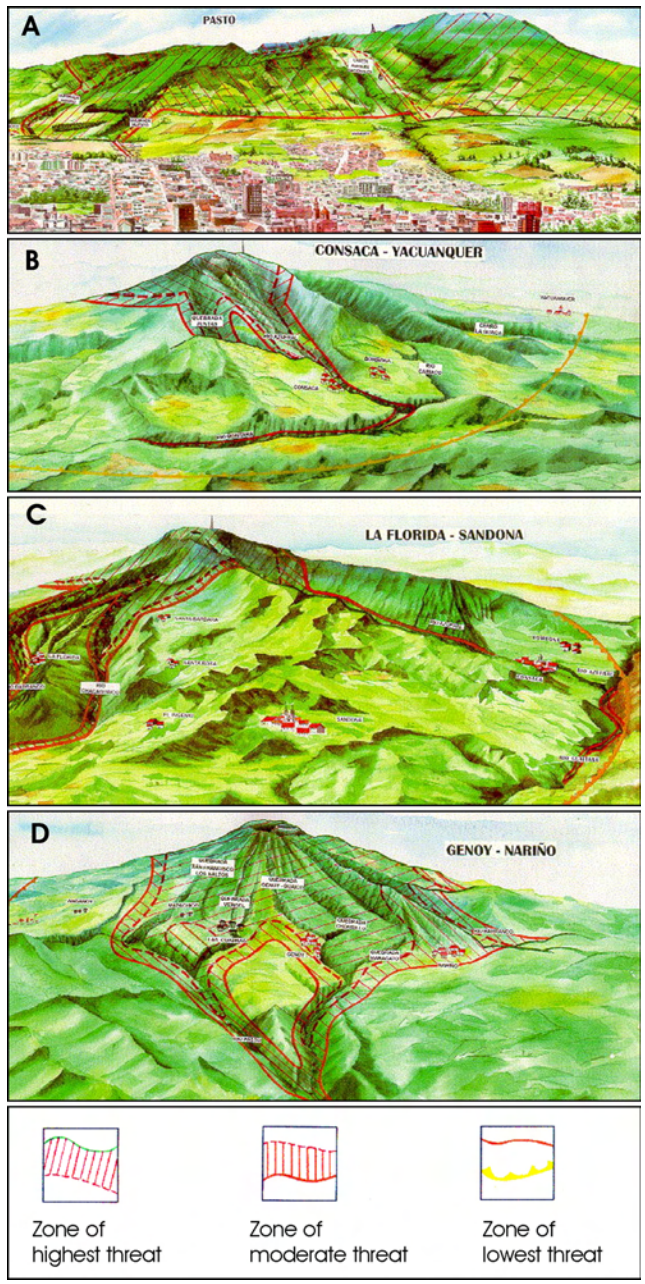

Figure 12. A sample of Galeras hazards graphics available during the 2004-2005 crisis. Galeras and surroundings appear in a series of perspectives that also illustrate likely paths of destructive processes. The artwork emphasizes important geography, labels many settlements, and portrays familiar buildings and skylines. Hazard zones are shown by symbols (see key at the bottom). Views are as follows: A–NW-looking view (S-SE flanks, "Pasto"), B–NE-looking view (SW flanks, "Consaca-Yacuanquer"), C–SE-looking view, (NW flanks, "La Florida-Sandona"), and D–SW-looking view, (NE flanks, "Genoy-Nariño"). Copyrighted images courtesy of Observatorio Vulcanológico y Sismológico de Pasto, INGEOMINAS.

volcano had been declared off limits to visitors. Several higher plumes followed.

According to the Washington VAAC, several ash plumes emitted were visible on satellite imagery during 7-10 August 2004. The highest rising plume reached ~ 6 km altitude.

INGEOMINAS reported that on 11 August at 2349 an eruption sent an ash-and-gas cloud to an unknown height and generated visible incandescence. According to the Washington VAAC, satellite imagery showed an ash plume that rose to ~ 10.7 km altitude. This plume spread in all directions, but mainly to the NE, E, and SW. Later, a thin plume reached a height of ~ 7.3 km altitude and drifted SW into northern Ecuador. A distinctly separate plume also occurred, drifting NW at an altitude of ~ 6.1 km.

Figure 13 shows a graphical depiction of the two plumes issued by the Washington VAAC, which incorporated GOES-12 satellite imagery as part of an advisory sent out at 0807 on 12 August 2004. The observations were from about an hour earlier. This following message was in the 'remarks' part of the advisory.

"Ash heading [NE] earlier in the night can no longer be seen in satellite imagery. A faint plume of ash is heading SW into northern Ecuador but is slowly becoming diffused in satellite imagery. The ash heading SW is estimated to FL240 [~ 7.3 km altitude]. An ash plume moving NW from the summit is estimated to FL200 [~ 6.1 km altitude]. We will continue to closely monitor and advise earlier than normal if needed."

The next advisory noted that ash had ceased to be visible in the imagery after 0715 (1215 UTC) on 12 August 2004 (in other words, after the image associated with the graphic in figure 13).

Fine ash from the 11 August eruption was deposited in villages near the volcano, including La Florida (~ 10 km NW of the volcano), Nariño, Sandoná, and Consacá, and

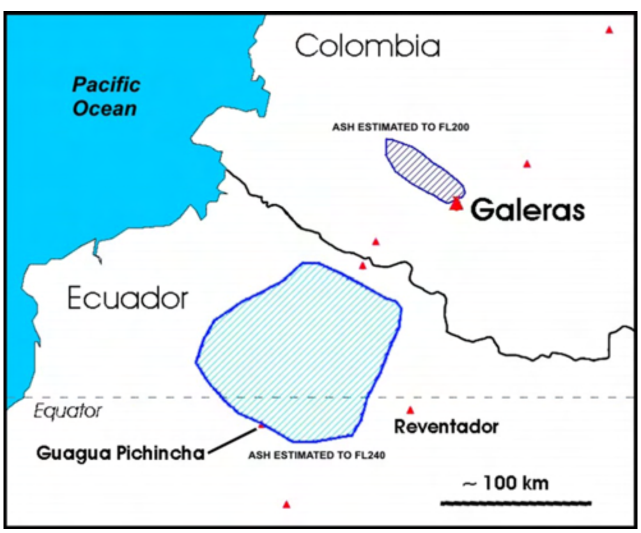

Figure 13. The Galeras ash plumes were distributed in a Volcanic Ash Advisory (VAA) issued at 1307 UTC on 12 August 2004. When this image was taken at 1215 UTC, the two visible plumes had separated widely; one lingering slightly N of the volcano, the other, larger, reached a higher altitude and drifted over Ecuador. Plume top altitude estimates were 'flight level' (FL) 200 and 240, equivalent to 20,000 and 24,000 feet, ~ 6.1 and ~ 7.3 km altitude. Information sources listed included the GUAYAQUIL Meteorological Watch Office (MWO) and the GOES-12 satellite. (This VAA was issued under the header FVXX20 KNES 121307). Courtesy of the Washington VAAC; analysis by Jamie Kibler.

farther afield in Ancuya, Linares, and Sotomayor (~ 40 km NW of the volcano). News articles reported that during these episodes ~ 230 families were evacuated, mainly from the volcano's N flank. The village of La Florida on the volcano's NW flank was most strongly impacted by the eruption. Ash contaminated potable water in some villages, impacted farm animal's health, and left hundreds of dead fish floating in rivers. On 16 August, ash emissions continued, depositing ash in several villages.

INGEOMINAS reported that gas-and-ash emissions continued at Galeras as of 18 August. Ash fell in villages near the volcano, including La Florida, Sandoná, El Ingenio (within 15 km of the volcano), and farther afield in Samaniego and Sotomayor (between 20 and 40 km from the volcano). During 19 August to 1 September, there was a decrease in the level of seismicity and the number of ash emissions. But, gas-and-steam emissions continued.

During September 2004, tremor associated with ash-and-gas emissions was recorded at Galeras. On the 23rd, ash deposits were seen on the upper N flank. By the 27th, the amount of tremor had decreased significantly, a change that coincided with a decrease in ash emissions. During most of October 2004, emissions of gas and fine ash continued at Galeras. Plumes rose to a maximum height of ~ 1.5 km above the volcano. Instruments recorded small-amplitude tremor associated with gas-and-ash emissions.

INGEOMINAS reported that at 1544 on 21 November 2004 Galeras erupted explosively. A resulting shock wave was felt as far away as Cimarrones (18 km N of the volcano), Chachagui (17 km N of the volcano), and Laguna de La Cocha (20 km SW of the volcano). Effects of the shock wave varied from a loud roar, to the vibration of large windows, to the vibrating sensation of an earthquake. Hot ballistic blocks fell nearly 3 km from the volcano on its eastern flank, producing short-lived forest fires. The eruption produced an ash-and-gas column that rose to an estimated 9-10 km altitude and drifted to the S and W. The Washington VAAC reported that satellite imagery of 21 November at 1815 (i.e., 22 November at 0015 UTC) revealed two separate plumes, a situation somewhat analogous to 11-12 August (figure 13). One set of plumes from the 21 November eruption were estimated to reach 9 km altitude, and they blew to the W. Other plumes interpreted as low-level ash were estimated to be near 4-5 km altitude; these remained in the vicinity of the volcano and showed little motion.

January-September 2005. During January 2005, low-level relatively shallow seismicity continued, and a small amount of deformation towards the W portion of the volcanic cone occurred. On 30 January an emission of gas and ash rose ~ 800 m above the volcano. During the first week of February 2005, small gas-and-ash emissions continued. Ash was deposited in the sectors of Consacá (~ 15 km W of the volcano) and La Florida, and in the city of Pasto (~ 10 km E). Low-level seismicity and a small amount of deformation were recorded.

According to a news article, on 24 May 2005 the Colombian government ordered the evacuation of ~ 9,000 people living near Galeras due to an increase in volcanic activity. INGEOMINAS reported that during 16-23 May, small shallow earthquakes occurred beneath the volcano. Earthquakes believed associated with fracturing within the volcano increased during the night of 21 May to the morning of 22 May. Deformation continued to be recorded at the volcano's summit. There were no ash emissions. Galeras remained at alert level II ('probable eruption in terms of days or weeks') as it has since 19 April 2005.

During early June 2005, seismicity and deformation decreased in comparison to the previous week. On 6 June the alert level was decreased from II to III ('changes in the behavior of volcanic activity have been noted'). During July and August 2005, seismicity chiefly remained low. One exception, a M 2.5 volcano-tectonic earthquake on 4 July 2005, was felt in sections of some towns near the volcano. Generally, observers also noted small amounts of deformation and low rates of gas discharge, with continued emissions from the main and secondary craters. Thirty volcano-tectonic earthquakes were recorded at Galeras during 19-21 August 2005. The earthquakes occurred 3-4 km NW of the volcano's active cone, near the towns of Santa Bárbara, Nariño, and La Florida. About five earthquakes felt by nearby populations occurred at depths of 6-8 km, with the largest (M 4.7) occurring at a depth of 6 km on 21 August.

During September 2005, minor seismicity and minor deformation continued. Seismic signals included 365 minor events near the volcano at less than 6 km depth. The larger September record consisted of 179 volcano-tectonic events, 291 long-period events, 258 hybrid events, and 96 tremor episodes. Some of these earthquakes correlated with gas and fine ash discharges. Flyovers at the end of September confirmed that gas emissions were significantly reduced compared to August 2005.

October INGEOMINAS reports noted occasional steam plumes visible from Pasto, often correlated with and presumably related to increases in rainfall and infiltration of water into hot portions of the volcano. A 5 October 2005 overflight revealed a small increase in gas emissions compared to similar flights during September 2005. Seismicity fluctuated and some instrumentally measured deformation continued.

Reference: Gomez, D., Hellweg, M., Buttkus, B., Boker, F., Calvache, M. L., Cortes, Faber, E., Gil Cruz, F., Greinwald, S., Laverde, C , Narváez, L., Ortega, A., Rademacher, H., Sandmann, Seidl, D., Silva, B., and Torres, R., 2004, A Volcano Reawakens: Multiparameter Observations of Activity Transition at Galeras Volcano (Colombia), Transactions, American Geophysical Union, Fall meeting (session entitled "Sources of Oscillatory Phenomena in Volcanic Systems I; Posters"), December 2004, San Francisco, CA

Background. Galeras, a stratovolcano with a large breached caldera located immediately W of the city of Pasto, is one of Colombia's most frequently active volcanoes. The dominantly andesitic Galeras volcanic complex has been active for more than 1 million years, and two major caldera collapse eruptions took place during the late Pleistocene. Long-term extensive hydrothermal alteration has affected the volcano. This has contributed to large-scale edifice collapse that has occurred on at least three occasions, producing debris avalanches that swept to the W and left a large horseshoe-shaped caldera inside which the modern cone has been constructed. Major explosive eruptions since the mid Holocene have produced widespread tephra deposits and pyroclastic flows that swept all but the southern flanks. A central cone slightly lower than the caldera rim has been the site of numerous small-to-moderate historical eruptions since the time of the Spanish conquistadors.

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Sierra Negra

Galápagos Islands
0.83°S, 91.17°W; summit elev. 1,490 m
All times are local (= UTC - 6 hours)

At about 1730 on 22 October 2005 Sierra Negra began erupting. This shield volcano with a large oval-shaped caldera is located at the S end of Isabela Island. Circumferential fractures define the northern edge of the caldera. Volcán Chico, noted for its 1963 and 1979 eruptions, is comprised of a series of scoria cones and other vents

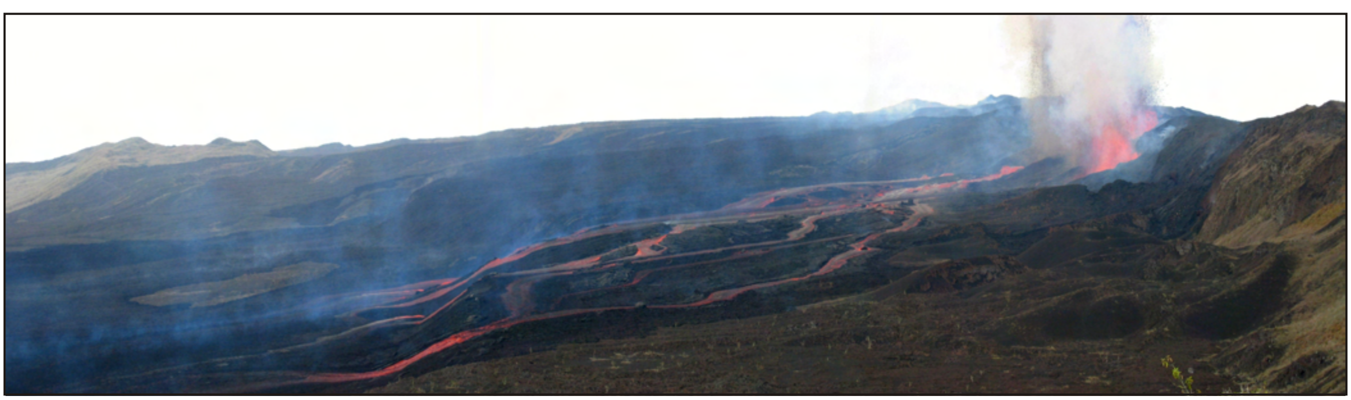

Figure 14. View looking W from the NE rim of Sierra Negra's caldera (right) on 23 October 2005. The caldera floor is to the left. The four active vents are superimposed in this photo, aligned along the E-W fracture that lies at the base of the inner caldera wall. Numerous lava flows descended southwards to the left where they joined to form one single flow of a'a lava ~ 1 km wide and 7 km long that had already reached the southern inner wall of the caldera on 23 October. Courtesy of M. Hall.

aligned along several prominent fractures on the outer slope of the N caldera rim. The present activity is not related to the Volcán Chico fracture system, but is venting from fractures along the N inner caldera wall. The most prominent fracture can be traced westward ~ 3 km where it lies along the rim. This initial report was provided by a scientific team from the Instituto Geofísico.

Figure 15. A 150-m-high lava fountain rises on 23 October 2005 from one of four active vents that define the active fracture system at the base of the northern inner wall of Sierra Negra's caldera. From these four principal vents lava flows moved southwards at velocities estimated at close to 20 m/second on 23 October. Courtesy of M. Hall.

The eruption was preceded by a seismic event at 1438 on 22 October, felt in the coastal village of Villamil (20 km SE of the caldera border) and by Park Wardens on Cerro Azul. Others reported single earthquakes on 19 October and two weeks earlier. At 1730 the eruption began with an explosion heard by many people in the Villamil area. Hikers in the area of the subsequent lava emission in the mid-afternoon of both 21 and 22 October witnessed no unusual activity. By 1745 the eruption column had reached an estimated altitude of 5 km, and the setting sun illuminated the light gray eruption column. At 1815 the team observed the column after sunset from Point (Punto) Ayora, Santa Cruz Island (80 km E) and estimated its height at 10 km. The still-rising column was 4-6 km wide, not spreading laterally, and a small lenticular cloud was beginning to form a cap over the column. As night fell, the western sky above the caldera was a burgundy red, suggesting that lava had covered an extensive area of the caldera floor. Satellite imagery of the eruption at 1745 showed an eruption cloud at an estimated altitude of at least 15 km moving SW. A very large hotspot in the multispectral imagery was also observed and continued on 27 October.

Observations at 1945 from the Santa Cruz highlands (75 km away) employing a camcorder with night vision capabilities confirmed extensive lava fountaining estimated to be 200-300 m high along a segment of the caldera rim, as well as the incandescence from a lava flow several kilometers long descending the NW outer flank. Although the complete eruption column was not visible, it may have reached an altitude close to 20 km and had spread out. Tourist boats between Isabela and Fernandina Island reported seeing two lava flows descending the N flank.

During an overflight between 0715 and 0900 on 23 October the team did not witness active lava flows or evidence of lava having entered the sea. A thin khaki-colored ash cloud layer was observed, between about 1,200 and 1,500 m altitude, that had spread out laterally and extended E as far as St. Cruz Island and N to Santiago Island. Later in the day the plume was directed NNW in agreement with satellite information. From the plane the team confirmed that the main eruption was venting from four craters along a 500-m-long fracture at the base of the NNE inner caldera wall. The highest lava fountaining (up to 200 m high) was being generated at the two middle vents, while the end vents were feeding many lava flows S onto the caldera floor. The fracture apparently extended W along the inner wall, but then climbed to the caldera rim where its trace was not obvious. However, small vents with fountaining and incandes-

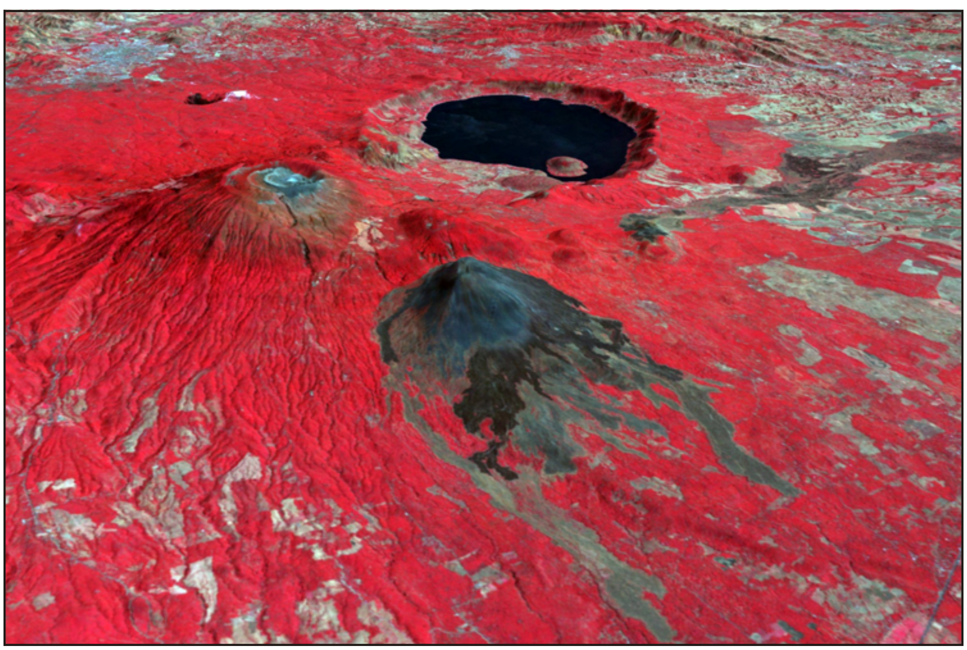

Figure 16. An ASTER image of Santa Ana from 2001 featured in one of several *Earth Observatory* reports. N is to the top left of the image and Santa Ana is the large, blunt-topped edifice closest to the left side of the image. In the color version of this image can be seen a tiny blue spot in the center of the inner-most crater—a crater lake (often called the lagoon). Behind Santa Ana is a large (7-km-diameter) lake inside the Coatepeque caldera. In the center is Izalco volcano, with dark-colored historical lava flows. Courtesy of NASA's Earth Observatory.

cent lava were observed on the rim along this general fracture system, implying that the active fracture extended ~ 2 km W of the main vents.

During the mid-day hours of 23 October the team ascended the S flank, followed the E rim of the caldera, and reached a point ~ 800 m from the active vents, from which the following description was made. From the four principal vents the lava flowed S with exceptional force, volume, and speed downslope in three main channels (figures 14 and 15). Based on the apparent speed of the lava, and the more than 10-m height of the waves in the stream of passing lava, the team estimated that the main lava flow was traveling nearly 20 m/second as it left its vent. The W channels, some 30-50 m wide, maintained their red incandescent color and high speeds, albeit less than that near the vent.

By 1500 the E channel was slowing and cooling to a gray surface color; this thin solid veneer was subsequently fragmented when the flow went over the edge of the bench and cascaded to the caldera floor. On the caldera floor the incandescent lavas of all three channels disappeared under the black solidified a'a lava that already covered about 12% of the caldera. In the 22 hours since the eruption had begun, the lavas had formed one large flow 1-1.5 km wide that traveled SE along the base of the E interior caldera wall, then W along the S wall reaching a point almost halfway across the caldera. As such it had traveled a total distance of 7 km and had started small brush fires on the floor and interior walls of the caldera. With an estimated thickness of no more than 3 m, the volume of the lava ejected by 1530 on 23 October was calculated at about 25 million cubic meters.

Along the trail leading to the vent area an increasing amount of scoria fragments was observed on the rim's edge. Fragments ~ 1 cm in size were first observed ~ 4 km SE of the active vents, and they increased in size (up to 15 cm) and abundance towards the vents. Very little fine ash was in the air or on the ground along the E cal-

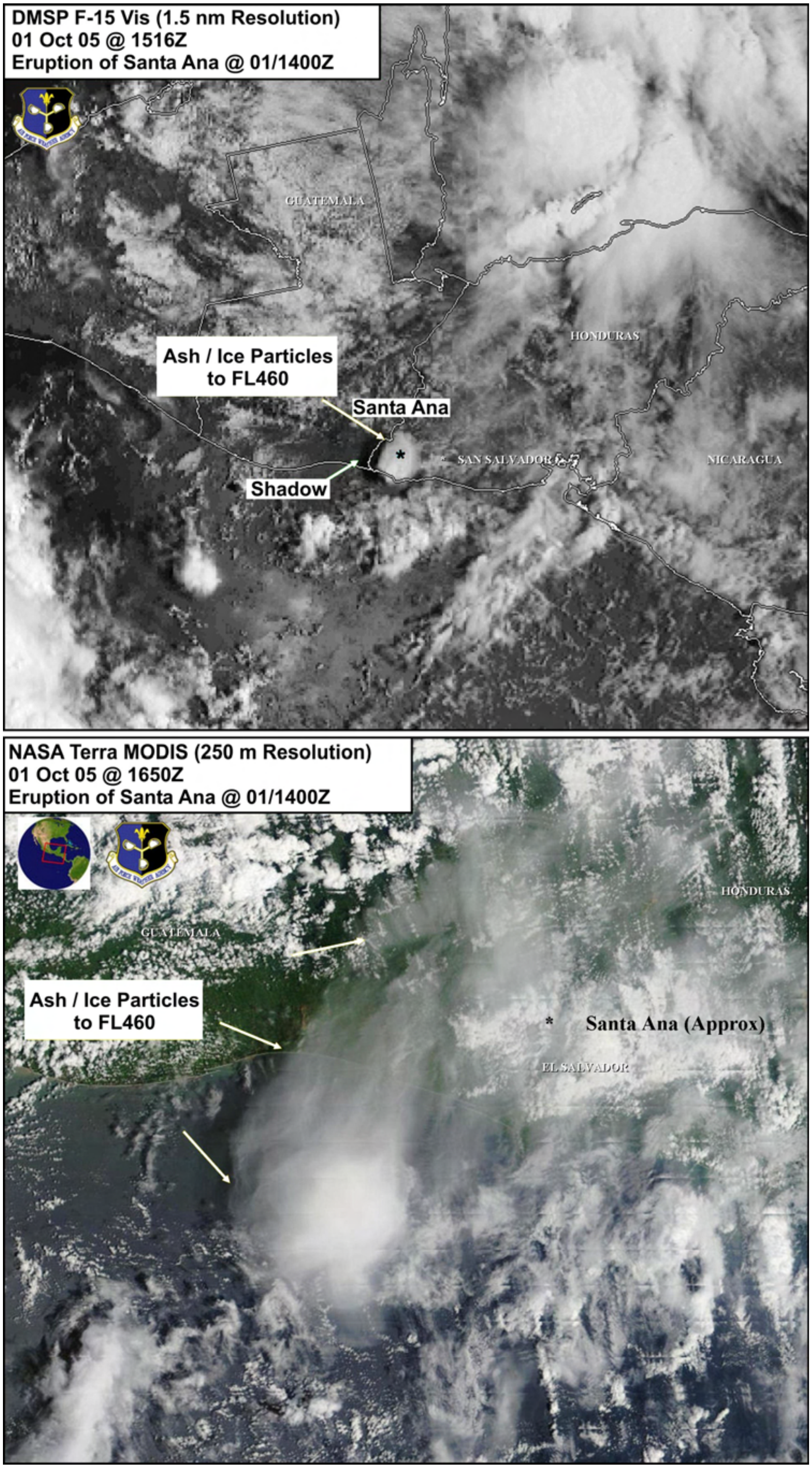

Figure 17. Two images of a Santa Ana eruptive plume on 1 October 2005. (top) The plume at 1516 UTC; (bottom) the plume at 1650 UTC. Note that the label 'FL 460,' stands for 'flight level 460,' which is equivalent to an altitude of 46,000 feet or 14 km. Courtesy of the US Air Force Weather Agency.

dera rim. The scoria was black, exceedingly vesiculated, with vesicles from millimeter to many centimeters in diameter; it seemed comparable in density to popcorn. No crystals were observed in the glassy scoria material. At their closest approach to the vent, scoria fragments formed a deposit 3-5 cm thick.

An explosion heard at 1900 on 25 October was accompanied by a dark eruptive column and minor ashfall along the E rim of the caldera and probably elsewhere. By early 26 October the Park Wardens were reporting that one of the four principal vents had shut down. Observations made late on 26 October indicated that the a'a flow on the caldera floor had slowed and was still several kilometers from the sulfur mine area. Civil Defense officials also reported that apparently less lava was leaving the vents and that lava extrusion might have shifted to the outer N flank, possibly to the Volcán Chico fracture system.

The only inhabited areas include the small town of Villamil, located 20 km SE of the caldera's border on the S coast, plus several other small populated areas about halfway between the caldera and Villamil. There was no immediate threat to those residents, given the fact that in order to spill out of the caldera and descend the S flanks the entire 100-m depth of the caldera would have to fill with lava. The southern caldera border has not been active in the recent geologic past.

Background. The broad shield volcano of Sierra Negra at the southern end of Isabela Island contains a shallow 7 x 10.5 km caldera that is the largest in the Galápagos Islands. The 1,490-m-high volcano is elongated in a NNE direction. Although Sierra Negra is the largest of the five major Isabela volcanoes, it has the flattest slopes, averaging less than 5 degrees and diminishing to 2 degrees near the coast. A sinuous, N-S-trending ridge occupies the west part of the caldera floor, which lies only 100 m below its rim. Volcán de Azufre, the largest fumarolic area in the Galápagos Islands, lies within a graben between this ridge and the west caldera wall. The most recent lava flows of Sierra Negra occupy the upper northern flank in an area dotted with cinder and spatter cones. Prior to the current eruption, unlike most other Isabela island volcanoes, the caldera floor was devoid of young lava flows. Sierra Negra, along with Cerro Azul and Volcán Wolf, is one of the most active of the Isabela Island volcanoes.

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Santa Ana

El Salvador
13.853°N, 89.630°W; summit elev. 2,381 m
All times are local (= UTC - 6 hours)

This report discusses a 1 October 2005 eruption at Santa Ana (also called Ilamatepec) that sent a plume to 14 km altitude and led to initial estimates cited in the press of two deaths (perhaps from landslides), several injuries, and the evacuation of over 2,000 people. Observations of glowing fumaroles and release of magmatic gas during 2000-2001 were previously reported at Santa Ana (*BGVN* 26:04). Servicio Nacional de Estudios Territoriales (SNET) scientists noticed that between the summer of 2000 and April 2001 there was increased venting of a well-developed hydrothermal system through the crater lake, hot springs, and fumaroles, but these changes were not accompanied by detected seismicity, which was then taken to suggest that the increase in hydrothermal activity was not driven by the arrival of new magma beneath the crater. An ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) image from 3 February 2001 shows the volcano's setting well before the eruption (figure 16).

SNET reported that a sudden eruption at Santa Ana took place around 0820 on 1 October 2005. They estimated that it produced an ash-and-gas plume to a height of ~ 10 km above the volcano. According to the Washington VAAC, ash was visible on satellite imagery at an altitude of ~ 14 km. The US Air Force Weather agency provided images of the plume (figure 17).

Ash fell in towns W of the volcano, including in Naranjos, Nahuizalco, Juayúa, Ahuachapán (NW), and La Hachadura (at the border, ~ 40 km W, figure 18). SNET produced a graphic similar to an isopach map that showed near-source thicknesses provisionally to over 10 cm. The 10 cm isopach stretched ~ 5 km W; the 1 mm isopach, ~ 20 km W. The outermost isopach, presumably where measurable ash fell, was not closed; instead it was cut off along the Guatemalan border (~ 40 km to W of Santa Ana) and the caption said that ash would fall into valleys in Guatemala and to the sea. Volcanic blocks up to a meter in diameter fell as far as 2 km S of the volcano's crater. Lahar deposits were seen SE of the volcano. The alert level within a 4-km radius around the volcano's central crater was raised to Red, the highest level.

According to news reports, two people were killed by landslides (possibly caused by heavy rain in the area) in the town of Palo Campana, and thousands of residents near the volcano were evacuated. As many as 1,400 hectares of crops were damaged by ash (1 hectare = 10,000 m^2). News also mentioned other processes such as a flood of boiling mud and water, and molten rocks, some the size of small automobiles, that will be discussed in later reports. A several-minute-long video from the LPG Television website appears as both a hyperlink and an active file on our website. In addition to numerous interviews with evacuees, it shows a host of features including what appear to be the swaths left by previously inflated mudflows passed down steep-sided valleys.

Prior to the eruption, no significant change in seismicity was observed. On 3 October, after the eruption, seismicity fluctuated and small explosions occasionally occurred. Earthquakes associated with explosions were recorded. In addition, there was a decrease in the amount of SO_2 emitted from the volcano.

Strong degassing had been measured at the volcano since June 2004. An ash emission occurred on 16 June 2005, and a slight increase in seismicity and a significant increase in gas emission were measured from 27 July until at least 30 August. SNET also reported a significant increase in seismic activity at Santa Ana on the night of 27 August. A cluster of 17 volcano-tectonic earthquakes were recorded, with four located S of the volcano. Afterwards,

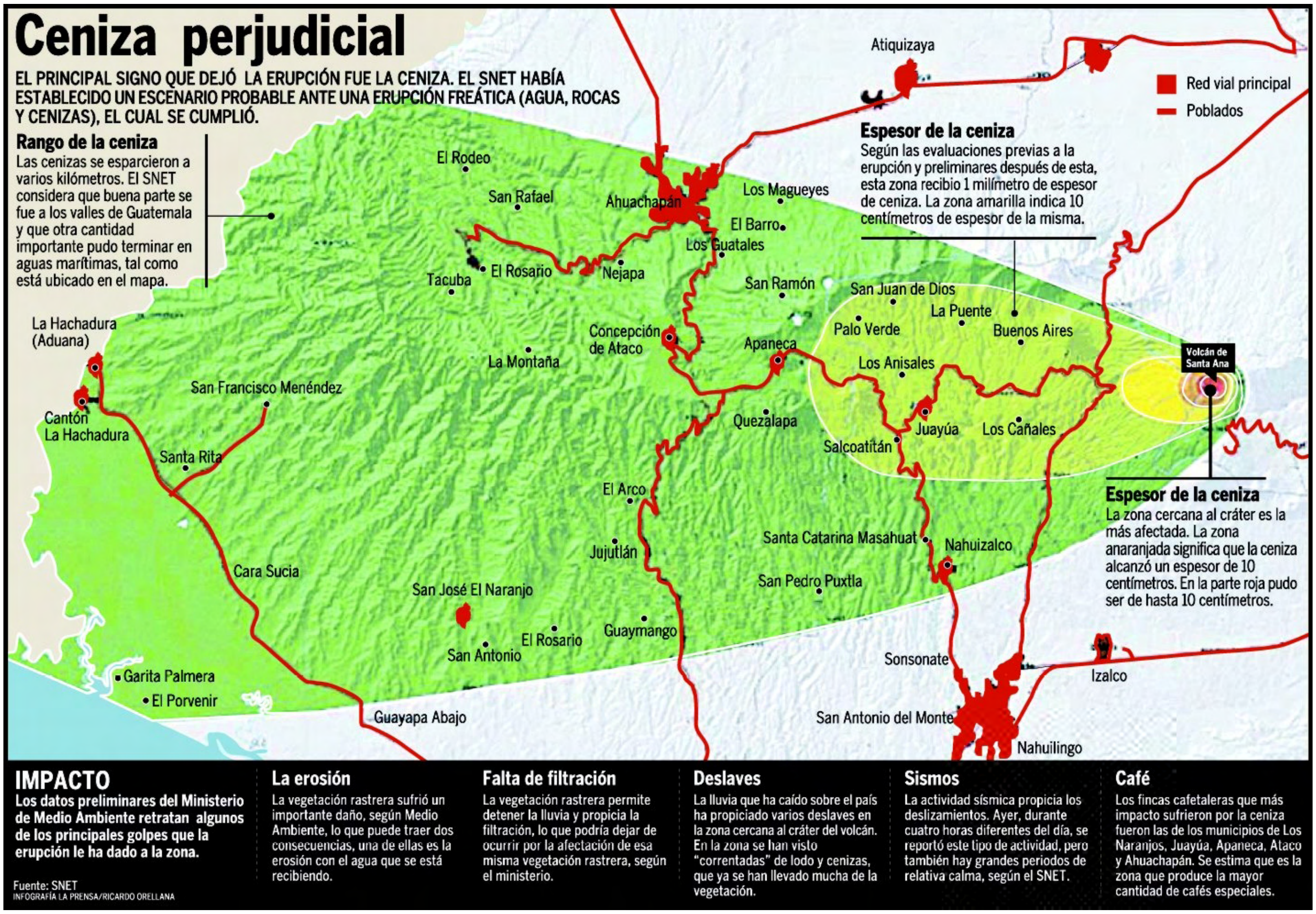

Figure 18. Graphic from SNET showing ashfall distribution from Santa Ana that appeared in the newspaper, *La Prensa Grafica*, following the 1 October eruption. N is upwards; Santa Ana lies ~ 40 km E of the Guatemalan border. This clearly transmitted the message that the ashfall was variable and W-directed over parts of El Salvador and neighboring Guatemala. The bottom of the graphic discussed the impact of the ash fall, including damage to specialty coffee farms. Credit: Ricardo Orellana, *La Prensa Grafica*.

continuous high-frequency tremor was recorded until at least 30 August. Observations made on 29 August revealed incandescent rocks in the fumarole field, effects attributed to hot gases heating the rocks to sufficient temperature to glow. A significant increase in SO_2 emission was recorded, and gas-and-steam plumes rose 500-1,000 m above the volcano's crater. As a safety measure, access to the volcano's crater was restricted.

From 27 July until the eruption on 1 October, seismicity and gas emissions were above normal levels, and Santa Ana was at alert level yellow. During the first week of September, tremor continued to be recorded, and on 2 September a cluster of at least eight small earthquakes occurred, which were not felt by local residents. Gas plumes rose to ~ 500 m above the volcano, and the SO_2 flux was over 1,000 metric tons per day during the first two weeks of September. Satellite imagery from 5 September showed a thermal anomaly.

Microseismicity increased significantly on 12 September. During a visit to the volcano on 8 September, larger areas of incandescence were visible at a field of fumaroles than during a visit on 29 August. Satellite imagery showed a thermal anomaly at the volcano on several days during the second week of September.

During 15-19 September gas plumes rose to ~ 500 m above the volcano, and the SO_2 flux reached a maximum of 3,320 metric tons per day on 16 September. Microseismicity remained at relatively high levels. No significant changes were seen at the volcano's crater when observed on 19 September in comparison to 13 September. Intense degassing continued and the crater lake (lagoon) remained a dark coffee color. Incandescence was visible inside some cracks.

During a visit to the crater on 21 September, observers noted that the lagoon had become greener and small rock landslides occurred in the field of fumaroles. Gas plumes rose to ~ 1 km above the volcano on 26 September.

Following the eruption of 1 October, small explosions, degassing, and low-to-moderate seismicity occurred at Santa Ana during 5-11 October. Inclement weather prohibited ground and satellite observations, and sulfur-dioxide (SO_2) measurements during much of the report period. During an aerial inspection of the volcano on 11 October, no changes were observed at the crater. Around 11 October, SO_2 measurements were around 600-700 metric tons per day. The alert level within a 5-km radius around the volcano's central crater remained at Red.

Background. Santa Ana, El Salvador's highest volcano, is a massive, 2,381-m-high andesitic-to-basaltic stratovolcano that rises immediately west of Coatepeque caldera. Collapse of the volcano during the late Pleistocene produced a voluminous debris avalanche that swept into the Pacific Ocean, forming the Acajutla Peninsula. Reconstruction of the volcano subsequently filled most of the collapse scarp. The broad summit of the volcano is cut by several crescentic craters, and a series of parasitic vents and cones have formed along a 20-km-long fissure system that extends from near the town of Chalchuapa NNW of the volcano to the San Marcelino and Cerro la Olla cinder cones on the SE flank. Historical activity, largely consisting of small-to-moderate explosive eruptions from both summit and flank vents, has been documented since the 16th century. The San Marcelino cinder cone on the SE flank produced a lava flow in 1722 that traveled 13 km E.

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Cleveland

Aleutian Islands
52.825°N, 169.944°W; summit elev. 1,730 m
All times are local (= UTC - 8 hours)

Mount Cleveland produced significant ash plumes during March 2001 (*BGVN* 26:04). Volcanic unrest continued through 4 May 2001, and signals consistent with volcanic seismicity were detected by an Alaska Volcano Observatory (AVO) seismic network 230 km E. By the end of May, neither eruptive activity nor thermal anomalies were observed. Until July 2005, no alert level was assigned, and AVO monitoring produced no reports on Cleveland.

Cleveland lacks a real-time seismic network. Accordingly, even during times of perceived quiet there is an absence of definitive information that activity level is at background. AVO's policy for volcanoes without seismic networks is to not get assigned a color code of Green.

Satellite imagery of Cleveland taken during 24 June to 1 July 2005 showed increased heat flow from the volcano and a possible debris flow. AVO stated that although observations were inhibited by cloudy weather, they indicated the possibility of increased volcanic activity. AVO did not assign a Concern Color Code to Cleveland due to the lack of seismic monitoring and limited satellite observations.

Satellite images during 1-8 July showed increased heat flow, thin ash deposits, and possible debris flows extending ~ 1 km down the flanks from the summit crater. AVO assigned a Concern Color Code of Yellow on 7 July. On 18 July satellite imagery showed steam emanating from Cleveland's summit and evidence of minor ash emissions. Meteorological clouds obscured Cleveland during the third week of July. During 22-29 July satellite images showed minor steaming from the summit, possible fresh localized ash deposits, and a weak thermal anomaly.

On 4 August satellite images showed a thermal anomaly. On 27 August AVO reduced the Concern Color Code at Cleveland from Yellow to "Not Assigned" because there had been no evidence of activity since a thermal feature was observed on satellite imagery from 11 August. A thermal feature was detected on several satellite images obtained on 31 August, and one on 19 September, but there was no evidence of eruptive activity.

On 7 October, AVO raised the Concern Color Code to Orange after detecting a small drifting volcanic ash cloud. The cloud was seen in satellite data at a spot ~ 150 km ESE of Dutch Harbor at 1700 UTC. Based on data from a regional seismometer at Nikolski, AVO concluded that the ash came from a small Cleveland eruption at approximately 0145. AVO, in consultation with the National Weather Service, estimated the top of the ash cloud to be no more than 4,600 m altitude. The ash cloud dissipated and was not detected via satellite after 1800 UTC. Three days passed during which there were no new observations of eruptive activity at Cleveland from satellite data, pilots, or ground-based observers. Accordingly, on 10 October the Concern Color Code was reduced to Yellow.

Background. Beautifully symmetrical Mount Cleveland stratovolcano is situated at the western end of the uninhabited, dumbbell-shaped Chuginadak Island. It lies SE across Carlisle Pass strait from Carlisle volcano and NE across Chuginadak Pass strait from Herbert volcano. The 1,730-m-high Mount Cleveland is the highest of the Islands of the Four Mountains group and is one of the most active of the Aleutian Islands. Cleveland is joined to the rest of Chuginadak Island by a low isthmus. Numerous large lava flows descend the steep-sided flanks of the volcano. It is possible that some 18th to 19th century eruptions attributed to Carlisle should be ascribed to Cleveland (Miller et al. 1998). In 1944 Cleveland produced the only known fatality from an Aleutian eruption. Recent eruptions from Mount Cleveland have been characterized by short-lived explosive ash emissions, at times accompanied by lava fountaining and lava flows down the flanks.

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