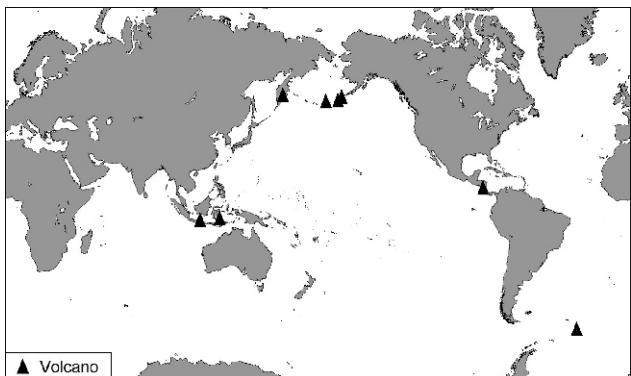


# Bulletin of the Global Volcanism Network



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## Okmok

Aleutian Islands, USA

53.43°N, 168.13°W; summit elev. 1,073 m

All times are local (= UTC - 9 hours [or 8 hours, early April-late October])

This report discusses the important explosive eruption of Okmok (figure 1) that began on 12 July 2008 (*BGVN* 33:06) and summarizes the period from mid-July to mid-August 2008. Vigorous eruptions continued with many plumes over 4 km altitude and some as tall as ~ 11 km. The information in this report is mostly compiled from daily and weekly AVO postings. Remote sensing data showed vigorous eruption plumes that spread over North America; these plumes were unusually complex and well-documented in photographs by pilots, including some over Montana (USA), thousands of kilometers from the volcano. Other powerful eruptions in the region included those at Cleveland and an SO<sub>2</sub>-rich eruption from Kasatochi. Near Okmok, cloud cover often restricted views.

On 19 July seismicity increased markedly and reached a level commonly associated with vigorous ash emissions. The seismic data was consistent with explosive ash plumes and an image (AAVHRR thermal IR (Channel 4)) indicated cloud temperatures of -50°C, suggesting an altitude of at least 9.1 km.

Satellite imagery from 20 July revealed an ash plume ~ 20 km from Okmok drifting SE at 3.7 km altitude. Nearly continuous volcanic tremor changed to tremor of a more episodic character, and the overall seismic intensity declined. Additional ash plumes observed on satellite imagery and spotted by pilots rose to altitudes of 4.6-6.1 km. On this day a photograph taken from an Alaska Airlines jet captured an impressive plume from Okmok from 11.3 km (37,000 ft) altitude (figure 2).

Aerial photographs and video footage was collected by AVO staff and others on 20 and 21 July. It confirmed the presence of multiple vigorous vents on the caldera floor.

The flights on 21 July revealed Okmok ash on the snow at Makushin volcano. During 21-22 July, ash plumes continued to be present and rose to altitudes of 6.1-9.1 km and drifted SE. Okmok's seismicity remained episodic, but well above background. On 23 July, tremor that was episodic in



Figure 2. A 20 July aerial photo of the Okmok eruption made looking S from a spot ~ 24 km away (taken at approximately 1950 ADT). Estimated tops of ash and vapor were at 6.2 km (20,000 ft.) altitude. Photo taken by Phil Walgren.

duration shifted to nearly continuous and grew to mid-level amplitudes. Although cloud cover obscured views of Okmok that day, previously emitted ash plumes were visible to the ESE. On 24 July, a thermal anomaly was possibly present on satellite imagery. Lahar damage to bridges and roads in Fort Glenn was evident. Around this time, the sailing vessel "Minnow" endured ashfall during a 30-minute interval. The thickness of ash deposited was not disclosed, but ash removal required five hours of cleaning.

Seismic amplitude increased on 25 July. Based on pilot reports and observations of satellite imagery, AVO reported that ash plumes rose to altitudes of 10.7-12.2 km.

On 26 July, seismicity decreased and satellite imagery indicated that ash plumes rose to altitudes of 6.1-6.7 km. Seismicity increased again on 27 July. Satellite imagery possibly indicated another thermal anomaly; a possible plume at an altitude of less than 3 km was also noted.

Two photos (figures 3 and 4) illustrate the new delta resulting from fresh ash deposits eroded and carried to the mouth of Crater Creek. The first photo was taken 27 July, the second, 2 August.

On 28 July, tremor decreased. Ash plumes at altitudes of 8.2-10.7 km drifted E and SE. Tremor shifted from nearly continuous to episodic. Later that day and on 29

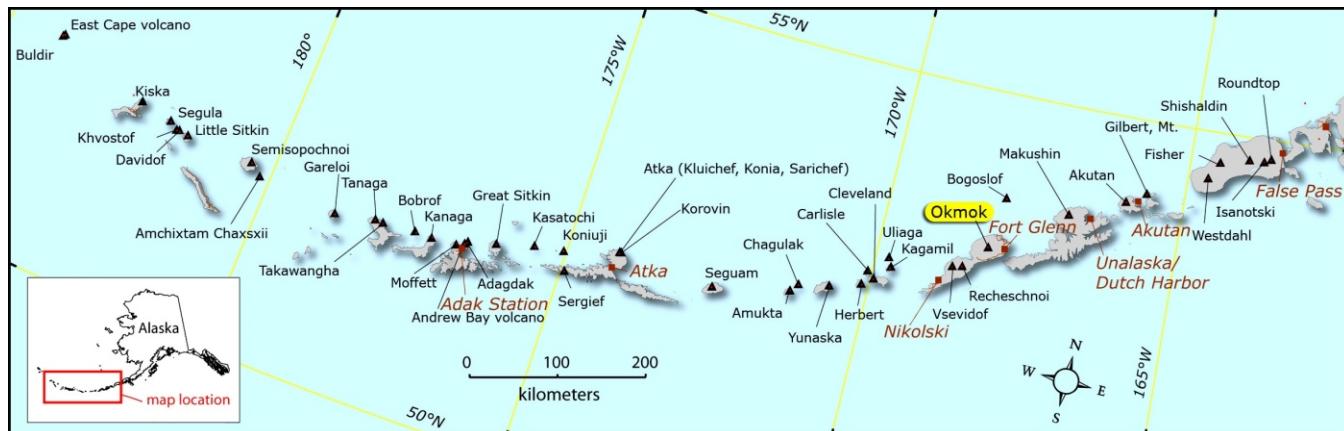


Figure 1. Map showing Okmok and vicinity. Courtesy of Janet Schaefer, Alaska Volcano Observatory / Alaska Division of Geological & Geophysical Surveys (AVO/ADGGS).



Figure 3. A 27 July 2008 photo illustrating the broad delta formed by lahars along Okmok's Crater Creek. The "Equinox," the shipwreck on the left side of the photo, used to be awash before the July 2008 eruption. Photo courtesy of Lonnie Kennedy.



Figure 4. Another view of the new Okmok lahar delta formed at Cape Tanak, where Crater Creek enters the sea. The shipwreck lies in the center of this photo. Photo taken 2 August 2008 by Jessica Larsen, Alaska Volcano Observatory / University of Alaska Fairbanks, Geophysical Institute (AVO/UAF-GI).



Figure 5. Before-and-after photographs of the falls on Crater Creek, the outflow stream draining Okmok caldera on its NE side. The right photo was taken on 2 August, three weeks after the onset of the 2008 eruption. The left photo is approximately the same view taken in September 2004. Okmok is treeless, but at lower elevations is covered with a verdant blanket of wildflowers and grasses. The index image (lower-left corner) is from a digital elevation map (DEM). Both photographs and the DEM are by Janet Schaefer, AVO/ADGGS.

July, discrete plumes containing some ash rose to altitudes of 6.1-10.7 km and drifted E to SE.

According to pilot reports and analysis of satellite imagery for 30 July, ash plumes then rose to altitudes of 4.6-6.1 km and drifted W. Seismicity alternated between periods of continuous and pulsating tremor. On 31 July, ash plume at altitudes of 9.1-9.8 km were seen on satellite images. On 31 July, reports from a fishing boat 11.3 km N indicated visibility had ceased due to ashfall. The National Weather Service issued an ashfall advisory for Umnak Island and Unalaska/Dutch Harbor that remained in effect until 2400 on 1 August.

Strong volcanic tremor on 2 August prompted AVO to raise the Volcano Alert Level and the Aviation Color Code to the highest level. Cloudy conditions prevented satellite observations. Later that day, AVO geologists in the area reported that ash-and-steam plumes rose to minimum altitude of 6.1 km. The seismicity then decreased. Next, observers in Fort Glenn on Umnak Island reported smelling sulfur and seeing a larger ash plume than earlier that day. The plume drifted ESE.

AVO scientists observed the eruption during a visit on 2 and 3 August. They saw significant ashfall accumulated in the caldera and on the upper flanks. Lahars and lahar deltas had formed in drainages from the SE to the NE flank (figure 5). Continuous ash jets escaped from three or more vents in the NE sector of the caldera.

Figure 6 shows a view of a 3 August eruption, as seen from a commercial airliner. The plume was also seen mid-day on 3 August (figure 7). On that day, both helicopter and ground-based observers indicated an ash plume at lower altitude along with a steam plume at higher altitude. Satellite imagery revealed ash plumes at altitudes of 9.1-10.7 km drifting SSW.

On 4 August, ashfall reported in the settlement of Nikolski (80 km SW) had accumulated to a depth of 3 mm. During 4-5 August, satellite imagery and pilot observations indicated that ash plumes rose to altitudes of 3-7.6 km and drifted SW and W.

Elevated seismicity occurred during 6-8 August, and declined on 9 August. According to satellite imagery for 9-10 August, there were steam plumes possibly containing



ash rising up to 4.6 km altitude. On 11 August, steam plumes rose to less than 6.1 km altitude and drifted SE. Ash plumes that rose to around a hundred meters above the crater were reported by an observer in Nikolski. These plumes were not detected on satellite imagery due to cloud cover. On 12 August, a pilot reported an ash plume at an altitude of 4.6 km.

AVO reported that a new vent was active on 13 August. Emissions that day, possibly from multiple vents, were rich in both ash and steam. Low-level steam-and-ash plumes were visible on satellite imagery drifting SE at altitudes of 3-4.6 km. During 14-17 August satellite observations were hindered due to cloud cover; seismic levels fluctuated, possibly indicating that steam-and-ash emissions continued. During 18-19 August, ash plumes were seen on satellite imagery at altitudes of 3-4.6 km.

No thermal anomalies related to Okmok were measured by MODIS satellites during January-August 2008.

**Geologic Summary.** The broad, basaltic Okmok shield volcano, which forms the NE end of Umnak Island, has a dramatically different profile than most other Aleutian vol-

canoes. The summit of the low, 35-km-wide volcano is cut by two 10-km-wide calderas formed during eruptions about 8,250 and 2,400 years ago that produced dacitic pyroclastic flows that reached the coast. Numerous satellite cones and lava domes dot the flanks of the volcano down to the coast. Some of the post-caldera cones show evidence of wave-cut lake terraces; the more recent cones, some of which have been active historically, were formed after the caldera lake disappeared. Hot springs and fumaroles are found within the caldera and at Hot Springs Cone, 20 km to the SW. Historical eruptions have occurred since 1805 from cinder cones within the caldera.

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



Figure 6. View of Okmok eruption, taken from a NE-bound Alaska Airlines flight at ~10.7 km (35,000 ft) altitude on 3 August 2008 (between the hours of 2000 and 0008). Plume tops estimated to ~2.1 km (~7,000 ft) altitude using nearby Mount Vsevidof (summit elevation, 2,149 m / 7,051 ft) for reference. Courtesy of Burke Mees.



Figure 7. View of Okmok's ash plume emitting from multiple vents near intracaldera Cone D. Photo taken on 3 August 2008 by Jessica Larsen, Alaska Volcano Observatory / University of Alaska Fairbanks, Geophysical Institute (AVO/UAF-GI).

## Cleveland

Aleutian Islands, USA  
52.825°N, 169.944°W; summit elev. 1,730 m  
All times are local (= UTC -10 hours)

Minor explosions were reported from Cleveland volcano on 15 and 29 February 2008 Cleveland (BGVN 33:02); such events have been typical during the last several years. This report discusses subsequent behavior and observations into late August, including thermal anomalies, explosions, ash plumes, and an inferred lava flow.

AVO noted that during the two weeks prior to 9 May 2008, an increasing number of thermal anomalies were visible on satellite imagery. On 7 May, a small ash plume rose to an altitude of below 4.6 km. Also, around the same time, a ship N of Nikolski on Umnak Island (~75 km ENE) reported receiving a dusting of ash (figure 8).

During June and early July 2008, satellite and webcam views were mostly obscured by clouds and fog, and AVO received no reports of eruptive activity. Satellite analysts noted a minor thermal anomaly on 8 June.

On 21 July, AVO raised the alert level/aviation color code for Cleveland to Watch/Orange based on reports from pilots and observers on fishing boats. Reports from fishing boats indicated that an eruption started at about 1200 and ash near sea level may have drifted NW. Pilots reported that an ash-and-steam plume rose to altitudes of ~4.6-5.2 km and drifted SE.

Satellite imagery for 22 July revealed a steam plume possibly containing some ash drifting more than 50 km ESE. It reached altitudes of 3-6 km. Thermal anomalies led analysts to infer a possible lava flow. Also, in harmony with this interpretation, on 22 July the MODVOLC algorithm registered its first alert thus far in 2008 (3 pixels) and near-daily alerts followed as late as 29 July (table 1).

AVO reported that satellite views were hindered on 23 July due to cloud cover. On 24 July, a low-level ash plume and a strong thermal anomaly were noted near the summit.

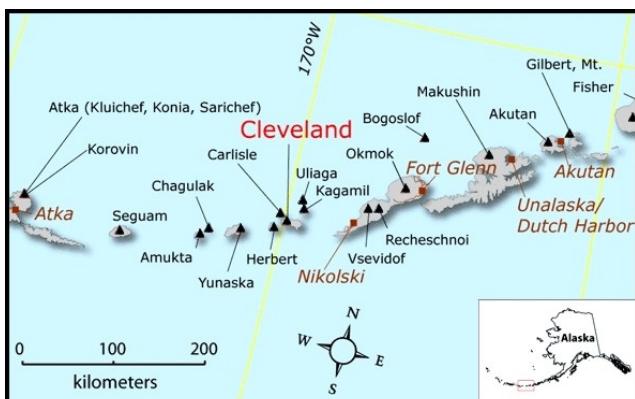


Figure 8. Map of the Aleutian Islands focused around Cleveland volcano. From E to W, the noted settlements are Atka, Nikolski, Fort Glenn, Unalaska/Dutch Harbor, and Akutan. Courtesy of the Alaskan Division of Geological and Geophysical Surveys.

This thermal anomaly again suggested the presence of an active lava flow. The MODIS measurements shown in table 1 for 24 July indicated several thermal anomalies to the W of the cone and pixels that are displaced downslope, E of the cone, several almost reaching the ocean. The thermal anomalies continued to be detected during 26-28 July, and possible ash plumes drifted SE, E, and NE at altitudes of 3-6.1 km during 27-29 July.

According to David Schneider of AVO, the MODVOLC algorithm has a higher trigger threshold than an analyst and MODVOLC also has fewer observations each day since it only uses MODIS satellite data. AVO uses MODIS, AVHRR, and GOES satellites to reduce the chance of missing thermal anomalies due to cloud cover. Both MODVOLC and AVO use mid-IR data (in the 3.0 to 3.5 micron range) to detect high temperature thermal anomalies.

AVO reported that thermal anomalies detected at Cleveland's summit by various satellites during 30 July-5 August 2008 also suggested the presence of an active lava flow. The anomaly on 30 July extended about 6-9 km. On 31 July, a diffuse plume drifted less than 20 km NE, N, and NW at an altitude of 6.1 km. The plume was seen from an airplane on 1 August.

On 5 August, thermal anomalies appeared on the W, S, and SE flanks. They possibly indicated the presence of pyroclastic flows or hot lahars. On 6 August 2008, AVO reported that the thermal anomalies noted at Cleveland's summit and on the W, S, and SE flanks had decreased in intensity since first noted on 21 July, indicating that the lava flows slowed or stopped. The hazard status was lowered to Yellow/Advisory. During 7-10 August 2008, a weak thermal anomaly at Cleveland's summit was intermittently visible when not obscured by clouds and drifting ash from Kasatochi (~ 390 km WSW).

On 11 August, thermal anomalies on satellite imagery again indicated that lava flowed down the flanks. On 12 August an ash plume rose to an altitude of 7.6 km and drifted 100 km SW. Cloud cover prevented satellite observations during 13-26 August, although a possible thermal anomaly was present on 24 August. On 11 August the hazard status rose to Orange/Watch, but on 25 August it dropped to Yellow/Advisory.

**Geologic Summary.** Beautifully symmetrical Mount Cleveland stratovolcano is situated at the western end of the

Date (UTC)	Time (UTC)	Pixels	Satellite
22 Jul 2008	1255	3	Aqua
23 Jul 2008	0010	3	Aqua
24 Jul 2008	0840	2	Terra
24 Jul 2008	1245	3	Aqua
24 Jul 2008	1420	5	Aqua
27 Jul 2008	1315	1	Aqua
27 Jul 2008	2240	1	Terra
29 Jul 2008	0855	1	Terra

Table 1. Thermal anomalies ("alerts") at Cleveland registered by the MODIS satellite as processed by the MODVOLC algorithm during the interval 1 January-9 September 2008. The only recent alerts during that interval were during the period of 22-29 July. Courtesy of Hawai'i Institute of Geophysics and Planetology (HIGP) Thermal Alerts System.

uninhabited, dumbbell-shaped Chuginadak Island. It lies SE across Carlisle Pass strait from Carlisle volcano and NE across Chuginadak Pass strait from Herbert volcano. Cleveland is joined to the rest of Chuginadak Island by a low isthmus. 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. The native name for Mount Cleveland, Chuginadak, refers to the Aleut goddess of fire, who was thought to reside on the volcano. 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.

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

## Kasatochi

Aleutian Islands, USA

52.177°N, 175.508°W; summit elev. 314 m

All times are local (= UTC -10 hours)

Kasatochi, which apparently had not erupted during the last century, erupted explosively with little warning on 7 August 2008. The island is generally uninhabited, ~3 km in diameter, and lies ~ 800 km W of the tip of the Alaska Peninsula (figures 9 and 10). The eruptive history of this volcano includes several unconfirmed eruptions in the 1800's, and a small confirmed eruption in 1760. Much of the infor-

mation in this report was taken from the Alaska Volcano Observatory (AVO) website or provided by John Eichelberger of the U.S. Geological Survey (USGS). No seismic or other geophysical monitoring instrumentation is present on Kasatochi. Seismic networks reside on neighboring islands, such as Great Sitkin Island ~ 40 km W.

The first indication of activity on Kasatochi was around 2 August 2008, when a U.S. Fish and Wildlife Service (USFWS) field crew of two biologists on the island experienced continual small tremors. On 6 August, for a period of about 12 hours during the morning and afternoon, the AVO noted a rapid increase in earthquakes on the island. On the evening of 6 August, AVO elevated the aviation color code/volcano alert level to Yellow/Advisory.

By 7 August 2008, the number and magnitude of earthquakes increased, accompanied by volcanic tremor. Earthquakes as large as M 5.6 were detected. On the morning of 7 August, the field crew reported periods of continuous ground shaking lasting 5–10 min, as well as numerous rockfalls and a strong sulfur odor. Between approximately 1400 and 2035, three major explosions occurred. According to satellite data, ash reached an altitude of at least 13.7 km in the vicinity of Kasatochi, and drifted SSW.

The two biologists (Ray Buchheit and Chris Ford) were conducting a summer-long study of seabirds and living in a cabin on the island. According to Rozell (2008), the two were rescued by a charter boat captain only hours prior to the 7 August eruptions. After the earthquakes and other signs on the morning of 7 August, the biologists radioed their contact in Adak to explain the situation. The two fueled up their skiff and were prepared to jump in and follow a GPS course to Great Sitkin Island, heading across rough seas ~ 40 km W. But the refuge staff chartered a larger boat from Adak, which succeeded in getting the biologists off the island and to safety.

Between 2100 and 2300 on 7 August, observers from a ship near Kasatochi reported ashfall with tephra up to pebble size. They noted spectacular lightning, thunder, and total darkness during this time. In response to this eruptive activity, AVO elevated the aviation color code/volcano alert level to Orange/Watch and then to Red/Warning.

Ash emissions became continuous following the last of the three explosive events of 7 August, and (downward looking) satellite imagery disclosed a continuous ash cloud bent in a counterclockwise spiral. By 8 August, that plume had extended SE for more than 950 km at an altitude exceeding 10.7 km (figure 11).

The eruption continued through 8 August and satellite imagery continued to detect a plume from Kasatochi until



Figure 9. Map of Aleutian Islands showing locations of active volcanoes, including Great Sitkin, Kasatochi, Cleveland, and Okmok. Map prepared by Seth Snedigar, AVO/Alaskan Division of Geological and Geophysical Surveys.



Figure 10. Photograph of Kasatochi as it appeared in 1961. The crater diameter was ~ 750 m. The (pre-eruption) crater-lake surface was less than 60 m above sea level. Courtesy of Dan Rogers, AVO/USGS.

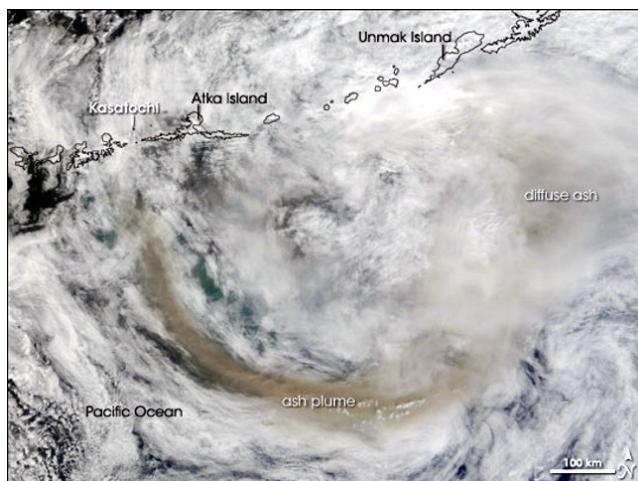


Figure 11. Image of plume from Kasatochi captured 8 August 2008 by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite. The bright clouds provide good contrast for the volcanic plume, which is dark brown. Weather patterns caused the plume to bend counterclockwise. Courtesy of NASA Earth Observatory.

slightly after midnight on 9 August. By the morning of 9 August, seismicity declined and ash emissions were not observed in either satellite data or from pilots or passing mariners. The drifting SO<sub>2</sub> plume was seen on satellite imagery 1,850 km ESE of the volcano. The plume was elongated NE-SW over a distance of 1,200 km.

During the days after 9 August, eruptive activity declined gradually. Seismic activity persisted at least through 5 September. The ash cloud produced during the previous week had detached and spread out over North America and was beginning to extend over parts of the North Atlantic. The distribution of gases and aerosols no longer appeared as a single intact cloud.

According to news reports on 10 and 11 August, Alaska Airlines had cancelled over 40 flights into and out of Alaska because of the ash plume. One report from Reuters stated that Alaska Airlines cancelled 44 flights. Those cancellations affected more than 5,200 passengers. According to

an Anchorage Daily News report on 10 August, a member of Alaska Airlines staff was reported as saying, "The entire state is unflyable." The total number of flights cancelled by this and other carriers is unknown.

Occasional earthquakes and periods of tremor continued to be recorded. During 17-19 August, the smell of sulfur was reported from Adak, about 85 km SW of Kasatochi Island. Active fumaroles and hot pyroclastic-flow deposits over much of the volcano were observed on 22-23 August by visiting scientists (see below). On September 3 and 4, passing mariners observed vigorous steam and gas plumes rising above the crater and extending up to ~ 30 km downwind. On 4 September, the aviation color code/volcano alert level was reduced to Yellow/Advisory.

**Sulfur dioxide measurements.** On the days following the eruptions, the Ozone Monitoring Instrument (OMI) on NASA's Aura satellite tracked a dense cloud that contained about 1.5 megatons (million tons) of sulfur dioxide ( $\text{SO}_2$ ). This was one of the largest volcanic  $\text{SO}_2$  clouds scientists have observed from satellite measurements since the 1991 Pinatubo eruption in the Philippines. However, some fraction may be due to increased instrument sensitivity achieved since that time.

The three panels comprising figure 12 depict the early distribution of Kasatochi's  $\text{SO}_2$  plumes. The 8 August 2008 OMI image shows a highly-concentrated  $\text{SO}_2$  distribution E and SE. By 10 August the  $\text{SO}_2$  cloud had become elongate and sinuous, and had detached from the source. It extended S and SW but a long NW projection reached mainland Canada where it spread N and S to Alaska and Washington state. The zones of greatest  $\text{SO}_2$  concentration on 12 August appeared near the Yukon-Alaskan border. Areas of lower concentrations were complex but covered much of Canada and adjacent coastal areas at least as far as Greenland. A small outlier (not shown on map) was also present between Greenland and Iceland. The detached trailing edge resided over the N Pacific but farther S than in previous images.

**Post-eruption visit.** On 22-23 August 2008, Chris Waythomas (USGS/AVO) and Ray Buchheit (USFWS) visited the volcano. They observed numerous active fumeroles and hot pyroclastic-flow deposits. The entire island had been swept by surges and pyroclastic flows. Pyroclastic-flow, -surge, and fall deposits, in places containing boulders up to 2 m across, formed a new shoreline well beyond the pre-existing sea cliffs (figure 13). The visitors found no signs of life remaining on the island. The island's isolated ecosystem, which had been monitored by USFWS since the 1930s, had been totally destroyed.

Figure 14 shows the extent of island's new shoreline and the new crater rim compared to the island's pre-eruption morphology. Newly deposited material extended the shoreline in a low-lying band around most parts of the island, in some places, ~ 300 m outboard of the pre-existing sea cliffs. In general, the crater rim expanded, particularly on the W side where it enlarged by ~ 200 m. A crater lake remained; and vents in the S crater were identified. During the visit, fresh slumps were apparent in fresh deposits perched on the crater rim and smaller "secondary" surge deposits were identified (figure 15).

**Thermal anomalies.** According to David Schneider of AVO, thermal anomalies at Kasatochi were visible using a combination of MODIS, AVHRR, and GOES satellite sensors; increasing the number of satellite observations per day reduces the chance of missing anomalies due to cloud

cover. The Hawai'i Institute of Geophysics and Planetology (HIGP) Thermal Alerts System measured no MODIS/MODVOLC thermal anomalies at Kasatochi during August and early September 2008. AVO measured thermal anomalies through breaks in the clouds on 5 September 2008 and during a relatively clear day on 7 September.

**Reference.** Rozell, N., 2008, Tiny Aleutian island has big impact: Alaska Science Forum, Article 1920, 13 August

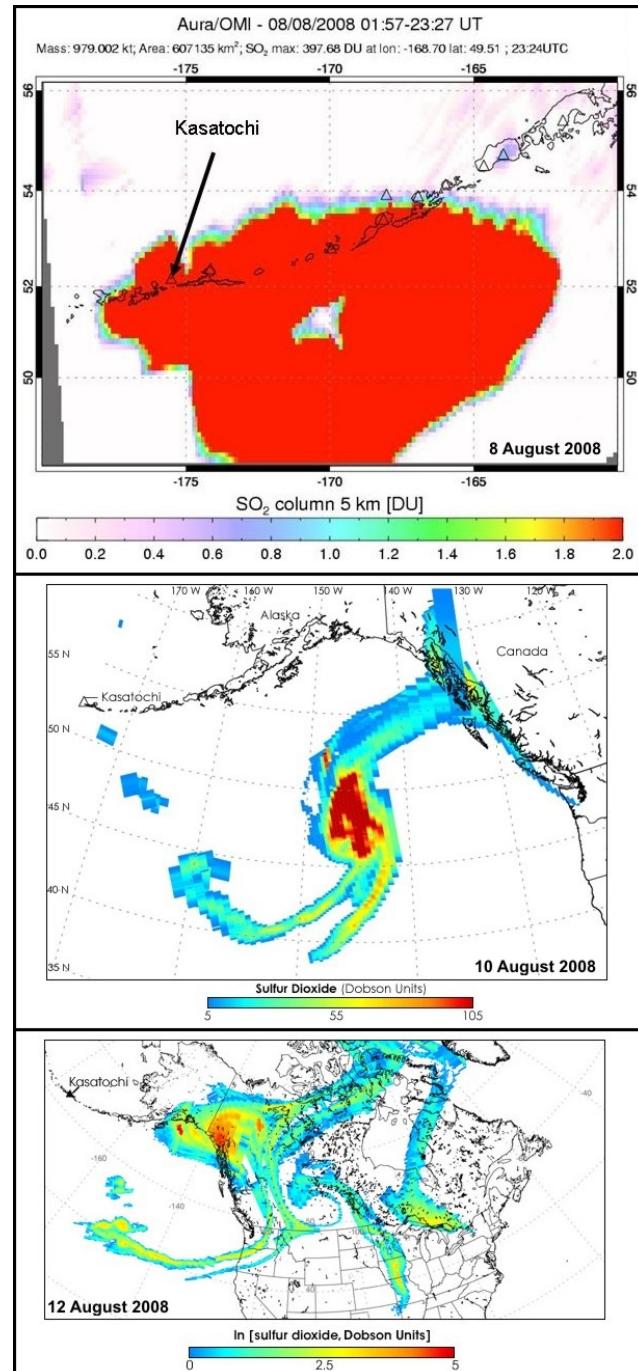


Figure 12. The  $\text{SO}_2$  cloud as measured by Ozone Monitoring Instrument (OMI) on NASA's Aura satellite on (top) 8 August 2008, (middle) 10 August 2008, and (bottom) 12 August 2008. Winds were moving the gas in a large counterclockwise loop over the Pacific Ocean and back toward Alaska, but also spreading streamers over the Arctic and eastward across the United States and Canada. Note the different scales for each image. A Dobson Unit is a commonly used measure of the concentration of a gas in a 15-km tall column of the atmosphere. Images courtesy of Simon Carn.

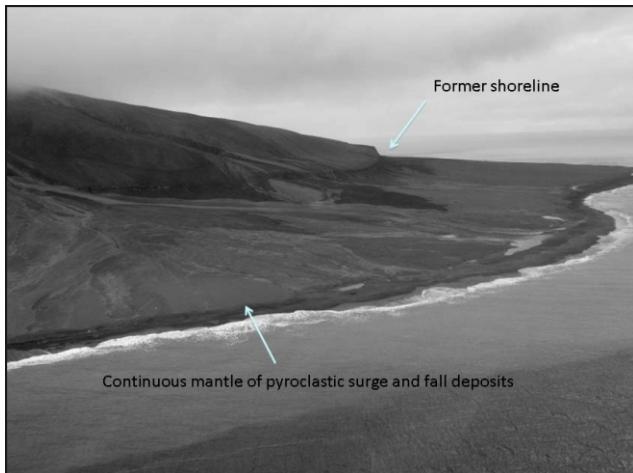


Figure 13. Fresh deposits of pyroclastic material form a new shoreline at Kasatochi. Courtesy of Chris Waythomas and Ray Bucheit.

2008 (URL: <http://www.gi.alaska.edu/ScienceForum/ASF19/1920.html>). (The Alaska Science Forum is a public service provided by the Geophysical Institute, University of Alaska Fairbanks, in cooperation with the UAF research community.)

**Geologic Summary.** Located at the northern end of a shallow submarine ridge trending perpendicular to the Aleutian arc, Kasatochi is small  $2.7 \times 3.3$  km wide island volcano with a dramatic 750-m-wide summit crater lake. The summit of Kasatochi reaches only 314 m above sea level, and the lake surface lies less than about 60 m above the sea. A lava dome is located on the NW flank at about 150 m elevation. The asymmetrical island is steeper on the

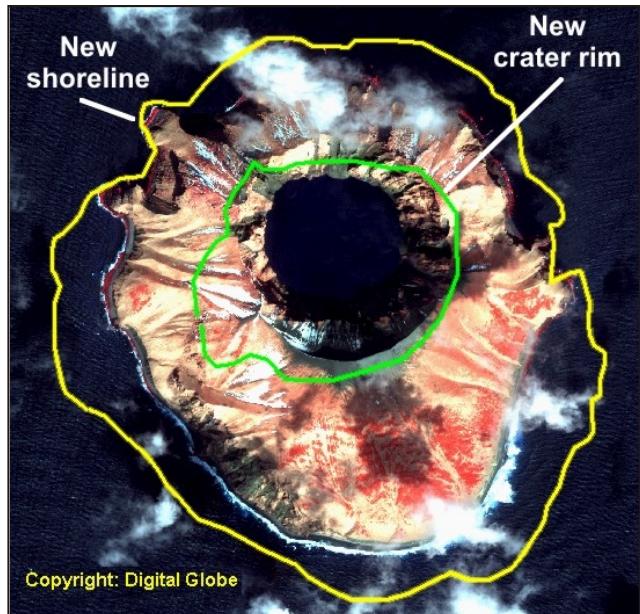


Figure 14. New shoreline (outer boundary) and new crater rim (inner boundary) found after the 7 August 2008 eruption of Kasatochi. The background (base) is a satellite image from April 2004 (Copyrighted by Digital Globe). Courtesy of John Eichelberger, USGS.

northern side than the southern, and the volcano's crater lies N of the center of the island. Reports of activity from the heavily eroded Koniujii volcano to the E probably refer to eruptions from Kasatochi. A lava flow may have been emplaced during the first historical eruption in 1760.

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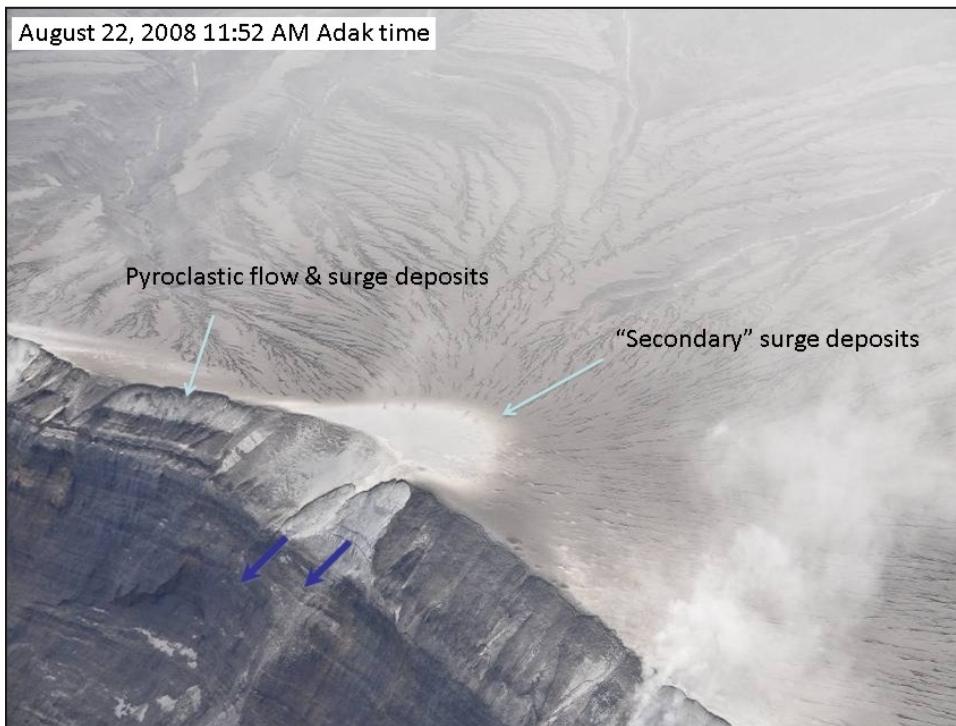


Figure 15. Aerial view of Kasatochi's crater rim, taken at 1152 on 22 August 2008 (with crater rim and upper wall cutting diagonally across the photo's left corner and the surface of freshly deposited tephra occupying most of the rest of the photo). During the visit, small (secondary) ash clouds and surges (light-colored areas) were produced by slope failure (in direction of at arrows down the crater wall). Photo courtesy of Chris Waythomas (AVO) and Ray Bucheit (USFWS).

## Karymsky

Kamchatka Peninsula, Russia  
 54.03°N, 159.26°E; summit elev. 1,536 m  
 All times are local (= UTC +12 hours)

Karymsky stratovolcano, one of most active of the Eastern Volcanic Zone of the Kamchatka arc, began an eruptive cycle in January 1996 lasting through at least September 2008. This report covers activity from June 2008 to September 2008 (figure 16).

During June–September, there were alternating periods of strengthening and weakening activity. Ash plumes were emitted and hot avalanches repeatedly descended the flanks. Seismic events usually had local magnitudes ( $M_L$ ) less than 2.5. Local shallow earthquakes were associated with crater explosions. Satellite data registered thermal anomalies usually on the crater, suggesting the eruption of hot magmatic material such as a lava flow or fragmental avalanches. An increase in the anomaly to 4–7 pixels usually accompanied a lava flow. Code Orange days during the reporting period occurred on the following days (table 2).

**Geologic Summary.** Karymsky, the most active volcano of Kamchatka's eastern volcanic zone, is a symmetrical stratovolcano constructed within a 5-km-wide caldera that formed during the early Holocene. The caldera cuts the south side of the Pleistocene Dvor volcano and is located outside the north margin of the large mid-Pleistocene Polovinka caldera, which contains the smaller Akademia Nauk and Odnoboky calderas. Most seismicity preceding Karymsky eruptions originated beneath Akademia Nauk caldera, which is located immediately south of Karymsky volcano. The caldera enclosing Karymsky volcano formed about 7600–7700 radiocarbon years ago; construction of the Karymsky stratovolcano began about 2000 years later. The latest eruptive period began about 500 years ago, following a 2300-year quiescence. Much of the cone is mantled by lava flows less than 200 years old. Historical eruptions have been vulcanian or vulcanian-strombolian with moderate explosive activity and occasional lava flows from the summit crater.

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## Kelut

Java, Indonesia  
 7.93°S, 112.308°E; summit elev. 1,731 m

According to Alain Bernard, the lava dome that extruded in late 2007 (*BGVN* 33:03) continued to increase in size until it covered much of the crater lake and it rose to overwhelm the drainage inlets. Bernard noted that dome growth had seemingly ceased by April 2008. Around that time (but at unstated date), VSI made initial estimates of the dome's dimensions as 200 m high, 400 m wide, with a volume of  $35 \times 10^6 \text{ m}^3$ .

The lake was almost gone by the middle of May 2008. The temperature of flow of waters at the end of the drainage tunnel (~ 960 m away from the dome) has been reported to

Date	Thermal anomaly (pixels)	Comments
27 Aug 2008	--	Local shallow earthquakes; ash plume 2.9–3.2 km altitude
28 Aug 2008	4	Local shallow earthquakes; ash plume 2.6–3.0 km altitude
29 Aug 2008	4	Local shallow earthquakes; ash plume 3.0–3.8 km altitude
31 Aug 2008	1	Local shallow earthquakes; ash plume 3.0 km altitude
01 Sep 2008	--	Local shallow earthquakes; ash plume 3.3 km altitude
08 Sep 2008	--	Local shallow earthquakes; ash plumes reaching 2.2–3.2 km altitude
13 Sep 2008	2	Local shallow earthquakes
14 Sep 2008	2	Local shallow earthquakes; ash plume 2.9 km altitude

Table 2. Thermal anomalies at Karymsky from NOAA-15 satellite images and visual observations for the interval from June to September 2008. Courtesy of Kamchatka Branch of the Geophysical Service of the Russian Academy of Sciences (KB GS RAS).



Figure 16. A photo from December 2007 showing a plume emerging from Karymsky's summit crater with lake-filled Academy Nauk caldera in the background. Photo by A. Ozerov.

be higher than in the crater lake, 66.7°C. Both phreatic and magmatic degassing was very minor. A very small amount of ash was emitted, and there were no lahars.

On 12 May 2008, the eruption status was downgraded to Green, a level indicating that either no significant eruption is expected or that fewer than 100,000 people within 100 km of the volcano would be affected by activity.

**Geologic Summary.** The relatively inconspicuous, 1,731-m-high Kelut stratovolcano contains a summit crater lake that has been the source of some of Indonesia's most deadly eruptions. A cluster of summit lava domes cut by numerous craters has given the summit a very irregular profile. Satellitic cones and lava domes are also located low on the eastern, western, and SSW flanks. Eruptive activity has in general migrated in a clockwise direction around the summit vent complex. More than 30 eruptions have been recorded from Gunung Kelut since 1000 AD. The ejection of water from the crater lake during Kelut's typically short, but violent eruptions has created pyroclastic flows and lahars that have caused widespread fatalities and destruction. After more than 5,000 persons were killed during an eruption in 1919, an ambitious engineering project sought to drain the crater lake. This initial effort lowered the lake by more than 50 m, but the 1951 eruption deepened the crater by 70 m, leaving 50 million cubic meters of water after repair of the damaged drainage tunnels. After more than 200 deaths in the 1966 eruption, a new deeper tunnel was constructed, and the lake's volume before the 1990 eruption was only about 1 million cubic meters.

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Brussels, Belgium (URL: <http://www.ulb.ac.be/sciences/dste/volcano/garde/page%20de%20garde.html>); *Volcanological Survey of Indonesia*, Center of Volcanology and Geological Hazard Mitigation, Saut Simatupang, 57, Bandung 40122, Indonesia (URL: <http://portal.vsi.esdm.go.id/joomla/>).

## Batu Tara

Lesser Sunda Islands, Indonesia  
7.792°S, 123.579°E; summit elev. 748 m

Our last report on Batu Tara (*BGVN* 33:02), also known as Palau Komba, covered eruptive activity from 13 October 2007 through 12 March 2008. Satellite imagery during that period revealed near daily thermal anomalies and frequent plumes, at least some of which were ash-bearing. Ash or ash-and-steam plumes continued to be seen between 12 March and 25 August 2008 (table 3).

Tristram Burley, a marine geophysicist, was on the 67-m-long motor vessel (MV) *Bergen Surveyor* passing 24 km to the N of Batu Tara on 25 August (figures 17 and 18). He observed six distinct eruptions of ash plumes from the westernmost area of the summit crater during a 45-minute period. The plumes were produced periodically roughly every 7 minutes. They rose to an estimated 350–750 m above the summit and drifted W. The N side of the island, the only part visible to him, showed no visible evidence of either lava flows or pyroclastic density currents accompanying the eruption plumes.

**Geologic Summary.** The small isolated island of Batu Tara in the Flores Sea about 50 km N of Lembata (formerly Lomblen) Island contains a scarp on the eastern side similar to the Sciara del Fuoco of Italy's Stromboli volcano. Vegetation covers the flanks of Batu Tara to within 50 m of the 748-m-high summit. Batu Tara lies N of the main volcanic arc and is noted for its potassic leucite-bearing basanitic and tephritic rocks. The first historical eruption from Batu Tara, during 1847–52, produced explosions and a lava flow.

**Information Contacts:** Darwin Volcanic Ash Advisory Centre, Bureau of Meteorology, Commonwealth of Australia (URL: <http://www.bom.gov.au/info/vaac>); Tristram Burley, Benfield UCL Hazard Research Centre, Department of Earth Sciences, UCL, 136 Gower Street (Lewis Building), London, WC1E 6BT UK (URL: <http://www.benfieldhrc.org>; Email: [tristram.burley@uclmail.net](mailto:tristram.burley@uclmail.net)).

Date	Plume top altitude (km)	Drift direction(s)	Remarks
12 Mar 2008	2.1	SE	
13 Apr 2008	2.4	NW	
14 Apr 2008	2.4	NW, W	
20-21 Apr 2008	NR	NR	
25-26 Apr 2008	NR	NR	
03 May 2008	3	NW	
07 May 2008	3	NW	
11-13 May 2008	1.8	NW, W	TA on 12-13 May
29 May-1 Jun 2008	1.8 - 3	WNW, NW	TA on 1 June
14-15 Jun 2008	2.1	NW	TA on 14 June
19-22 Jun 2008	1.5	NW, W	TA on 20 June
28 Jun 2008	1.8	W, WNW	
30 Jun 2008	1.8	W, WNW	
01 Jul 2008	1.8	W, WNW	
02-05 Jul 2008	1.8	W, NW	
08-09 Jul 2008	1.8	W, NW	
09-15 Jul 2008	1.8	WNW	TA on 9 July
16-18 Jul 2008	1.8	W	TA on 16 July
24-29 Jul 2008	1.5 - 3.7	WSW, W, NW, N	
30-31 Jul 2008	1.5	W	
06-08 Aug 2008	1.5	W, NW	
10-11 Aug 2008	1.5	W, NW	
14-17 Aug 2008	1.5	W	
25 Aug 2008	1.1-1.5	W	Also see Tristram Burley's observations in text.

Table 3. Ash or ash-and-steam plume activity from Batu Tara, based on observations of satellite imagery and pilot reports. Key: NR = not reported, TA = thermal anomaly. Courtesy of the Darwin Volcanic Ash Advisory Centre (VAAC).



Figure 17. Photo of an ash plume erupting from Batu Tara on 25 August 2008, as taken from the MV *Bergen Surveyor*, which was about 24 km N of the volcano. Courtesy of Tristan Burley and Kenneth Rae.

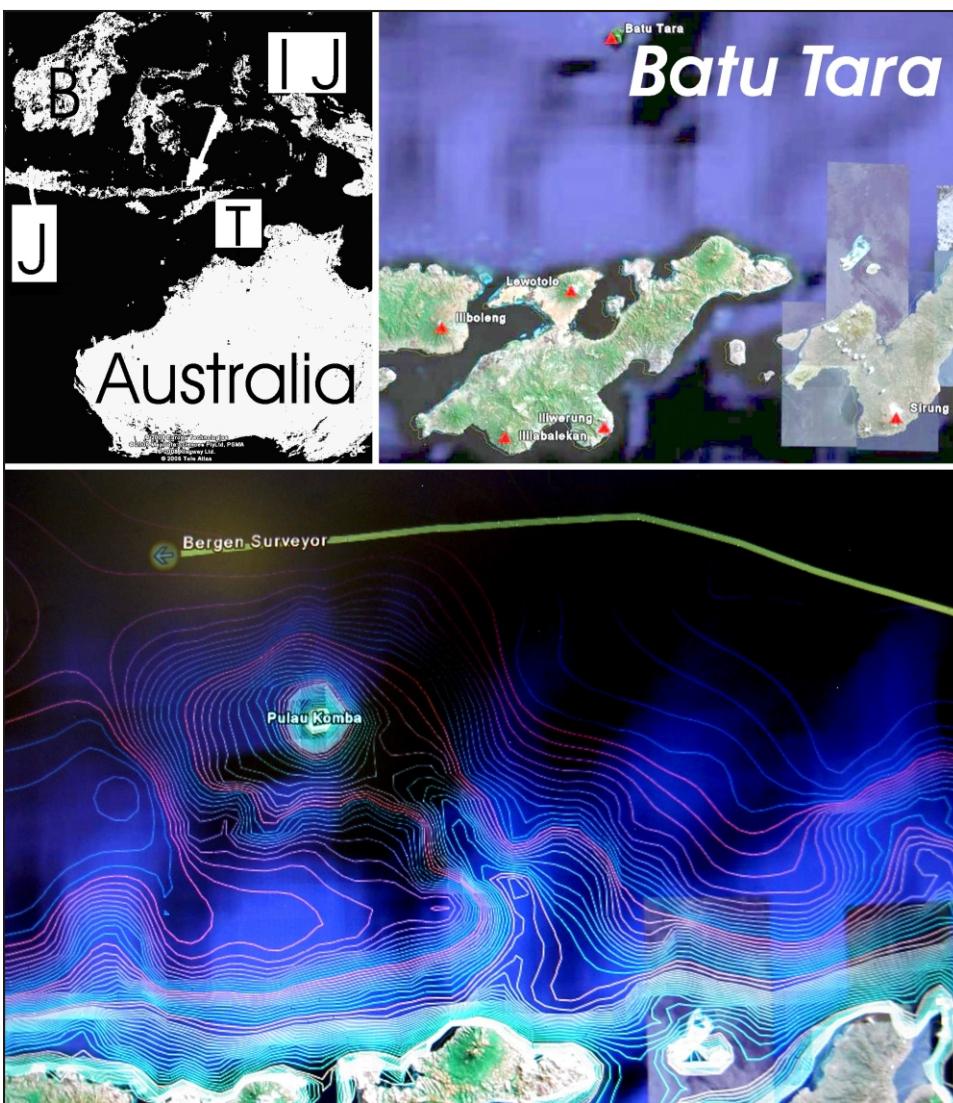


Figure 18. A series of maps to illustrate the setting and location of Batu Tara in the Lesser Sunda Islands of Indonesia. At upper left is a large-scale index map centered on Batu Tara (arrow tip), identifying Australia, Timor Island (T), Irian Jaya (IJ), Java (J), and Borneo (B). The map at upper right (from Google Earth) indicates Holocene volcanoes (small triangles). For scale, Batu Tara lies ~47 km N of the coast of Lembata Island (formerly Lomblen Island). At bottom is a bathymetric map of Batu Tara ("Palau Komba") and the W-traveling path of the MV *Bergen Surveyor* on 25 August 2008. Courtesy of Tristan Burley and Kenneth Rae.

## Rincón de la Vieja

Costa Rica  
10.830°N, 85.324°W; summit elev. 1,916 m

Activity at Rincón de la Vieja was last reviewed in May 2007 (*BGVN* 32:10), when low-level fumarolic activity was noted. During June 2007, the seismographic station 5 km to the SW of the crater registered seven low-frequency earthquakes and three low-frequency tremors. The first tremor occurred on 12 June and lasted 2 hours and eight minutes; the second and third occurred on 27 and 28 June and they lasted 37 minutes and 38 minutes, respectively.

The July earthquake activity was consistent with June; 6 low frequency quakes were recorded. Again, tremor activity occurred on 28 and 29 July, the first lasted 35 minutes and the second lasted 17 minutes. Little activity was noted during August and September, and October activity consisted only of tremors. On 23 October, the tremor lasted 37 minutes, and on 24 October it lasted 25 minutes.

No significant seismicity was recorded during the first three weeks of November. The seismic recording instrument went out of service from 22 November through December and January.

During February, 2008, 44 low-frequency earthquakes were registered in two groups; the first on 6 and 7 February and the second between 17 and 23 February.

Technical difficulties in March precluded a complete record of seismic activity; however, when recording was available, 116 low frequency earthquakes were noted.

Technical problems persisted in April, however during the first part of the month there was a low-frequency earthquake and 1.16 hours of tremor. Two deep earthquakes were also noted; the first registering M 3.5 at a depth of 11 km and the second M 2.9 at a 25 km depth.

**Geologic Summary.** Rincón de la Vieja, the largest volcano in NW Costa Rica, is a remote volcanic complex in the Guanacaste Range. The volcano consists of an elongated, arcuate NW-SE-trending ridge that was constructed within the 15-km-wide early Pleistocene Guachipelín caldera, whose rim is exposed on the south side. Rincón de la Vieja, sometimes known as the "Colossus of Guanacaste," has an estimated volume of 130 cu km and contains at least 9 major eruptive centers. Activity has

migrated to the SE, where the youngest-looking craters are located. The twin cone of 1916-m-high Santa María volcano, the highest peak of the Rincón complex, is located at the eastern end of a smaller, 5-km-wide caldera and has a 500-m-wide crater. A plinian eruption producing the 0.25 cu km Río Blanca tephra about 3500 years ago was the last major magmatic eruption from the volcano. All subsequent eruptions, including numerous historical eruptions possibly dating back to the 16th century, have been from the prominent crater containing a 500-m-wide acid lake (known as the Active Crater) located ENE of Von Seebach crater.

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## Montagu Island

South Sandwich Islands

58.42°S, 26.33°W; summit elev. 1,370 m

MODVOLC thermal alerts and a recent ASTER image indicate that the eruption of Mount Belinda, on Montagu Is-

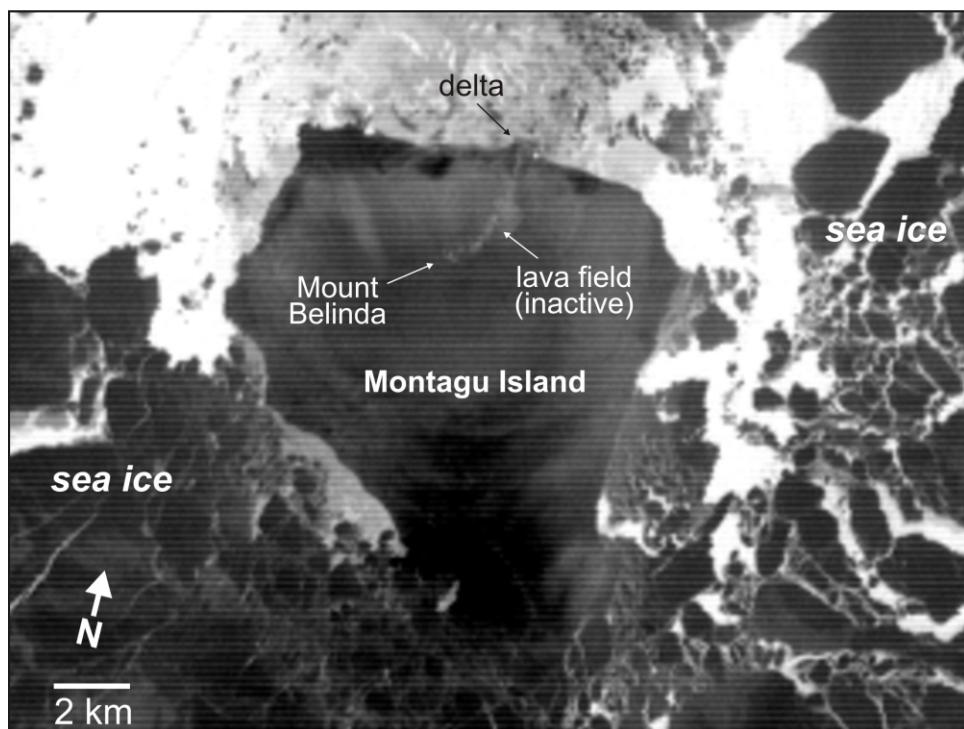


Figure 19. ASTER thermal image taken on 19 July 2008 showing Montagu Island and surroundings. The absence of eruptive activity is shown by the lack of high thermal radiance areas. The September 2005 lava delta on the N coast had not eroded away. Courtesy of Matt Patrick.

land, which began in 2001, has ceased. There have been no MODVOLC alerts over the volcano since September 2007 (*BGVN* 33:03) and a cloud-free ASTER thermal image from 19 July 2008 confirms the absence of a thermal anomaly at the summit of Mount Belinda.

The eruption, the first recorded historical activity at the volcano, began in October 2001 and probably ceased in September 2007, amounting to almost six years of persistent activity. The activity was characterized by low-level ash emission from the summit of Mount Belinda, an intra-caldera cone. At least three effusive events produced lava flows that cut into the island's ice cover. The largest effusive event, in September 2005, created a flow which traveled 3.5 km to reach the sea, creating a 500 m wide delta on the N shore. This delta remained on a July 2008 ASTER image (figure 19).

**Geologic Summary.** The largest of the South Sandwich Islands, Montagu consists of a massive shield volcano cut by a 6-km-wide ice-filled summit caldera. The summit of the 10 x 12 km wide island rises about 3000 m from the sea floor between Bristol and Saunders Islands. Around 90% of the island is ice-covered; glaciers extending to the sea typically form vertical ice cliffs. The name Mount Belinda has been applied both to the high point at the southern end of the summit caldera and to the young central cone. Mount Oceanite, an isolated 900-m-high peak with a 270-m-wide summit crater, 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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