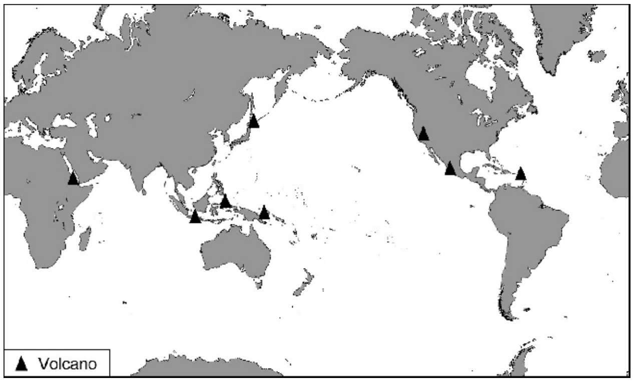
Bulletin of the Global Volcanism Network



Volume 33, Number 10, October 2008

Smithsonian
National Museum of Natural History

Editors: Rick Wunderman, Edward Venzke, Sally Kuhn Sennert, and Yukio Hayakawa

Volunteer Staff: Robert Andrews, Hugh Replogle, Michael Young, Paul Berger,
Jacquelyn Gluck, Stephen Bentley, and Ludmila Eichelberger

Global Volcanism Program · National Museum of Natural History, Room E-421, PO Box 37012 · Washington, DC 20013-7012 · USA
Telephone: (202) 633-1800 · Fax: (202) 357-2476 · Email: gvn@si.edu · URL: http://www.volcano.si.edu/

The text of the *Bulletin* is also distributed through the Volcano Listserv (volcano@asu.edu).

Dalaffilla

Ethiopia
13.792°N, 40.55°E; summit elev. 613 m
All times are local (= UTC + 3 hours)

During November 2008, lava extruded from fissures and by 8 November covered a heavily faulted zone spreading over about 15 km^2 in the Afar (or Danakil) depression. This eruption is ~ 25 km NW of Erta Ale volcano, in the Erta Ale volcanic range (figure 1). The range lies along the axis of the the NW-trending Danakil depression, a hot, arid, and desolate rift basin with a floor in places ~ 100 m below sea level. Going NW along the rift from Erta Ale, the named volcanic centers include Bora Le Ale, Dalaffilla, Alu, and Gada Ale. The tectonically active area (figure 2) has extremely low population density and scientists' field reports have yet to emerge. Prior to this event, there were five eruptive episodes in the region since 1967, three of those since September 2005 (table 1).

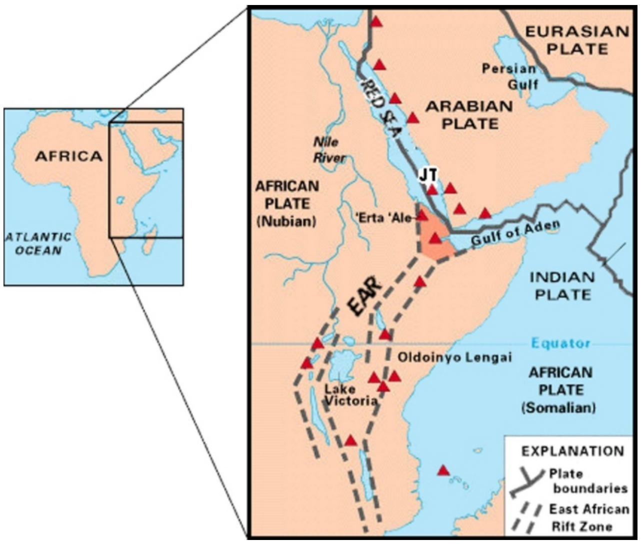


Figure 1. Sketch map of the Afar triangle region with highly simplified tectonics and some of the region's volcanoes indicated as triangles. The Afar region (shaded) contains the Afar (rift-rift-rift) triple junction. Continental rifting takes place along the East African rift (EAR), with the Nubian plate on the W, and the Somalian plate on the E. The Arabian plate resides on the N. Note Erta Ale volcano in the N Afar (along the Danakil depression). The volcano Jebel et Tair (location approximate) is indicated with "JT." Revised from a map prepared by the USGS.

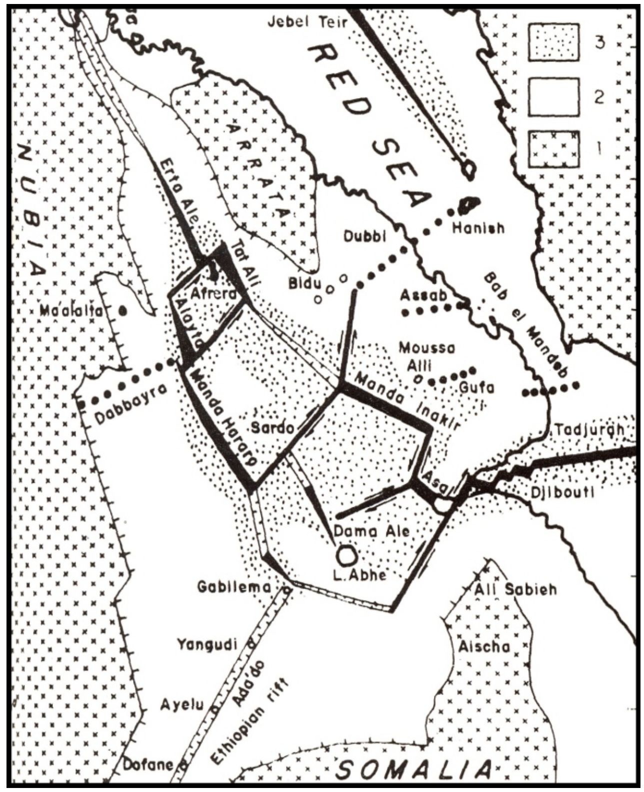


Figure 2. A schematic map of the Afar indicating key volcanic and tectonic features including the Erta Ale volcanic range and Jebel at Tair volcano in the Red Sea. Key patterns: 1) Outcropping continental basement, 2) Continental rift material, and 3) Oceanic crust formed during the last 3-4 million years. Modified from Barberi and Varet (1975).

Volcano	Location (with respect to Erta Ale)	Eruption date or date range	Comment
Erta Ale (Ethiopia)	—	1967-present	Active lava lake(s) ongoing through present [eg. *CSLP* 22-71, BGVN 33:06]
Ardoukôba (Djbouti)	300 km SE	7-14 Nov 1978	Ardoukôba (Asal rift) produced small cinder cone and lava flows on rift floor [*SEAN* 03:11, 03:12]
Dabbahu (Ethiopia)	113 km SE	Sep 2005	Short-lived explosive eruption with apparent dome in the deep portion of the elongate crater (Also see Wright and others, 2006) [*BGVN* 30:09]
Manda Hararo (Ethiopia)	160 km S	12 Aug-Sep 2007	Lava flows, numerous small spatter and scoria cones; occasional flames. Recent fault movement. Located in the Karbahi graben between the settlements of Semera and Teru [*BGVN* 32:07]
Jebel at Tair (Yemen)	250 km NNE	30 Sep 2007-1 Jan 2008	An explosive and effusive eruption of lava on inhabited island in the S-central Red Sea (evacuation and fatalities) [*BGVN* 32:10, 32:04]
Dalaffilla (Ethiopia)	25 km NW	3 Nov 2008	This is the first BGVN report on either Dalaffilla or adjacent Alu volcanoes (mainly satellite data available thus far in late November 2008).

Table 1. A synopsis of known Afar region eruptions since 1967, including the case at hand, Dalaffilla. Taken from GVP records (CSLP and SEAN are Smithsonian BGVN predecessors; reports are all on the GVP website).

The conical summit of Dalafilla (which means "cut neck" in the Afar language) lies about 6 km SE of the center of the elongated summit horst of Alu (figure 3). The current eruption took place from vents between these two rift-axis centers, both of which have extensive vents, fissures, and faults trending along the rift axis. Determination of the provenance of flank vents can be problematical in a rift setting such as this that displays adjacent, but slightly offset elongated, rift-parallel volcanism. Preliminary analysis of satellite imagery suggests that the lava flows originated from fissures or vents extending downslope from the sides of the Dalafilla volcanic center.

Thermal radiance remained significant into at least early December. Available news reports claimed the area of new lavas as 20-fold larger than they turned out to be, casting doubt on their other descriptions of the eruption. Still, the plume reached 13-16 km altitude and delivered ~ 10,000-20,000 metric tons of SO_2 into the atmosphere.

Geolocation errors. During the early phases of this eruption, while attempting to determine the source volcano, it became apparent that the GVP coordinates for Alu were displaced towards the E in the area with the new flows. Inaccurate volcano locations can result from older, imprecise, base maps, especially in remote areas. They may also be caused by the lack of a global datum, even when precise maps are available. More recent satellite imagery and mapping techniques are gradually improving the situation, and the location for Alu has been corrected (see figure 7 below).

Eruptive activity. Charles Holliday found Meteosat-9 infrared (IR) satellite data to constrain the eruption's start on 3 November 2008. He went on to estimate the plume's maximum height, which first occurred about one hour after any cloud was first visible. He had images every 15 minutes and found no sign of an eruption cloud as late as 1245 UTC (0945 local time). This was followed by a small initial cloud appearing at 1300 UTC, which then grew to larger clouds blowing E. Looking at the Meteosat-7 IR data, Holliday found the eruption at around 1350 UTC.

Holliday determined the sequence of coldest pixels (table 2). He found the coldest pixel of the set in an image representing Meteosat-9 at 1350 UTC, about -73°C, and by comparing an atmospheric sounding made over Abha, Saudi Arabia inferred a maximum plume height of 15.7 km. The coldest pixel, -64°C, was in a Meteosat-7 IR image from 1350 UTC. Comparison with the same OEAB sounding as above obtained a maximum plume height 13.5 km.

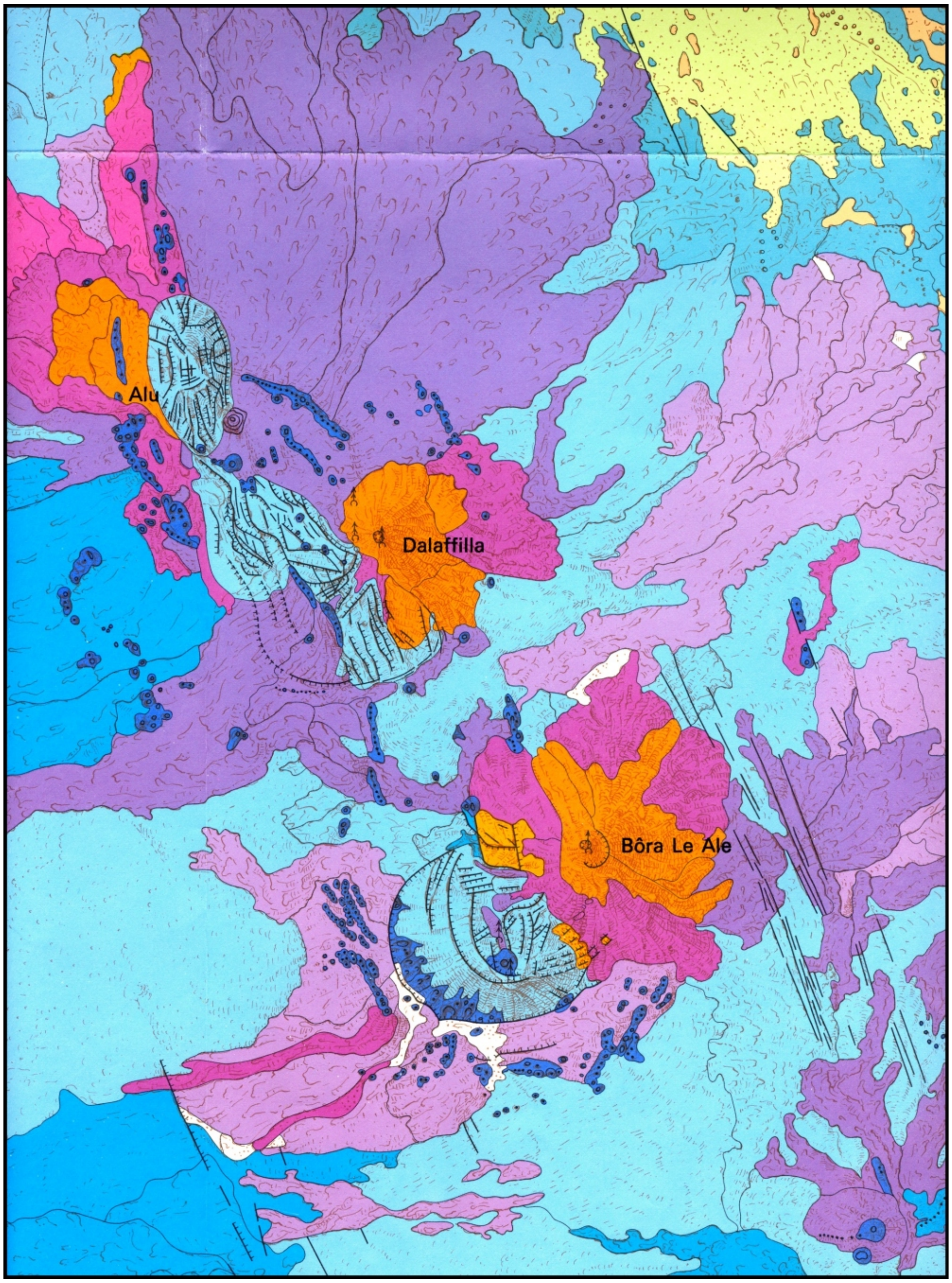


Figure 3. Geological map (1972) of a portion of the Erta Ale Volcanic Range (Danakil Depression – Ethopia) showing the relative locations of volcanoes Alu, Dalaffilla, and Bora Le Ale. The new deposits are most extensive in an area E to SE of Alu, along the axial trend that corresponds with Dalaffilla. N is to the top; the original map was at a scale of 1 to approximately 100,000. In the colored version of this map, orange and brighter purple colors represent silicic rocks and darker purple and blue colors represent basaltic rocks. From Barbari and Varet (1972).

Activity could also be identified in a MODIS (Moderate-resolution Imaging Spectro-radiometer) image from 4 November (figure 4), a composite using three of 36 available bands, from orange-red and into the IR (bands 7-2-1). Although the areas of high thermal flux may lack detail on this 250-m resolution image, that area lacks the SW-directed spur seen on some later photos.

In a 6 November message Simon Carn noted that in terms of sulfur dioxide (SO_2), the November eruption generated a large cloud. As detected by the Ozone Monitoring Instrument (OMI) and the Atmospheric Infrared Sounder (AIRS), the cloud initially drifted E over the Arabian peninsula. The cloud was clearly linked to the eruption because MODIS/MODVOLC data from the Hawai'i Institute of Geophysics and Planetology (HIGP) Thermal Alerts System confirmed an extensive hotspot.

A total of 0.1-0.2 Tg (tetragram) of SO_2 (1 Tg = 10^{12} g = 10^9 kg = 10^6 Tons) was measured in the eruption cloud by OMI at ~ 1100 UTC on 4 November, by which time the SO_2 cloud had reached S Iran. The cloud had dissipated and moved east by the next day (figure 5). On 6 November, the plume appeared the same or even stronger than the one the previous day. But on subsequent days the plumes became much smaller.

Time (UTC) on 3 November	Coldest pixel from IR image Meteosat-9 (Meteosat-7)
1300	-66°C (–)
1315	-73°C (–)
1330	-71°C (–)
1345	-71°C (@1350 UTC, -64°C)
1400	-73°C (–)
1415	-73°C (–)
1430	-71°C (–)

Atmospheric sounding at 1200 UTC from Rawinsonde station at Abha, Saudi Arabia, WMO 41112, OEAB; located ~ 545 km NNE (at 18. 24°N, 42.66°E). Equatorial subpoints (IR resolution):

Meteosat-7, 57.5°E (5 km) Meteosat-9, 0° (3 km)

Conclusion (Plume top estimates):

Meteosat-9, 15.7 km altitude @ 1315 UTC

Meteosat-7, 13.5 km altitude @ 1350 UTC

Table 2. Times and coldest pixels related to the Dalaffila eruption seen in Meteosat-9 IR satellite data on 3 November 2008. The last two rows include ancillary data and results used to describe the coldest pixels on the Meteosat-9 and -7 IR data. The data were used to estimate the maximum cloud height (reached around 1400 UTC). The Meteosat-7 IR data for other times was not available but the one entry (at 1350 UTC) was described as the coldest. Courtesy of Charles Holliday.

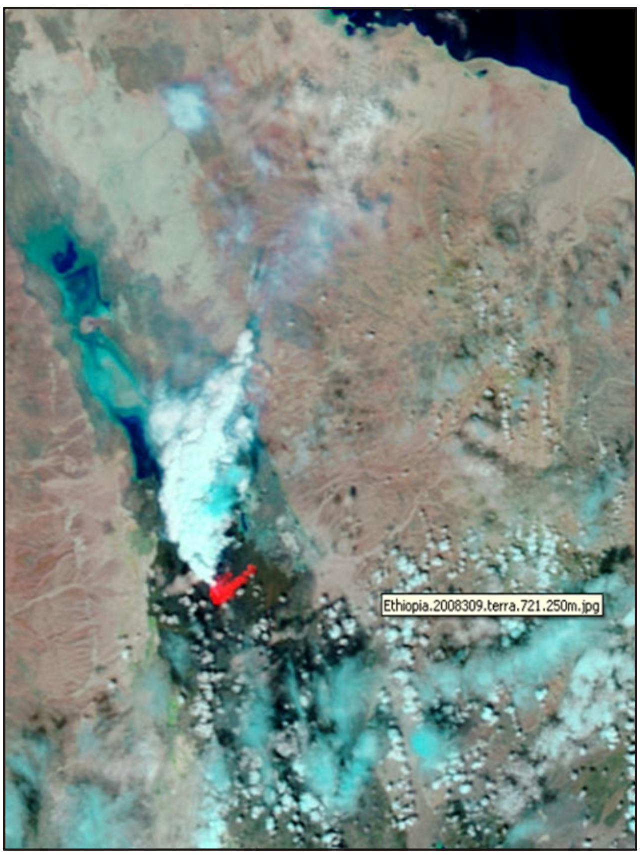


Figure 4. The Dalaffilla eruption as it appeared on a MODIS image for 0730 UTC on 4 November 2008. By this time the lava had spread considerably NW but the spur of lava seen later to the SW was not in evidence on this image with pixel size of 250 m. The image compiled bands 7, 2, and 1. Courtesy of NASA.

NASA's Earth Observatory first discussed this phase of the eruption with reference to a MODIS image captured on 4 November. Owing to an extensive white plume, the analysts could not make out the lava field, but they saw widespread haze towards the N (figure 6) that they and NOAA analysts interpreted as vog (volcanic smog, which results from volcanic gases such as SO_2 mixing with water vapor and oxygen in the presence of sunlight).

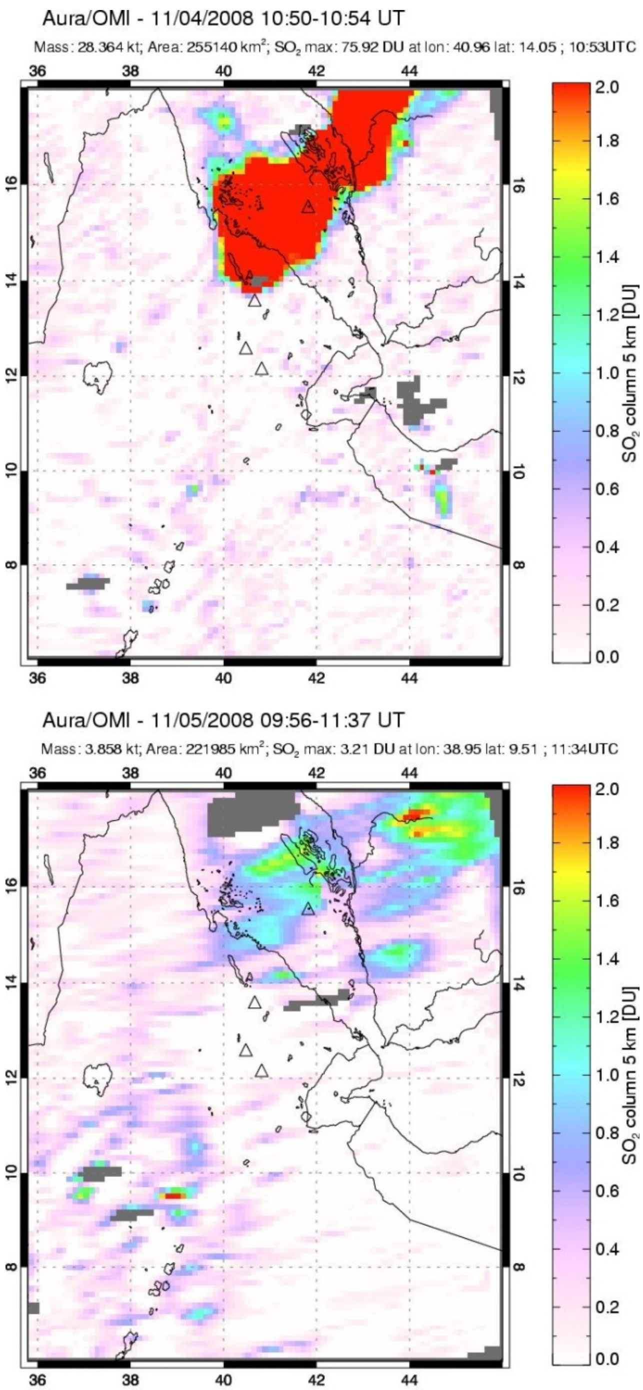


Figure 5. OMI snapshots of the Dalafilla SO_2 plume stretching NE on 4-5 November 2008. During 1050-1054 UTC on 4 November there was a very dense, broad, and unbroken plume truncated at the image's N margin. For 5 November during 0956-1137 UTC, an often more diffuse and segmented plume with greatest density near the Yemen-Saudi Arabian border. The 2° N-S increments scribed on the margins represent 222 km. Courtesy of Simon Carn and the OMI website.

Matthew Patrick of the USGS processed and provided a nighttime ASTER image, taken 8 November 2008 at 1942 UTC, showing the lava flow between Dalaffilla and Alu volcanoes, and Simon Carn superimposed it on Google Earth imagery (figure 7). Carn noted that the underlying pre-eruption Google Earth imagery shows relatively youthful cinder cones and lava flows in this region.

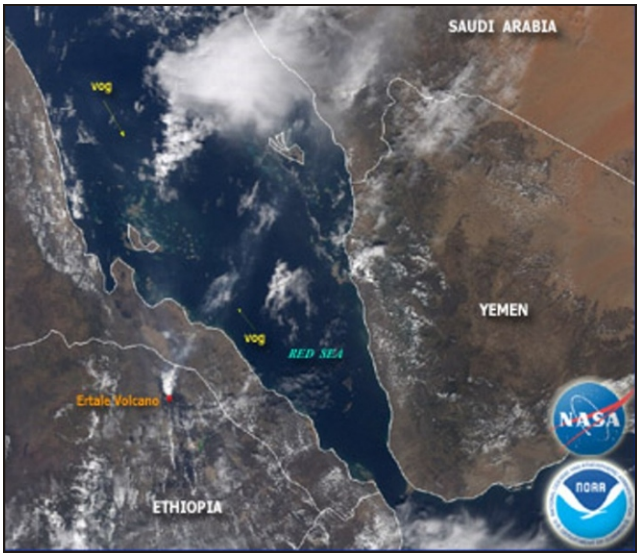


Figure 6. A MODIS image from showing widespread haze to the N of the Dalaffila eruption site at 0735 UTC on 4 November. At this early phase of the eruption analysts incorrectly attributed the eruption to Erta Ale. Courtesy of NOAA/NASA.

Figure 7. The pattern of high thermal flux in the Dalaffila area superimposed on a Google Earth map with the corrected placemark locations. Courtesy of Matt Patrick and Simon Carn.

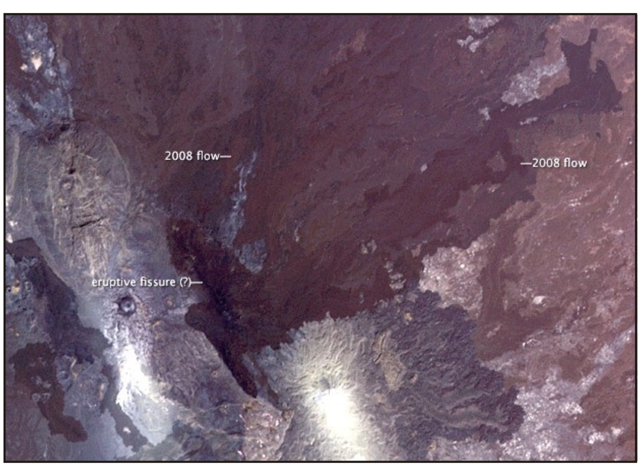


Figure 8. Dalaffilla (bottom center) and Alu (ellipse, left center) volcanoes and the new lava flow field that flowed downslope to the NE. Courtesy of NASA Earth Observatory.

Patrick made these preliminary assessments based on 90-m resolution thermal infrared (TIR) data from 8 November, and on later visible data. The registration between these data sets was imperfect in the E-W direction. The lava flow comprised a multi-lobed field from a fissure or fissure system. Flow direction was transverse to the rift axis, to the NE. The flow field on 8 November was 9.3 km long by ~ 3. 0 km wide, and its surface area was 14.9 km^2. The flows originated from NW-trending fissures extending over a distance of 2.7 km.

Patrick later noted that the main channel originated along a fissure that cut the surface near a prominent older cinder cone. The cone was visible in the pre-eruption Google Earth imagery. The geologic map by Barberi and Varet (1970), shows similar NW-SE-trending eruptive fissures of likely Holocene age (cutting the youngest basalts) in this same area between Dalafilla and Alu (figure 3).

A second Earth Observatory report featured one ASTER image made before the eruption, and another several weeks after on 16 November (figure 8). That figure presents one of the better images for inspecting the upper lava flow field (which appears dark in the image).

MODVOLC thermal anomalies. In harmony with the IR data above, satellite thermal alerts (anomalies) measured by the Hawai'i Institute of Geophysics and Planetology (HIGP) Thermal Alerts System swelled. For years before 3 November 2008 they stood at zero. On 3 November they rose to 148 pixels. On passes the next day the number of thermal-alert pixels had dropped and continued to descend (at 0735 UTC, 31 anomalies; at 1040 UTC, 18 anomalies). Thereafter through at least early December, many days had 1 to 10 thermal alert pixels. On occasional days, particularly during 5-17 November, as many as 26 appeared. As of early December, the anomalies were still around several pixels. Spatially, these anomalies typically overlay and extended beyond the flow field.

References: Barberi, F., and Varet, J., 1970, The Erta Ale volcanic range (Danakill depression, Northern Afar, Ethiopia): Bull Volc., v. 34, p. 848-917.

Barberi, F., and Varet, J., 1972, Geological map of the Erta Ale volcanic range (Danakil depression, Northern Afar, Ethiopia): Centre National de la Recherche Scientifique (France) and Consiglio Nazionale delle Ricerche (Italy), approximate scale, 1:100,000, includes explanatory text, ISBN 2-222-01521-9.

Barberi, F., and Varet, J., 1975, Volcanological research in Afar (L.R. Wager Prize Lecture): Bull. Volc., v. 39, no. 2, p. 5-13.

Wright, T.J., Ebinger, C., Biggs, J., Ayele A., Yirgu, G., Keir, D., and Stork, A., 2006, Magma-maintained rift segmentation at continental rupture in the 2005 Afar dyking episode: Nature, v. 442, p. 291-294 (20 July 2006), doi:10. 1038/nature04978.

Wood, J., and Guth, A., 2008, East Africa's Great Rift Valley: a complex rift system: Geology.com (URL: http:// geology.com/articles/east-africa-rift.shtml)

Geologic Summary. Dalaffilla, also referred to as Gabuli, is a small, but steep-sided conical stratovolcano that rises 300 m above surrounding lava fields SE of Alu volcano. This morphology, unusual for the Erta Ale Range volcanoes, results from the extrusion of viscous, silicic lava flows with primary slopes up to about 35 degrees. These silicic flows extend primarily to the E; on the W they are blocked by walls of a horst structure along the crest of the Erta Ale range. Other basaltic lava flows from regional fissures surround the 613-m-high volcano. Fumarolic activity occurs in the 100-m-wide summit crater and has weathered surrounding lava flows.

Information Contacts: *Jacques Varet*, Geoscience for a Sustainable Earth, BRGM 3, avenue Claude-Guillemin, 45060 Orléans cedex 02, France (Email: j.varet@brgm.fr); *Charles Holliday*, U.S. Air Force Weather Agency (AFWA)/XOGM, Offutt Air Force Base, NE 68113, USA (Email: Charles.Holliday@afwa.af.mil); *Matthew R. Patrick*, Hawaiian Volcano Observatory (HVO), U.S. Geological Survey, PO Box 51, Hawai'i National Park, HI 96718, USA (URL: http://hvo.wr.usgs.gov/; Email: hvo-info@hvomail.wr.usgs.gov); *Simon Carn*, Dept of Geological and Mining Engineering and Sciences, Michigan Technological University, 1400 Townsend Dr., Houghton, MI 49931, USA (URL: http://www.volcarno.com/, Email: scarn@mtu.edu); *Hawai'i Institute of Geophysics and Planetology (HIGP) Thermal Alerts System*, School of Ocean and Earth Science and Technology (SOEST), Univ. of Hawai'i, 2525 Correa Road, Honolulu, HI 96822, USA (URL: http://hotspot.higp.hawaii.edu/); *Gezahegn Yirgu*, Dept of Earth Sciences, Addis Ababa University, PO Box 1176, Addis Ababa, Ethiopia (Email: yirgu.g@geol.aau.edu.et); *NASA Earth Observatory* (URL: http://earthobservatory.nasa.gov/).

Soufrière Hills

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

Our previous report on Soufrière Hills (*BGVN* 33:04), characterized the eruptive behavior and monitoring of dome growth during March 2007-May 2008. The current report describes activity from the end of May 2008 through 4 December 2008.

Through the end of May, the Montserrat Volcano Observatory (MVO) generally reported continued pause in dome growth and low seismicity. An explosion on 29 May produced an ash plume that rose to an altitude of ~ 3 km and drifted SW; a pyroclastic flow descended a few hundred meters to the W. Aerial observation the following day suggested that the activity originated from the Gages vent. The explosion, which had no precursory seismicity, was heard in multiple areas to the NW.

Throughout June and the first three weeks of July, the background activity, while low, indicated continuing unrest. The pause in dome growth continued, but MVO emphasized that despite the lack of substantial lava extrusion, the dome remained hot and hazardous.

Mild ash was ejected from the Gages vent on 19 June. The event lasted for ~ 2 hours, and included several pulses. Due to strong E winds at low altitudes, the ash plume remained below ~ 1,200 m altitude and left Old Towne and Olveston untouched.

During mid- and late June, sporadic heavy rainfalls triggered minor mudflows down the Belham River. Access was accordingly prohibited. Also, a Maritime Exclusion Zone kept boats away from the island's S shore.

On 21 July, four mild eruptions occurred, typically venting ash or pyroclastic flows. The previous day there had been a large swarm of shallow volcano-tectonic earthquakes beneath the volcano and seismicity proceeded continuously throughout each of the first three eruptions. The first three eruptions lasted for about 50, 40, and 75 minutes, respectively. The third one generated the largest seismic signals, the fourth event was much smaller. Volcano-tectonic and hybrid seismic activity continued for the rest of the week without significant reduction. Small pyroclastic flows from collapses in the eroded chute on the dome's SE and E flanks traveled down the Tar River valley, with the largest reaching to within 500 m of the sea.

All four events generated ash columns rising more than 2 km. The first two events also generated ash clouds above the upper Tar River valley, probably caused by small pyroclastic flows. Ash clouds drifted W over Plymouth and St George's Hill; the source of the ash was probably the vent at Gages. Light ashfall occurred in parts of Old Towne. Rumbling, continuous at times, was heard in Salem, Old Towne and Olveston during each of the first three events. Lightning strikes could also be heard and sometimes seen. These events were most probably caused by ash venting from the lava dome, accompanied by small collapses on the E flank of the dome; however, there was no apparent change in the lava dome's shape.

After 20-25 July, seismicity increased significantly. On 26 July, a series of hybrid earthquakes slowly increased in both numbers and magnitude, eventually reaching about 15 events per hour. Seismicity decreased for a few hours, then increased again. Hybrid earthquakes with a few long-period events peaked at a rate of more than one per minute.

On the morning of 27 July, a short series of eruptions occurred. The first eruption generated a non-energetic ash column that rose ~ 2.5 km; the source of ash could not be seen due to cloud cover, but was probably the Gages vent. The ash cloud was blown to the W and NW, and there was ashfall in Plymouth and St George's Hill; pyroclastic flows were absent. Two other eruptions during the next 45 minutes were much smaller, with ash clouds below 1.5 km altitude. Seismicity continued at a slightly reduced level following these eruptions.

28 July dome collapse. On 28 July the seismic signals built up gradually over a few minutes, signals interpreted as consistent with a dome collapse rather than an explosion. Seismicity then displayed a series of sharp peaks consistent with explosive activity, but this activity stopped within about an hour. Next, there was a partial collapse on the dome's W side. A few explosions issued from the dome during the collapse. An infrasound sensor on St Georges Hill, which records low frequency sound waves, recorded a clear explosion signal that coincided with the largest peak recorded in the seismic signals.

The collapse generated three pyroclastic flows that traveled down the flanks. The largest, from the Gages area, split into two and traveled to Lee's Yard and Plymouth. A pyroclastic flow in Plymouth also split into two as it diverted around Round Hill, with a pyroclastic surge traveling over the top of the hill.

The two lobes of this W-traveling pyroclastic flow traveled almost to the sea, with one reaching the old Police headquarters and the other reaching the Pentecostal Church and the old Government House. This pyroclastic flow set fire to trees and vegetation on Gages Mountain, the lower flank of St George's Hill, and some buildings in Plymouth.

Another pyroclastic flow emerged from the channel created by erosion on the dome's SE flank. It descended E into the Tar River valley and traveled as far as the old Montserrat coastline. A much smaller flow followed a gully cut in volcanic material choking the upper White River; this flow only reached ~ 2 km or less from the dome.

Dates (2008)	Average SO_2	Minimum	Maximum
31 May-06 Jun	206	—	—
07 Jun-13 Jun	228	161	294
14 Jun-20 Jun	254	201	347
21 Jun-27 Jun	323	256	472
28 Jun-04 Jul	329	276	440
05 Jul-11 Jul	339	242	564
11 Jul-18 Jul	414	243	561
18 Jul-24 Jul	378	216	794
25 Jul-01 Aug	—	—	—
28 Jul	2-3,000 tons SO_2 released during the eruption		
01 Aug-08 Aug	1,121	671	2,069
09 Aug-15 Aug	1,016	364	1,791
16 Aug-22 Aug	1,122	274	2,033
23 Aug-29 Aug	466 (3 days)	239	758
30 Aug-05 Sep	—	—	—
06 Sep-12 Sep	1,422	562	4,599
13 Sep-19 Sep	989	657	1,217
20 Sep-26 Sep	1,239 (2 days)	—	—
26 Sep-03 Oct	840	463	1,523
03 Oct-10 Oct	522	201	968
10 Oct-17 Oct	—	—	—
17 Oct-24 Oct	531	277	668
25 Oct-30 Oct	1,283	689	2,540

Table 3. Sulfur dioxide emission were almost continuous and appear here as weekly averages and Minimum/ Maximum values. SO_2 values in tons/ day. Courtesy of MVO.

Post-eruption examination of the deposits found that the pyroclastic flows at the Tar River appeared to contain significant amounts of old dome material, which would reflect the partial dome collapse. In contrast, the pyroclastic flows at both Plymouth and White River contained mainly juvenile pumice, material thought to have risen some distance in a plume.

The material collapsed from the dome on the 28th occupied a volume of ~ 200,000-300,000 cubic meters. Satellite radar images indicated that the vent above Gages wall was enlarged by the explosion to ~ 150 x 60 m, elongated E-W. MVO interpreted the 28 July eruption as caused by input of new magma, possibly triggered by the partial collapse of existing dome material.

MVO stated that the 28 July eruption generated a large ash column and the fallout of airborne pumice in nearby communities. The ash column reached a maximum altitude of ~ 12 km and drifted primarily NW. While almost no ash fell on inhabited areas near the volcano, there were reports of ashfall from St Croix, Puerto Rico, and Guadeloupe. Satellite sensors indicated the release of at least 2,000-3,000 tons of sulfur dioxide (table 3). Two minor eruptions on 29 July generated small ash clouds. During the period of this activity, the Washington VAAC published numerous advisories for aviation (table 4).

Monitoring dome shape and finding new rockfall material. The 6 August MVO report noted that the only significant change in the past few months occurred in the area of the Gage's Wall vent. That area was the source of ash and mild explosive activity in the last few months. During the first weeks of August seismicity was relatively low.

X-band radar images of the dome (figure 9) taken from different sides allow comparisons between 9 October 2007 and 1 August 2008. Images such as these help MVO interpret changes in topography and other features such as the surface texture of pyroclastic flows. Radar images provide data not available using optical techniques such as aerial photography or satellite imagery. For example, this image illustrates an effect called layover, where topography appears to lean. The images are also quite sensitive to the moisture content (affecting conductivity) and roughness of the ground surface (which scatters the radar energy).

Date	Time (UTC)	Altitude	Drift	Remarks
21 Jul	1145	~ 1.8 km	W	
21 Jul	1315	~ 1.8 km	—	Plume to ~ 2 km; 16 km wide.
21 Jul	1915	~ 1.8 km	W, S	
22 Jul	0108	—	—	Ongoing emissions
22 Jul	0708	~ 1.8 km	W	Intermittent low level ash emissions
22 Jul	1245	~ 1.8 km	W	Reduced seismicity
22 Jul	1845	~ 1.8 km	W	
27 Jul	1345	~ 2.4 km	W	Small bursts of venting gases and ash; seismic signals increased
27 Jul	1945	~ 2.4 km	W	Dome collapse event began
29 Jul	0415	~ 12 km	W	Partial dome collapse on dome's W flank, accompanied by several explosions that generated ash plumes. Highest ash level noted at about 0340 UTC moving ESE.
29 Jul	0340	~ 12 km	SE	Weak hotspot in multi-spectral satellite data
29 Jul	1215	~ 7.6 km	NW	Partial dome collapse 0327 UTC
29 Jul	1815	~ 7.6 km	NW	
30 Jul	0615	~ 2.7 km	SW	Low-level emissions
30 Jul	1215	~ 2.7 km	NW	Thin low level plume
30 Jul	2345	~ 7.6 km	W	Residual ash and ongoing summit emissions
20 Oct	1415	~ 5.5 km	NW	Ash associated with a pyroclastic flow

Table 4. Washington VAAC advisories as a result of ash plumes from Soufrière Hills during 21 July 2008-20 October 2008. All reports were based on GOES-12 satellite source information.

In the radar images color channels represent different points or intervals of time: red, 9 October 2007; green, 1 August 2008; and blue, the difference between those two dates. The result is that yellow areas depict terrain unchanged between those times. Areas of magenta had rougher surfaces in 2007 than 2008; areas that are cyan had rougher surfaces in 2008 than in 2007.

A new lava extrusion started from the W side of the lava dome sometime between the 28 July dome collapse event and 8 August when a new channel of fresh rockfall material was seen below Gages Wall.

On 14 August the dome's W side was visible and observers noted that the explosion crater of 28 July was almost filled with new lava and lava had spilled over the lower and W side of the crater and generated rockfalls.

On 8 August, the Government of Montserrat instituted a new Hazard Level System, which replaces the Alert Level system. The system divides the southern two-thirds of the island into six zones, and includes two Maritime Exclusion Zones. Access into each of the zones is restricted depending on the Hazard Level assigned (1-5); the current level has been set at 3.

During the week of 15-22 August, MVO found evidence of increased growth of the dome's W side. Earthquakes and rockfalls increased. Rockfalls occurred on the dome's W side in a new channel below Gages Wall. Ash plumes occasionally generated by the rockfalls were most noticeable on 16 and 17 August. On 19 August a pyroclastic flow again descended the Tar River Valley. According to news reports, on 25 August a rainfall-induced pyroclastic flow on the W flank split into two parts and caused ashfall to the N. The event enlarged and steepened the rockfall gully below Gages Wall. Lahars likely descended the Tar River Valley on 29 and 31 August.

On 1 September, a lahar descended the Belham River valley to the NW; the event lasted ~ 50 minutes. A new vent was observed on the NW part of the lava dome, a little further N of the Gages vent. Incadescence was also observed at a scar on the lava dome and in an area N of the scar. Rockfalls descended the W side of the dome. MVO reported that seismicity continued at a low level and dome growth continued throughout September.

During October, slow growth on the W side of the dome was accompanied by mudflows. As a result of slow and continuous erosion of the lower part of the dome, occasional rockfalls occurred on both the W side in the gully over Gages Wall and on the E side in the Tar River Valley.

One notable volcano-tectonic event occurred on 5 October in coincidence with the arrival of seismic waves from a M 6.6 earthquake in central Asia. Although the rate of lava extrusion had declined significantly, thermal imagery captured during an overflight on 8 October revealed that a major E-W oriented fracture in the dome, aligned with Gages valley and extending vertically over a few tens of meters, was associated with very elevated temperatures. Several other very hot areas on the dome were visible as points of incandescence that night. Also on 8 October, mobile, hot lahars were observed in Plymouth near the Pentecostal Church. This indicated that the 28 July pumice flows were still very hot.

Toward the middle of October, activity was low and consisted mainly of mudflows spurred by tropical storms that evolved to become hurricane Omar. Strong headward erosion affected the dome's talus slope on the Tar River side. A large gap developed in the talus, exposing the dome's core and forming a large vertical cliff.

Between 10-17 October, instrumentation recorded five long-period, five hybrid, and one volcano-tectonic earthquakes and only two rockfalls. By the third week of October, activity had increased slightly. Seismicity for the week consisted of 22 long-period, eight hybrid, and eight volcano-tectonic earthquakes, and two rockfalls. Incandescence was again observed from MVO on 17 October. On 20 October, three small pyroclastic flows descended to the Tar River Valley, generating small ash clouds that drifted over unpopulated areas to the W and SW. These pyroclastic flows were probably caused by the slightly increased seismic activity and continued interaction of the hot dome with water from the intense rainfall following passage of hurricane Omar. As of 24 October, there was no evidence of ongoing lava extrusion. Through the end of October, activity was at a low level. MVO recorded only four rockfalls, two long-period rockfalls, and one volcano-tectonic event. Several mudflow signals were also recorded during periods of heavy rainfall. Limited observations on 26 October confirmed that a few small pyroclastic flows traveled ~ 1.5 km E on the Tar River side.

Headward erosion continued along several V-shaped chutes at the base of the dome on both the dome's Tar River and SE sides. A small pyroclastic flow descended the Tar River (runout of ~ 1 km) on 27 October; it generated small ash clouds that drifted over unpopulated areas to the W, and to the SW. On the dome's W flanks, the talus pile on the Galways side developed a well-incised network of gullies leading into the White River.

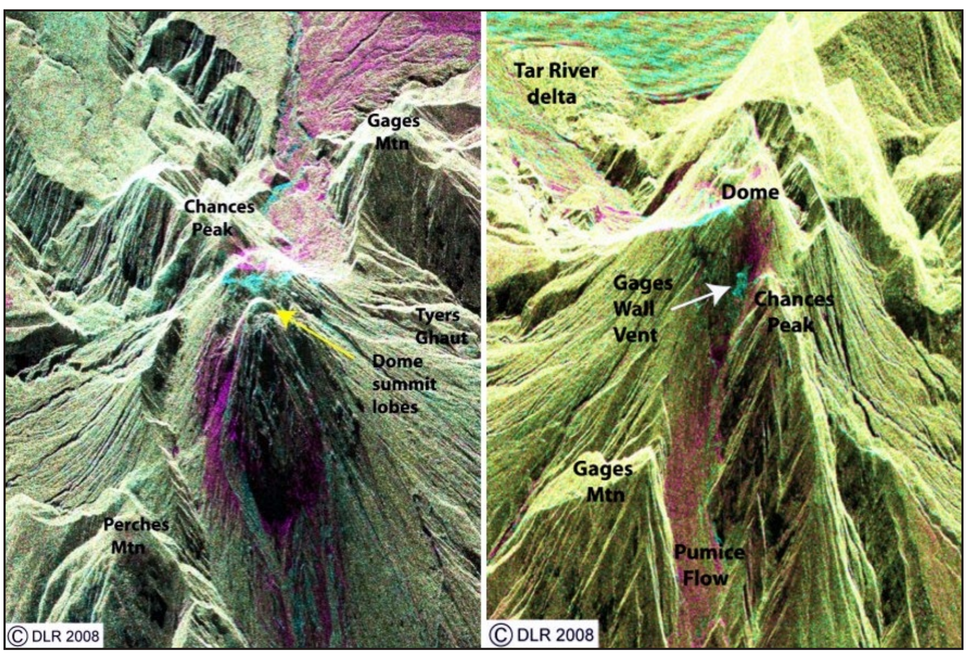


Figure 9. False-color satellite images with 2-3 m resolution showing Soufriere Hills from the E (left) and W (right) made to compare 9 October 2007 and 1 August 2008. These images used radar (TerraSAR-X, ~ 3 cm wavelength) data and provided views of such features as the 28 July 2008 pyroclastic flow deposits. In colored versions of these images, those 28 July deposits appear as magenta areas (rougher in 2007 than 2008). Similarly, the enlarged Gages Wall vent, which is best seen in the W view, is cyan-colored (rougher in 2008 than 2007). The image was made available to MVO thanks to the United Nations' International Charter, Geoff Wadge, and the German TerraSAR-X satellite. Courtesy of MVO.

On 2-5 December a series of explosions took place without clear seismic precursors. The first was the largest; MVO reported that incandescent blocks were ejected to 1 km from the dome's Gages vent. Pyroclastic flows began within 15 seconds of the first explosion's start at 0935 local time. They soon set vegetation and a few buildings into flames at Plymouth, and some of the fires continued for hours, one into the next day. The flows appeared devoid of pumice and were thought to be composed mainly of hot dome material. The event was judged smaller than the one on 28 July 2008, although the plume rose to over 10 km. The accompanying ash columns became the path for lightning strikes. Inhabited areas remained free of ash, which blew W. As of early December scientists had not assessed the impact of the 2 December events to the dome.

Geologic Summary. The complex, dominantly andesitic Soufrière Hills volcano occupies the southern half of the island of Montserrat. The summit area consists primarily of a series of lava domes emplaced along an ESE-trending zone. English's Crater, a 1-km-wide crater breached widely to the E, was formed during an eruption about 4000 years ago in which the summit collapsed, producing a large submarine debris avalanche. Block-and-ash flow and surge deposits associated with dome growth predominate in flank deposits at Soufrière Hills. Non-eruptive seismic swarms occurred at 30-year intervals in the 20th century, but with the exception of a 17th-century eruption that produced the Castle Peak lava dome, no historical eruptions were recorded on Montserrat until 1995. Long-term small-to-moderate ash eruptions beginning in that year were later accompanied by lava-dome growth and pyroclastic flows that forced evacuation of the southern half of the island and ultimately destroyed the capital city of Plymouth, causing major social and economic disruption.

Information Contacts: *Montserrat Volcano Observatory (MVO)*, Fleming, Montserrat, West Indies (URL: http://www.mvo.ms/); *Washington Volcanic Ash Advisory Center*, Satellite Analysis Branch (SAB), NOAA/NESDIS E/SP23, NOAA Science Center Room 401, 5200 Auth Rd., Camp Springs, MD 20746, USA (URL: http://www.ssd.noaa.gov/); *Caribbean Net News* (URL: http://www.caribbeannetnews.com/).

Colima

México
19.514°N, 103.62°W; summit elev. 3,850 m

A new episode of lava dome growth in the crater was first observed on 1 February 2007 (*BGVN* 33:04). During its initial stage (February-September 2007), the mean effusion rate was about 0.004 m^3/s. The rate of effusion increased significantly in October 2007, up to 0.033 m^3/s.

New observations during overflights on 1 August and 8 November 2008 showed a significant increase in the dome volume (figure 10), reaching ~ 1,200,000 m^3. The effusion rate during August-November 2008 increased up to 0.05 m^3/s. By late November, the dome filled more than 50% of the crater and could be easily seen above the crater rim (figure 11). This dome growth has been accompanied by 5-10 small explosions daily without significant variations during two years of activity (figure 12).

Geologic Summary. The Colima volcanic complex is the most prominent volcanic center of the western Mexican Volcanic Belt. It consists of two southward-younging volcanoes, Nevado de Colima (the 4320 m high point of the complex) on the north and the 3850-m-high historically active Volcán de Colima at the south. A group of cinder cones of late-Pleistocene age is located on the floor of the Colima graben west and east of the Colima complex. Volcán de Colima (also known as Volcán Fuego) is a youthful stratovolcano constructed within a 5-km-wide caldera, breached to the south, that has been the source of large debris avalanches. Major slope failures have occurred repeatedly from both the Nevado and Colima cones, and have produced a thick apron of debris-avalanche deposits on three sides of the complex. Frequent historical eruptions date back to the 16th century. Occasional major explosive eruptions (most recently in 1913) have destroyed the summit and left a deep, steep-sided crater that was slowly refilled and then overtopped by lava dome growth.

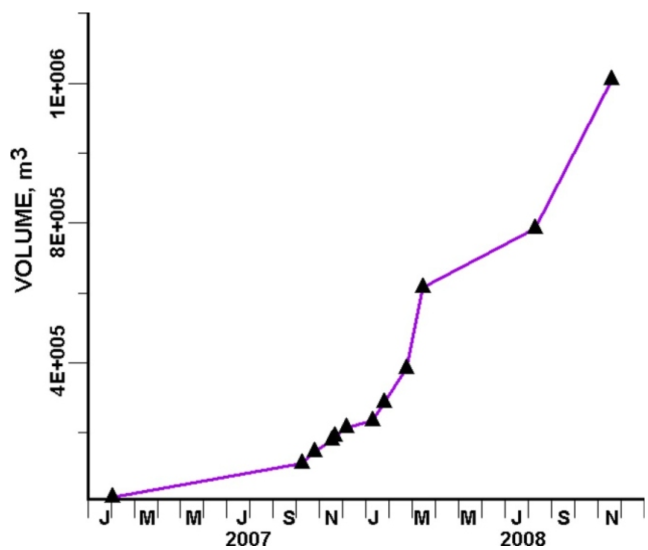


Figure 10. Cumulative volume of dome material extruded at Colima during January 2007-early November 2008. Courtesy of Colima Volcano Observatory.

Figure 11. Photo of the dome taken on 21 November 2008 from the top of Nevado de Colima (6 km N of Volcán de Colima). Courtesy of Colima Volcano Observatory.

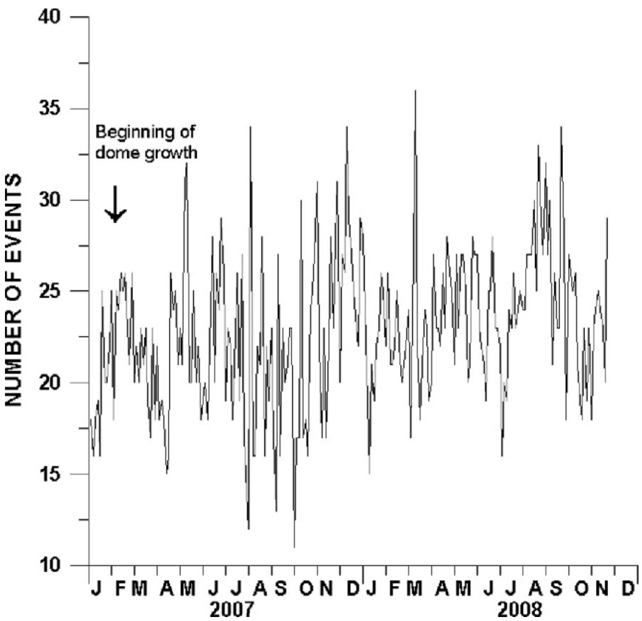


Figure 12. Variations in the number of small explosions (3-day sums) recorded by a seismic station situated at 1.6 km from the crater. Courtesy of Colima Volcano Observatory.

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

Garbuna Group

New Britain, SW Pacific
5.45°S, 150.03°E; summit elev. 564 m
All times are local (= UTC +10 hours)

Weak to moderate seismicity with an ash emission occurred during March 2008 (*BGVN* 33:02). According to the Rabaul Volcano Observatory (RVO), white vapor rose from Garbuna during the first 12 days of July; however on 13 July, moderate-to-strong emissions of pale-white to light-gray ash clouds were observed. The ash emissions formed a column that rose ~ 1 km above the summit area. Seismic activity was generally very low during the period.

Additional ash emissions occurred on 5 August, accompanied by incandescent lava ejection, and between 23 September and 1 October. Ash plumes rose ~ 1.6 km and drifted NW. During 1-4 October, forceful emissions of dense white plumes from Garbuna were accompanied by intermittent ash emissions that rose to an altitude of 1.6 km. RVO reported that occasional weak roaring and rumbling noises were heard in Garu village, about 9 km NW.

An overflight on 3 October revealed that existing vents at the summit had increased in size and new vents and fumaroles had appeared in the E sector of the lava dome. The main vent, which had been located on the cone's outside flank, had enlarged considerably (more than tripled in size) and had merged with the November 2005 vent. The original vent that opened on 17 October 2005 was larger and vigorously fuming. There was little evidence of juvenile material having been ejected and surprisingly little eruptive material around the summit; however areas more than 1 km away from the active vents were cratered, possibly from lithic bombs. Fumarolic activity in the summit region away from the currently active vents had ceased.

On 6-10 October the RVO reported that white plumes from Garbuna were emitted and deep booming noises were occasionally heard. On 7 October, an explosion produced forceful emissions of dense white vapor. Seismicity increased to a high level after the explosion. It was characterized by continuous overlapping tremors that continued for a while before declining to a low level again. RVO recorded low-frequency earthquakes on 6 and 8 October. No volcano-tectonic (high-frequency) earthquakes were recorded with those events.

Geologic Summary. The basaltic-to-dacitic Garbuna volcano group consists of three volcanic peaks, Krummel, Garbuna, and Welcker. They are located along a 7-km N-S line above a shield-like foundation at the southern end of the Willaumez Peninsula. The central and lower peaks of the centrally located 564-m-high Garbuna volcano contain a large vegetation-free area that is probably the most extensive thermal field in Papua New Guinea. A prominent lava dome and blocky lava flow in the center of thermal area have resisted destruction by thermal activity, and may be of Holocene age. The 854-m-high Krummel volcano at the south end of the group contains a summit crater, breached to the NW. The highest peak of the Garbuna group is 1005-m-high Welcker volcano, which has fed blocky lava flows that extend to the eastern coast of the peninsula. The last major eruption from both it and Garbuna volcanoes took place about 1800 years ago. The first historical eruption of the complex took place at Garbuna in October 2005.

Information Contacts: *Herman Patia*, *Steve Saunders*, and *Ima Itakarai*, Rabaul Volcano Observatory (RVO), PO Box 386, Rabaul, Papua New Guinea.

Merapi

Java, Indonesia
7.542°S, 110.442°E; summit elev. 2,968 m
All times are local (= UTC + 7 hours)

Our last report on Merapi (*BGVN* 32:02) described vigorous dome growth during March-July 2006. The increasingly unstable summit was the scene of numerous pyroclastic flows, avalanches, and volcanic earthquakes. According to the Center of Volcanology and Geological Hazard Mitigation (CVGHM), Merapi's long-term dome growth continued at low to modest levels during the rest of 2006 and early 2007.

Activity in May 2006 included dome growth (figures 13 and 14) and pyroclastic flows (figure 15). According to CVGHM, as a result of decreasing activity, the Alert Level was lowered to 3 (on a scale of 1-4) for all areas on 17 July 2006 and to Level 2 on 3 August 2006. Nearly continuous thermal anomalies were measured by the MODIS/MODVOLC satellite system during the period 14 May - 5 September 2006, and small anomalies were noted on 29 November 2006 and 5 January 2006. No thermal anomalies for Merapi have been measured by MODIS since 5 January 2007. The Darwin Volcanic Ash Advisory Center (VAAC)

Figure 13. Incandescent blocks stream down the growing lava dome on 15 May 2006. Courtesy of Discover Indonesia Online (Associated Press photo).

Figure 14. Newly extruded dome lava on the summit of Merapi seen from the N side on 21 May 2006. Courtesy of Tom Pfeiffer (Volcano Discovery).

Figure 15. Merapi erupting on 23 May 2006 as seen from Cangkringan, near Yogyakarta. The image captured a pyroclastic flow. Courtesy of Discover Indonesia Online.

noted a plume to 6.1 km altitude drifting NE on 19 March 2007 (table 5).

Geologic Summary. Merapi, one of Indonesia's most active volcanoes, lies in one of the world's most densely populated areas and dominates the landscape immediately north of the major city of Yogyakarta. Merapi is the youngest and southernmost of a volcanic chain extending NNW to Ungaran volcano. Growth of Old Merapi volcano beginning during the Pleistocene ended with major edifice collapse perhaps about 2,000 years ago, leaving a large arcuate

Date	Plume altitude	Other events
05 Jul-11 July 2006	4 km	
12 Jul-18 Jul 2006	4 km	Lava flows, 2 km SE.
19 Jul-25 Jul 2006	3.4 km	Daily lava flows, 1.5 km SE.
26 Jul-01 Aug 2006	3.4 km	Incandescent rock avalanches, 2 km SE.
02 Aug-04 Aug 2006	6.1 km	Rockfalls, 1 km SE.
10 Oct 2006	—	Incandescent material, 1 km.
20 Nov 2006	—	"Hot clouds," 3 km.
19 Mar 2007	6.1 km	
23 May-29 May 2007	—	Incandescent material and "hot clouds," 1 km SE. Ashfall 16 km W.
09 Aug 2007	4.6 km	
19 May 2008	11.6 km	

Table 5. Ash plumes and other events associated with Merapi between 5 July 2006 and 15 November 2008. Distances given under "Other events" represent maximum distances observed. Plume altitudes through 1 August 2006 were calculated from CVGHM information; subsequent plume altitudes were reported by the Darwin VAAC. Courtesy of CVGHM, Darwin VAAC, and various newspaper articles.

scarp cutting the eroded older Batulawang volcano. Subsequently growth of the steep-sided Young Merapi edifice, its upper part unvegetated due to frequent eruptive activity, began SW of the earlier collapse scarp. Pyroclastic flows and lahars accompanying growth and collapse of the steep-sided active summit lava dome have devastated cultivated lands on the volcano's western-to-southern flanks and caused many fatalities during historical time. The volcano is the object of extensive monitoring efforts by the Merapi Volcano Observatory.

Information Contacts: *Center of Volcanology and Geological Hazard Mitigation* (CVGHM), Jalan Diponegoro 57, Bandung 40122, Indonesia (URL: http://portal.vsi.esdm.go.id/joomla/); *Darwin Volcanic Ash Advisory Centre* (VAAC), Bureau of Meteorology, Northern Territory Regional Office, PO Box 40050, Casuarina, NT 0811, Australia (URL: http://www.bom.gov.au/info/vaac/); *Hawai'i Institute of Geophysics and Planetology (HIGP) Thermal Alerts System,* School of Ocean and Earth Science and Technology (SOEST), University of Hawai'i, 2525 Correa Road, Honolulu, HI (URL: http://hotspot.higp,hawaii.edu); *Discover Indonesia Online* (URL: http://www.indahnesia.com/); *Tom Pfeiffer*, Volcano Discovery (URL: http://decadevolcano.net/).

Gamalama

Halmahera, Indonesia
0.80°N, 127.33°E; summit elev. 1,715 m

On 11 May 2008, CVGHM reported that emissions from Gamalama had risen to higher altitudes during the previous two days. On 10 May, white-to-gray plumes rose to an altitude of 1.8 km and drifted N. On 11 May, white plumes increased throughout the day from 1.7 to 2.2 km altitude. Based on the visual observations and seismicity, CVGHM raised the Alert Level and warned residents and tourists not to go within 2 km of the summit. No thermal anomalies were measured by MODIS during this time.

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

Information Contacts: *Center of Volcanology and Geological Hazard Mitigation (CVGHM)*, Jalan Diponegoro 57, Bandung 40122, Indonesia (URL: http://portal.vsi.esdm.go.id/joomla/).

Akan

Hokkaido, Japan
43.384°N, 144.013°E; summit elev. 1,99 m
All times are local (= UTC + 9 hours)

A minor eruption on 21 March 2006 produced minor ashfall around the summit (*BGVN* 31:02). This report begins with activity seen at the Akan volcanic complex (figure 16) on 29 September 2008, which included a four-minute seismic tremor at Me-Akan, prompting the Japan Meteorological Agency (JMA) to raise the Alert Level to a "near-crater warning." The number of earthquakes had increased since 26 September. A white plume rose less than 100 m above the Me-Akan volcano group, which is part of the Akan volcanic complex.

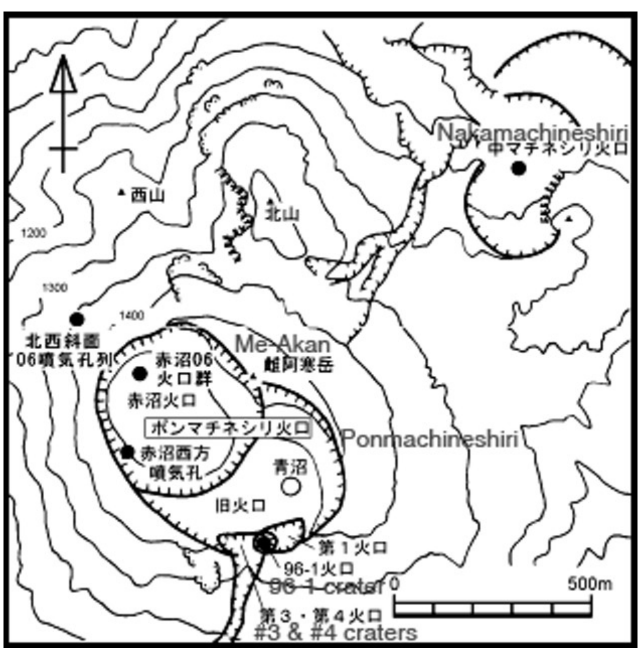


Figure 16. A map of Akan with translations for some of the critical features of interest. Courtesy of JMA.

On 17 October, JMA lowered the Alert Level to normal. Seismic tremor was no longer detected after 30 September, and seismicity had remained low after 3 October. On 17 November, JMA again raised the Alert Level to "near-crater warning" after the seismic network detected tremor that lasted 171 minutes.

On 18 November the summit was obscured by cloud cover, but web camera views showed that the snow-covered S slopes had turned black. During an overflight later that day, JMA scientists noted that the ash covered an area up to 400 m away from Ponmachineshiri crater on Me-Akan volcano. Ballistic lithics several tens of centimeters in diameter were deposited around the crater.

On 28 November Me-Akan erupted again (figures 17 and 18). An ash plume rose to an altitude of 2 km and drifted N, E, and SE. According to JMA, ash was deposited on the E flank up to 4 km away from the crater, and the black ash cover on snow surface appeared wider and thicker than on 18 November.

Geologic Summary. Akan is a 13 x 24 km, elongated caldera that formed more than 31,500 years ago immedi-

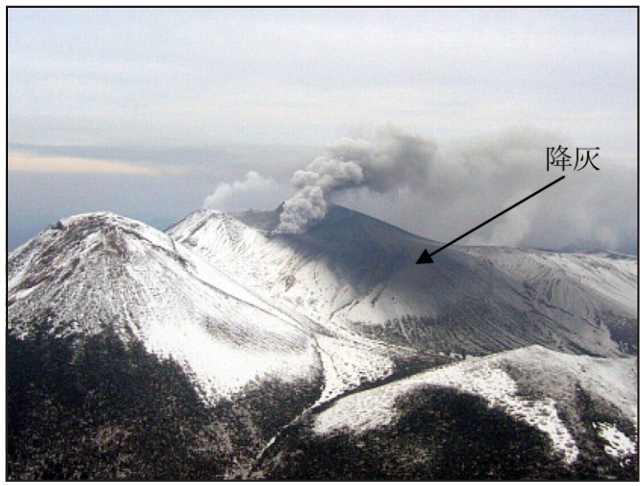


Figure 17. Part of the Akan volcanic complex as seen from the air looking NW at 1134 on 28 November 2008. The snow-covered slopes contain a distinct darkened area due to the presence of fresh ashfall (indicated with arrow). The larger plume at right originates from the 96-1 crater in the Ponmachineshiri crater. The smaller steam plume at left is commonly seen; it comes from a vent on the NW slopes (which were active in 1996). Courtesy of JMA.

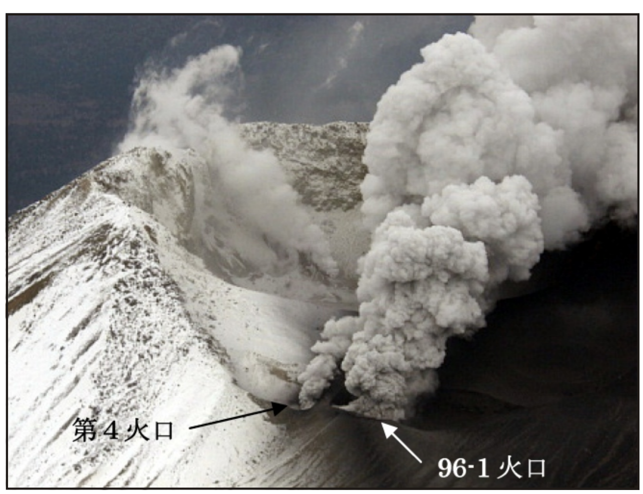


Figure 18. A view of Me-Akan from the S taken at at 1151 on 28 November showing views of steam emissions from both the "96-1 crater" (crater #1 of 1996) and the number 4 crater. Courtesy of JMA.

ately SW of Kutcharo caldera. Growth of four post-caldera stratovolcanoes, three at the SW end of the caldera and the other at the NE side, has restricted the size of the caldera lake. The 1-km-wide Nakamachineshiri crater was formed during a major pumice-and-scoria eruption about 13,500 years ago. Of the Holocene volcanoes of the Akan volcanic complex, only the Me-Akan group, east of Lake Akan, has been historically active, producing mild phreatic eruptions since the beginning of the 19th century. Me-Akan is composed of 9 overlapping cones. The main cone of Me-Akan proper has a triple crater at its summit. Historical eruptions at Me-Akan have consisted of minor phreatic explosions, but four major magmatic eruptions including pyroclastic flows have occurred during the Holocene.

Information Contacts: *Volcanological Division*, Seismological and Volcanological Department, Japan Meteorological Agency (JMA), 1-3-4 Ote-machi, Chiyoda-ku, Tokyo 100, Japan (URL: http://www.jma.go.jp/jma/indexe.html).

Long Valley

California, USA
37.70°N, 118.87°W; summit elev. 3,390 m

The Long Valley Observatory (LVO) of the United States Geological Survey (USGS) monitors and studies earthquakes, ground deformation, degassing, and other types of geologic unrest in and around the Long Valley caldera. The LVO posts hazard status as a color code in one of four categories: green, yellow, orange, and red (the most serious response). The Long Valley caldera (figures 19 and 20) is located along the E side of the Sierra Nevada in east-central California. The hazard status remained at Green throughout 2007-2008.

The broad resurgent dome in the caldera had essentially stopped inflating in early 1998, then slowly subsided so that by the end of 2006, the center of the resurgent dome was 75-80 cm higher than its height before the unrest in 1980. Seismic activity during 2006 within the caldera remained low with earthquakes less than than M < 2.0. The largest earthquake in the region was an M 4.3 event near Grinnell Lake in the Sierra Nevada 16 km S of the caldera.

Brief sequences of small (M < 1.7), rapid-fire earthquakes (spasmodic bursts) beneath Mammoth Mountain occurred on 19 September and 23-24 November 2006.

During 2007, the Long Valley caldera remained comparatively quiet. Earthquake activity within the immediate confines of the caldera included minor swarms beneath Mammoth Mountain on 17-26 January and 13 March and a swarm beneath the SE margin of the resurgent dome (2.5 km WSW of Hot Creek) on 13-15 March .

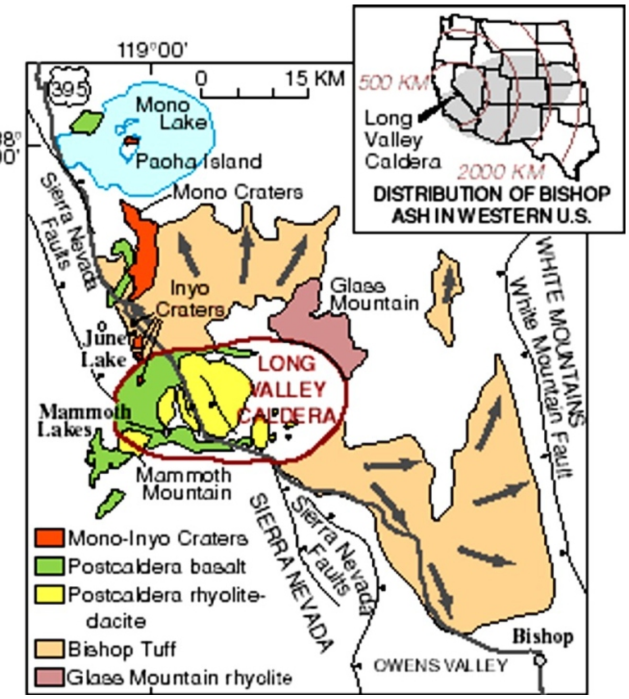


Figure 19. Map of Long Valley showing volcanic area just E of the Sierra Nevada mountain range. Courtesy of the USGS/LVO.

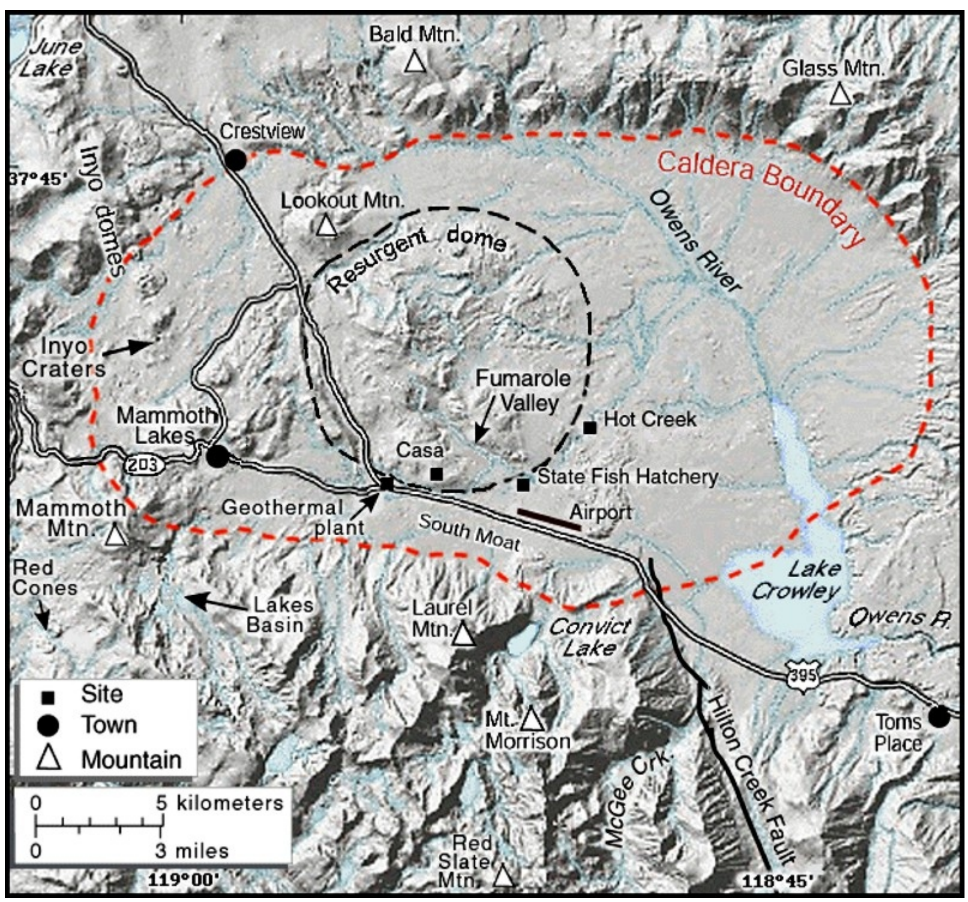


Figure 20. Map of Long Valley caldera showing internal resurgentdome location. Courtesy of the USGS/LVO.

The largest of these swarm earthquakes was a M 2.1 event on 15 March located ~ 2.5 km WSW of Hot Creek. Earthquake activity in the Sierra Nevada S of the caldera was greater than activity within the caldera. The largest earthquake in the region was a M 4.6 event on 12 June near Lake Dorothy (1.5 km SSW of Mount Morrison 9 km SSE of the caldera's margin). Aftershocks to this earthquake persisted through the remainder of June and included ~ 27 earthquakes of M > 2. A cluster of small earthquakes occurred on 21 December 2007; the largest was recorded at M 1.7.

On 22 November 2008, three earthquakes large enough to be located by the automatic earthquake detection system broke the quiescence at Long Valley and the area south of the volcano. One, magnitude M 1.4, was located beneath the resurgent dome inside the caldera. The others, M 1.7 and M 1.3, were located to the S in the Sierra Nevada.

Between 25 November and 1 December 2008, 13 minor earthquakes occurred in the Long Valley area. All were below magnitude 2.0; one was located N of Round Valley and the rest were S of the caldera in the Sierra Nevada.

As of November 2008, the carbon dioxide (CO_2) flux in the vicinity of Mammoth Mountain remained high but showed evidence of a gradual decline since 1995. The relatively high diffuse CO_2 gas flux of 50-150 tons/day in the Horseshoe Lake tree-kill area (16.6 km SSE of Long Valley and 2.67 km SE of Mammoth mountain) has been relatively constant over the past several years. Sporadic episodes of geysering in Hot Creek that began May 2006 continued through December 2007, but at a declining rate.

Geologic Summary: The large 17 x 32 km Long Valley caldera east of the central Sierra Nevada Range formed as a result of the voluminous Bishop Tuff eruption about 760,000 years ago. Resurgent doming in the central part of the caldera occurred shortly afterwards, followed by rhyolitic eruptions from the caldera moat and the eruption of rhyodacite from outer ring fracture vents, ending about 50,000 years ago. During early resurgent doming the caldera was filled with a large lake that left strandlines on the caldera walls and the resurgent dome island; the lake eventually drained through the Owens River Gorge. The caldera remains thermally active, with many hot springs and fumaroles, and has had significant deformation, seismicity, and other unrest in recent years. The late-Pleistocene to Holocene Inyo Craters cut the NW topographic rim of the caldera, and along with Mammoth Mountain on the SW topographic rim, are west of the structural caldera and are chemically and tectonically distinct from the Long Valley magmatic system.

Information Contacts: *Dave Hill*, Long Valley Observatory, U.S. Geological Survey, 345 Middlefield Rd., MS 977, Menlo Park, CA 94025, USA (URL: http://lvo.wr.usgs.gov/).