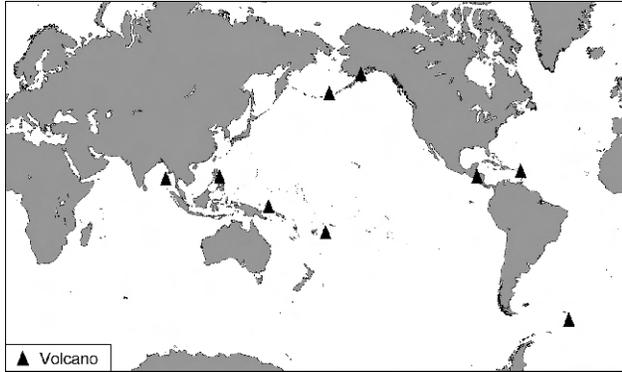


Bulletin of the Global Volcanism Network

Volume 31, Number 9, September 2006



Smithsonian
National Museum of Natural History

Home Reef (Tonga) <i>Extensive pumice rafts between Tonga and Fiji during August-October</i>	2
Rabaul (Papua New Guinea) <i>Strong eruption at Tavurvur ejected ash and large plumes to the troposphere . . .</i>	6
Bamus (Papua New Guinea) <i>Forceful vapor emission seen on 12 July 2006.</i>	9
Sulu Range (Papua New Guinea) <i>Volcano seismicity declines in September and October 2006.</i>	9
Barren Island (India) <i>Ongoing emissions, including lava, but late-September news reports of slowing pace . .</i>	10
Bulusan (Philippines) <i>Ten explosions recorded seismically between 21 March and 28 June 2006.</i>	10
Cleveland (Alaska) <i>Short duration explosions during August-October 2006</i>	11
Fourpeaked (Alaska) <i>Eruption on 17 September, followed by emissions until at least early November</i>	11
Soufrière Hills (Montserrat) <i>Extrusive dome dynamics during May-September 2006</i>	14
San Cristóbal (Nicaragua) <i>Multi-year update: 13 June 2004, local ash fall; early 2006, small eruptions . . .</i>	16
Montagu Island (S Sandwich Islands) <i>Five years of nearly persistent eruptive activity</i>	16

Editors: Rick Wunderman, Edward Venzke, Sally Kuhn Sennert, and Catherine Galley

Volunteer Staff: Robert Andrews, Jerome Hudis, Veronica Bemis, Jackie Gluck, William Henoch,
Hugh Replogle, Zahra Hirji, Stephen Bentley, Paul Berger, Jeremy Bookbinder, and Antonia Bookbinder

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).

Home Reef

Tonga Islands, SW Pacific
 18.992°S, 174.775°W; summit elev. -2 m
 All times are local (= UTC + 13 hours)

Pumice rafts drifting from Tonga to Fiji occurred during August–October 2006. The source of these pumice rafts was Home Reef, which was first observed to be in eruption on 9 August and was clearly building an island by 12 August (figure 1). A compilation of report sightings through mid-October 2006, plotted using Google Earth, shows the timing and distribution of the pumice rafts that are discussed in this report (figure 2). As is our convention, and as available, a list of contributors (and their vessels) is noted in last section of this report.

Pumice traveled both N and S around Fiji's Lau Group. To the N, pumice reached Taveuni through the Nanuku passage and entered the Koro sea, washing onto southern Vanua Levu, before moving into the Bligh Waters N of Viti Levu by 20 September. To the S, extensive pumice was seen N of Vatoa Island on 16 September, and on Kadavu Island by the end of the month. Pumice was also encountered by the *Encore II* W of Viti Levu on 30 September while enroute to New Caledonia.

Early observations of the eruption. The news service *Matangi Tonga Online* quoted Allan Bowe, the owner of the Mounu Island Resort in southern Vava'u, regarding volcanic activity in the direction of Home Reef during 9–11 August. Bowe heard “. . . what sounded like continuous thunder rumbling to the S and there was a huge plume of smoke and cloud rising up into the sky.” In another *Matangi* news article, Siasoi Fenukitau, a captain of one of the fishing boats of the Maritime Projects Co. (Tonga) Ltd., reported that around mid-September they sighted a new

volcanic island near Home Reef that was larger than Fotuha'a, a small island in Ha'apai with a population of about 134 people.

The yacht *Maiken* left Neiafu on 11 August, passing the N side of Late Island. After about 9 km the crew noticed brown, somewhat grainy streaks in the water. The streaks became larger and more frequent as they continued SW “until the whole horizon was a solid line to what looked like a desert.” The brownish pumice fragments the size of a fist were floating in water that was strangely green. They motored into the vast (many miles wide) belt of densely packed pumice, and within seconds *Maiken* slowed down from seven to one knot. Initially the thin layer on the surface was pushed away by the bow wave, but when they entered the solid field it started to pile up and “behaved like



Figure 1. Photograph of the new island being built by the eruption at Home Reef as seen on 12 August 2006. The island was ~1.5 km in diameter. View is towards the W from about 2.8 km away. Courtesy of Fredrik Fransson of the *Maiken*.

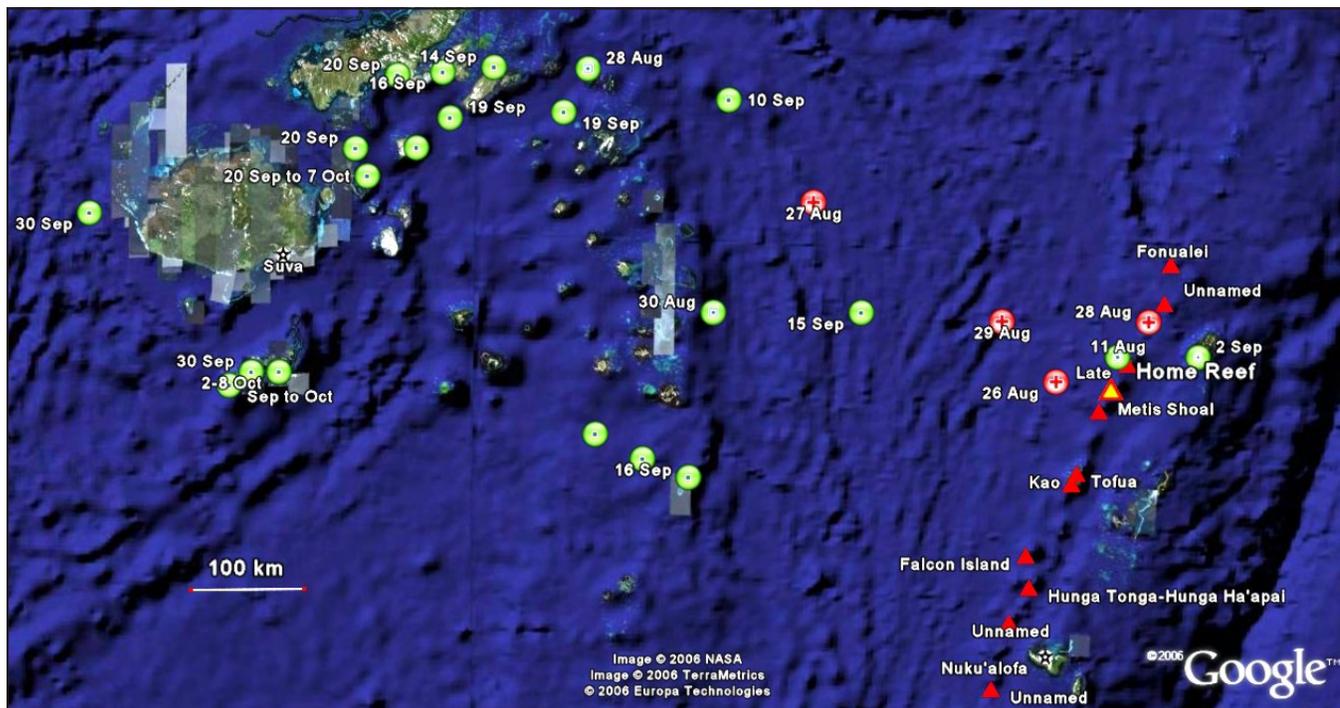


Figure 2. Map of Tonga (right) and Fiji (upper left) showing dates and locations where observers saw pumice rafts (placemarks with dots) or where mariners crossing between Tonga and Fiji failed to see rafts (placemarks with crosses). Some locations are approximate; see text for additional details and sources of each observation. The base map is from Google Earth with points plotted by *Bulletin* editors.

wet concrete” and “looked like rolling sand dunes as far as the eye could see.” After retreating from the pumice with only minor paint abrasion along the waterline, and then cleaning their intake filters, they decided to anchor in Vaiutukakau bay outside Vava’u for the night. The next morning, 12 August, they received radio confirmation of an eruption, but the vent and extent were uncertain. They decided to go S to avoid the pumice rafts floating NW, heading SSW until they encountered the pumice, then sailing alongside until the rafts were broken up enough to safely travel through.

As they approached Home Reef it became clear that one of the clouds on the horizon was a volcanic plume. Observations from a closer vantage point revealed that an intermittent “massive black pillar shot upwards toward the sky” and particles were raining down. Since the wind was pushing the plume NW, the *Maiken* motored up to within 2.8 km of the island (to 18°59.5’S, 174°46.3’W) while the sun was going down. Multiple peaks forming a crater open to the sea on one side were visible, and it looked like it was “made of black coal.” Not wanting to encounter more pumice rafts after dark, they continued SSW towards the southern part of the Lau Group.

Pumice sightings between Tonga and Fiji. Boats that later noted seeing pumice in Fiji did not report any activity or rafts near Tonga during 27-29 August. The *Soren Larsen* sailed through “a sea of floating pumice” one evening that “sounded like we were sailing through ice” just before reaching Fiji. This encounter was probably on 30 August when their online tracker located the ship just W of the central Lau islands after departing Neiafu on the 28th. No eruptive activity or pumice was noted in the online log of the *Soren Larsen* for 14-15 and 23-24 August when they transited to northern Tonga to the E of Home Reef.

While the *Encore II* crew was visiting the Mounu Island Resort on 2 September there were “grapefruit-sized” pumice pieces on the beach. A few days later, while listening to the “Rag of the Air” net broadcast out of Fiji, the *Encore II* crew learned of pumice rafts along their expected route. The operator of this broadcast, Jim Bandy, provides weather reports for boats going between Tonga and Fiji. One report was of a mass of pumice about 11 km long and at least a meter (“many feet”) deep. The *Encore II* departed from Neiafu on 8 September on a course around a set of Fijian islands and reefs called the Lau Group. The crew believed that this route, going NW around the Lau Group, helped them avoid most of the pumice.

As the *Encore II* approached their turning point about two thirds of the way to Fiji, on 10 September, they encountered “rivers of pumice” floating roughly parallel to their NW course due to the SE winds (figure 3). Some pumice fragments that they collected were about 5-10 cm in diameter, although most were about the size of pea gravel. The parallel streams of pumice, only a single layer in depth, were sometimes up to 90 m wide and 400 m long. The crew later heard reports from several boats that had taken a more westerly route through the Lau Group to Fiji and encountered much larger areas of pumice. The crew on the Norwegian sailboat *Stormsvalen* went through larger and thicker areas of pumice, leaving a track in the pumice as they went through (figures 4 and 5). They noted that boats traveling through the pumice during higher winds and seas encountered a problem of airborne pumice pelting the crews and their boats. One crew reported pumice covering their deck.

A sailboat blog entry by Sara Berman and Jean Philippe Chabot noted a “strong sulfur odor” in the direction of the volcano upon leaving Tongan waters around 20 September. As they progressed SW towards Fiji they passed through streams of pumice containing pieces ranging from very

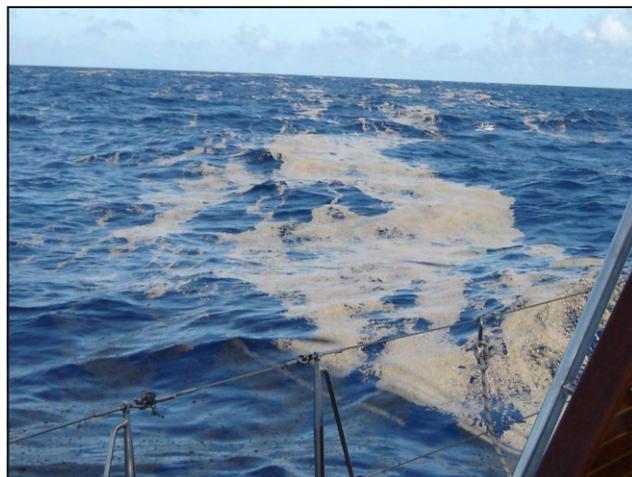


Figure 3. Photograph showing small areas of floating pumice just NE of the Lau Group of islands, Fiji, around 10 September 2006. Courtesy of the *Encore II* crew.



Figure 4. Photograph showing a large pumice raft near the Lau Group of islands, Fiji, on an unknown date in early to mid-September 2006. Courtesy of the *Stormsvalen* crew via the *Encore II*.



Figure 5. View of a large pumice raft after the passage of a sailing vessel near the Lau Group of islands, Fiji, on an unknown date in early to mid-September 2006. Courtesy of the *Stormsvalen* crew via the *Encore II*.

small pebbles to larger pieces the size of a baseball. Every time a wave crashed on deck they heard the pumice making its way onto the boat and into the cockpit.

On 30 September the *Windbird* log noted that “. . . cruisers are still having to avoid the huge pumice field that is floating about between Tonga and Fiji.”

Bob McDavitt’s “Weathergram” for 15 October noted that reports from yachts sailing between Tonga and Fiji indicated an absence of pumice. These observations suggest that the bulk of material produced by the eruption, or series of eruptions, had crossed to Fiji by mid-October.

Pumice rafts in northern Fiji. The earliest known direct observations of the floating pumice in Fiji come from a boat with callsign KB1LSY, the crew of which noted that “thick pumice” slowed them to 2 knots for 30 minutes during the early morning hours of 28 August. This occurred as they approached the northern islands of the Lau Group in Fiji, about 500 km NW of Home Reef.

According to Roberta Davis, the pumice arrived at Taveuni, Fiji, on 14 September. There were several rafts ~300 m from shore with other rafts scattered farther out. Local mariners noted that pieces in the top layer were approximately the size of pea gravel. Suspended below the surface were pieces almost as large as footballs. The beaches on the northern shores of Taveuni were covered in what appeared to be black popcorn. The pumice was present at Taveuni for up to 6 days.

On 19 September David Forsythe reported that large rafts of pumice were passing through the northern Lau group in Fiji (figure 6). He noted gooseneck barnacles up to 10 mm long on the largest pieces. *Bulletin* editors found compiled growth rates for various stalked barnacles (Thiel and Gutow, 2005), which indicated 17–29 days of growth.

The *Encore II* crew observed pumice along the S side of Vanua Levu, W of the Lau Group, around 16 September. They noted pumice at Fawn Harbour that obscured the channel into the harbor and it made a boat at anchor appear to be aground on an island. They also observed streams of pumice near the Makogai Channel on 20 September. The *Fiji Times Online* reported on 20 September that villagers living along the coastal areas of Saqani in Cakaudrove (Vanua Levu) were battling to clear their pumice-covered seashores and rivers. Villagers saw the pumice floating in the sea near their homes on 18 September, and by the next

day the pumice covered the river and villagers could not fish or travel by boats and bamboo rafts to their plantations.

While diving at the “Bligh Triangle” of Fiji at sites NW of Viti Levu, the crew aboard the *Nai’a* encountered floating pumice during 20 September–7 October. The pumice was “surrounding the *Nai’a* and the skiffs with occasional big carpets of floating rock.” Roman Leslie, an Australian volcanologist who was fishing in Koro (Lomaiviti Group), also observed the pumice in late September.

Scientists aboard the research vessel *Yokosuka* observed pumice settling to the shore of Viti Levu on 6 October. The rafts were in bands up to 70–80 m wide and several hundred meters long. The pumice fragments were fully abraded, and dominantly less than 1 cm in diameter with occasional large blocks up to 15–20 cm in diameter. The pumice seemed to be quite phenocryst-rich. The sound of the moving, abrading rafts was described as “sizzling.”

Pumice rafts in southern Fiji. A biologist aboard the National Geographic motor vessel *Endeavour* reported that on the morning of 16 September they observed an extensive region of floating pumice “. . . in long, wind-driven rows, approximately 1–5 m wide and up to several hundred meters long.” Pieces of pumice averaged 0.5–8 cm in longest dimension. The largest piece observed was approximately 15 cm in longest dimension. The observations continued over the next 90 km, for 3.5 hours, with little interruption, until they made landfall at Vatoa Island in the Lau Group. Moderate windrows of pumice, up to several inches deep, were observed on the beaches of Vatoa.

Roger Matthews arrived in Kadavu, Fiji, on 30 September and reported that pumice had been coming ashore for about a week. On the southern coast of the island near the airport, the layer of pumice on 30 September was 10–15 cm thick floating on top of ~1 m of water (figure 7). Farther NE, pumice that began coming ashore at the Matava Resort on 3 October carried goose barnacle shells that measured about 2–3 mm on the bigger clasts. By 7 October barnacle size on arriving pumice had increased to around 4–6 mm. While scuba diving, Matthews noted neutrally buoyant bits of pumice, generally in the 3–10 mm size range, down to at least 40 m water depth. The pumice did not appear to have an even size distribution (figure 8). There were a number of big clasts, 2–3 cm, with a large amount of material in the 8–15 mm range. In the shore deposits there appeared to be a



Figure 6. Panoramic view of Indigo Swan Beach filled with pumice, Naitaba Island, Fiji, as seen in September 2006. Courtesy of David Forsythe.

large volume of fines in the sub-2 mm size. The material was clean with no algae, just the occasional barnacles. The clasts contained phenocrysts up to 2 mm long. The raft



Figure 7. Pumice found floating in North Bay along the southern coast of Kadavu, Fiji, on 30 September 2006. Courtesy of Roger Matthews.



Figure 8. A close up view of pumice seen near Matava Resort on the S shore of Kadavu, Fiji, 3 October 2006. Courtesy of Roger Matthews.



Figure 9. Pumice deposits seen at ebb tide near Matava Resort on the S shore of Kadavu, Fiji, 8 October 2006. Some of the pumice has been used as fill behind the sea wall. Deposits can be seen on the steps into the water, and waves propagating through the pumice could still break. Courtesy of Roger Matthews.

drifted in and out depending on wind conditions, at times extending 75-100 m from shore, and invaded streams at high tide. On shore there were 20-cm-thick deposits, some of which was used as fill behind the sea walls (figure 9).

A 31 October story in the *Fiji Times* described transportation difficulties between Daviqele Village, on the W end of Kadavu, and other parts of the island due to pumice that a resident said had “covered [Naluvea Bay] for over two months now.” Similar problems were reported by Adrian Watt at Matava Resort on the S shore of Kadavu. In an email relayed by Roberta Davis, Watt noted that by 2 November the pumice had mostly stopped coming in, with “... just a few strands of small pieces being blown along wind lines here and there.” The pieces were generally 5-10 mm in diameter, but several were bigger, and one was larger than 30 cm across. Large bays on Kadavu's SE side were pumice choked, hampering boat travel, and clogged cooling systems damaged or destroyed many outboard engines.

Geologic Summary. Home Reef, a submarine volcano midway between Metis Shoal and Late Island in the central Tonga islands, was first reported active in the mid-19th century, when an ephemeral island formed. An eruption in 1984 produced a 12-km-high eruption plume, copious amounts of floating pumice, and an ephemeral island 500 x 1,500 m wide, with cliffs 30-50 m high that enclosed a water-filled crater.

Reference: Thiel, M., and Gutow, L., 2005, The ecology of rafting in the marine environment. II. The rafting organisms and community: *Oceanography and Marine Biology: An Annual Review*, 2005, v. 43, p. 279-418.

Information Contacts: Fredrik Fransson and Håkan Larsson, Yacht Maiken, 32 Macrossan St., Unit 70, Brisbane 4000, Australia (URL: <http://yacht-maiken.blogspot.com/>, Email: fredrikfransson@yahoo.com); Paul and Nancy Horst, Encore II (URL: <http://www.encorevoyages.com/>; Email: encore.crew@sbcglobal.net); KBILSY Crew (URL: <http://www.pangolin.co.nz/yotreps/tracker.php?ident=KBILSY>); Matangi Tonga Online, Vava'u Press Ltd., PO Box 958, Nuku'alofa, Tonga (URL: <http://www.matangitonga.to/>, Email: mfonua@matangitonga.to); Roger Matthews, Private Bag 93500, Takapuna, North Shore City 1332, New Zealand (Email: roger.matthews@northshorecity.govt.nz); Ken Tani, R/V Yokosuka (Email: kentani@jamstec.go.jp); David Forsythe, Naitauba Island, Fiji (Email: David_Forsythe@adidam.org); David Cothran, 1211 Colestin Rd., Ashland, OR 97520, USA (Email: david@gmail.com); Bob McDavitt's Weathergram (URL: [http://www.pangolin.co.nz/yotreps/list_manager.php#Bob McDavitt's Pacific Weathergrams](http://www.pangolin.co.nz/yotreps/list_manager.php#BobMcDavitt's%20Pacific%20Weathergrams)); Nick Sambrook, Tall Ship Soren Larsen, P.O.Box 60-660 Titirangi Auckland 0642, New Zealand (URL: http://www.sorenlarsen.co.nz/2006/V237_Tonga-Fiji/V237_Tonga-Fiji_Nick.htm, http://www.sorenlarsen.co.nz/Voylog_Track.htm, Email: escape@sorenlarsen.co.nz); Windbird Crew (URL: <http://handlesail.com/logs/?cat=1&paged=2>); NAI'A Liveboard Scuba Diving, Lautoka, Fiji (URL: <http://www.naia.com.fj/>, Email: explore@naia.com.fj); Roberta Davis, Makaira by the Sea, Taveuni, Fiji (URL: <http://www.fijibeachfrontatmakaira.com>, Email: makaira@connect.com.fj); Adrian Watt, Matava Resort, Kadavu, Fiji (URL: <http://www.matava.com/>, Email: matava@connect.com.fj); Sara Berman and Jean Philippe Chabot (URL: <http://zayasail.blogspot.com/2006/09/east.html>).

Rabaul

New Britain, SW Pacific
 4.271°S, 152.203°E; summit elev. 688 m
 All times are local (= UTC + 10 hours)

A 7 October Rabaul eruption obscured visibility in and around the caldera, which sits at the NE end of New Britain Island (figure 10). The eruption took place at the intra-caldera cone Tavorvur, and emissions included lava flows. Intermittent eruptions had occurred at Tavorvur since 1994, the last of which took place on 15 January 2006 (*BGVN* 31:02). Photos by pilots shortly after the eruption documented a dramatic umbrella-shaped plume, which rose to the tropopause and created an SO₂ cloud that later divided into two parts, one moving NW, the other SE.

Rabaul Volcano Observatory (RVO) observations. The RVO announced that a sustained eruption from Tavorvur did not appear to have been any immediate precursors apart from a small deflation. The sub-Plinian eruption began at about 0845 on 7 October 2006 and continued into the early afternoon. Semi-continuous to rhythmic air blasts were obvious in Rabaul town, with doors slamming and windows rattling. Rabaul received moderately heavy ashfall; heavy lapilli of ~ 1 mm diameter fell, and a few lithics up to 3 cm across fell around the S and SW parts of the caldera. According to Herman Patia at RVO, a small pumice raft accumulated in Greet Harbor and pumice was still drifting about several weeks later.

Ashfall affected the whole of the Gazelle peninsula (the name given to the bulbous, 50-km-diameter NE end of New Britain island). About 1 cm of ash was deposited on the SW side of the caldera in the Blue Lagoon-Vulcan sector. Ashfall occurred ~ 7 km SE of Rabaul caldera's center point in Kokopo and ~20 km S of the center point in Warangoi. The density of ashfall was such that Tavorvur was obscured from all directions. In the town of Rabaul the experience was very similar to the October 1996 and January 1997 Strombolian eruptions.

At 1200 on 7 October 2006 the RSAM was about 1900 units and its rate appeared to be decreasing. (The **Real-time Seismic Amplitude** is an often-used tool to summarize seismic activity during volcanic crises by presenting a measure of the average amplitude of ground shaking over successive 10-min intervals.)

Thick ash clouds rose to a height of about 18 km. The cloud subsequently dispersed over a broad western swath (N to W to S).

The nature of the eruption changed to Strombolian at 1415 hours, with activity characterized by frequent explosions accompanied by shock waves. At 1730 hours, the Strombolian activity began to subside. A moderate to bright glow was visible during the evening of 7 October on Tavorvur's N rim, accompanied by occasional explosions and loud roaring noises throughout the night.

In the morning of 8 October, thick white and blue vapor accompanied occasional ash explosions drifted N and NW of Tavorvur. Inspection from Rapindik (2 km NNW from Tavorvur) revealed lava flows emplaced down the cone's W and N flanks. The W flank flow went into the harbor and caused small secondary explosions; visibility of the N flank was poor due to the white vapor emission. The RSAM level decreased to the background value of ~ 70 units.

Herman Patia reported that by 28 October 2006 the eruption had quieted down with only occasional ash emission accompanied by rare explosions. Seismic activity was at a low level and ground deformation was at a low rate. On 30 October mild eruptive activity continued at Tavorvur. The activity consisted of continuous emission of thick pale to dark gray ash clouds that drifted N to NW of the volcano. Fine ash fall occurred in the NE caldera at Namanula, and also in surrounding areas downwind and on the E side of Rabaul Town. There were no audible noises and no glow visible. The low-level eruptive activity consisted of occa-

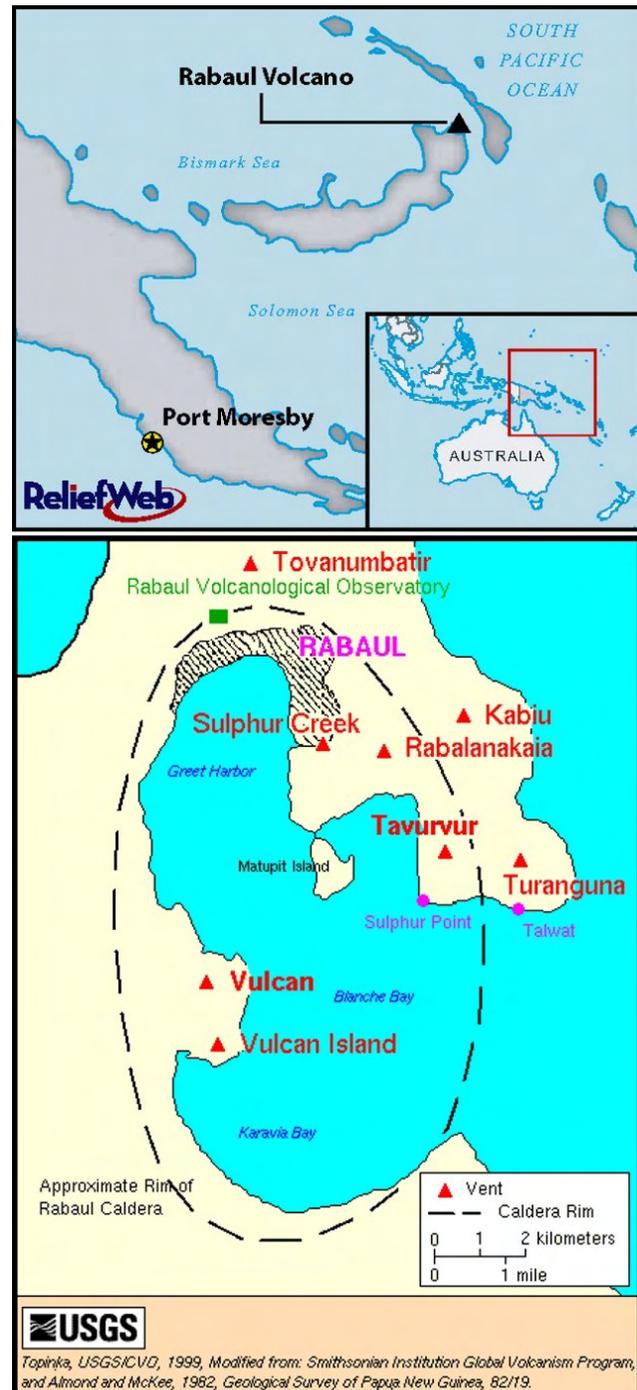


Figure 10. (Top) Index maps indicating the location and geography around Rabaul caldera. (Bottom) A map of Rabaul derived from work by Almond and McKee and prepared by Lyn Topinka (US Geological Survey). For other maps see previous *Bulletin* reports on Rabaul (most recently, *BGVN* 28:01).



Figure 11. Aerial photo taken 1 or 2 hours after the eruption of 7 October 2006 at ~ 3.7 km (~ 12,000 ft) and ~ 90 km (~ 50 nautical miles) from Tokua airport (Rabaul's new airport, on the S side of the caldera) while flying at a heading of about 060° (i.e. looking ENE). The flight was "on the Hoskins-Tokua track." Courtesy of Tony Gridley, Air Niugini.



Figure 12. Aerial photo taken 1 or 2 hours after the eruption of 7 October 2006 at ~ 3.7 km (~ 12,000 ft) and ~ 90 km from Tokua airport, heading about 060°. Courtesy of Tony Gridley, Air Niugini.

sional ash emissions similar to those that have occurred regularly since 1994.

Pilot observations. Figures 11 and 12 are pilot's photographs provided by Tony Gridley, Air Niugini, indicating the well-developed ash clouds visible 1-2 hours after the eruption. The photos are reminiscent of the 20 September 1994 photo of the eruption cloud taken from the orbiting Space Shuttle, an oblique, downward-looking perspective from the NE about 24 hours after the start of that eruption (BGVN 19:08).

Satellite observations. According to Andrew Tupper, the 7 October eruption was clearly visible on infrared and visible imagery (to around tropopause altitudes). Figure 13 shows the ash cloud imaged from the MODIS satellite on 7 October 2006. Figure 14 depicts the sulfur dioxide (SO₂) in Dobson Units (DU) from the Ozone Monitoring Instrument (OMI) for 7-9 October 2006. Further details appear in the figure caption. The SO₂ concentration-pathlengths on the figure are shown using the logarithmic scale of Dobson Units. (As one explanation of this unit, if all SO₂ in the air column the satellite observed was flattened into a thin layer at the surface of the Earth at a temperature of 0° C, then 1

Dobson Unit would make a layer of pure SO₂ 0.01 mm thick.)

Based on information from the RVO, the Darwin VAAC reported that a brief eruption of Rabaul on 11 October produced a plume that reached an altitude of 7.6 km altitude and dissipated NW. Continuous low-level emissions and vulcanian eruptions produced plumes to 1 km altitude during 12-17 October.

Moderate Resolution Infrared Spectroradiometry (MODIS) thermal anomalies. Table 1 shows the thermal anomalies as measured from the MODIS satellite during the eruption period. Note that there were no anomalies for several months before this period. The anomalies are in harmony with the observed lava flows.

News releases. According to Reuters news service the 7 October blast shattered windows up to 12 km from the caldera. In 1994, a large eruption at Tavurvur and the nearby Vulcan peak destroyed much of Rabaul, covering the airport and much of the town with ash, and forcing the construction of a new capital, Kokopo, 20 km away. Ash was falling on Kokopo, causing power and phone cuts. There were no reports of death or injuries. In addition Reuters

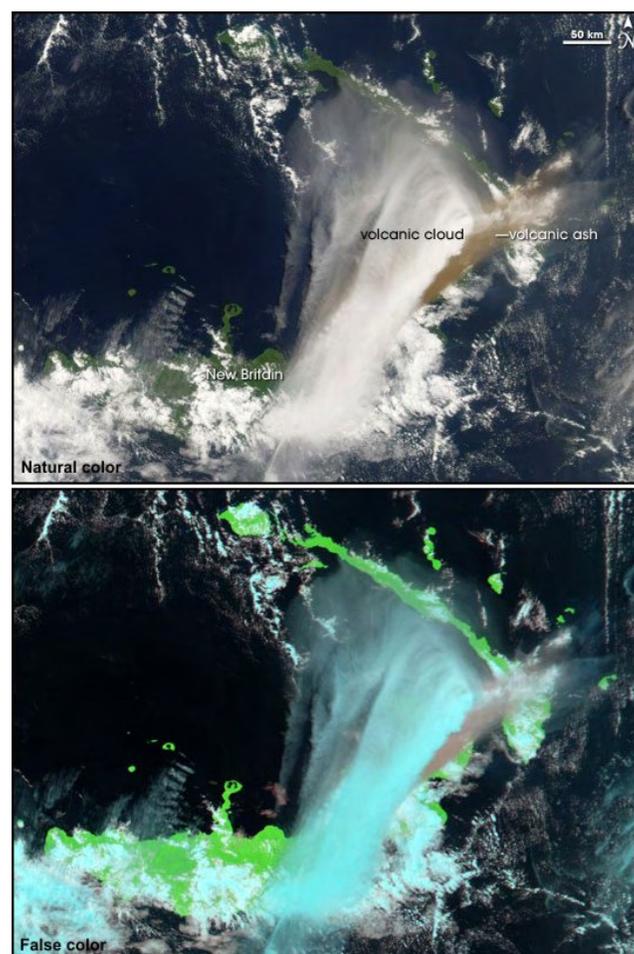


Figure 13. True-color (above) and false-color (below) images of a Rabaul eruption cloud created by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite, 7 October 2006. Volcanic emissions block the view of most of the island but Rabaul's approximate location is at the solid triangle. The brown or tan plume in the E clearly bears volcanic ash. The bright "cloud" to the immediate left of the brown ash represents a portion of the volcanic ash plume that reached a high enough altitude for the water content of that plume to turn to ice crystals that "white out" the ash content that would otherwise appear tan or brown. Courtesy of the NASA Earth Observatory web site.

noted that “Rabaul Chamber of Commerce President and hotelier Bruce Alexander told *Australian Associated Press* that around 2,000 people—or 90 percent of the local population—had fled the town as Mt. Tavorvur erupted. All flights into Tokua airport across the harbor from Rabaul had been canceled due to ash falls.”

According to *The Sydney Morning Herald*, with 90% of the residents absent and only essential personnel in Rabaul, local officials feared looters. Accordingly, extra police were called in, and armed police patrols were stepped up.

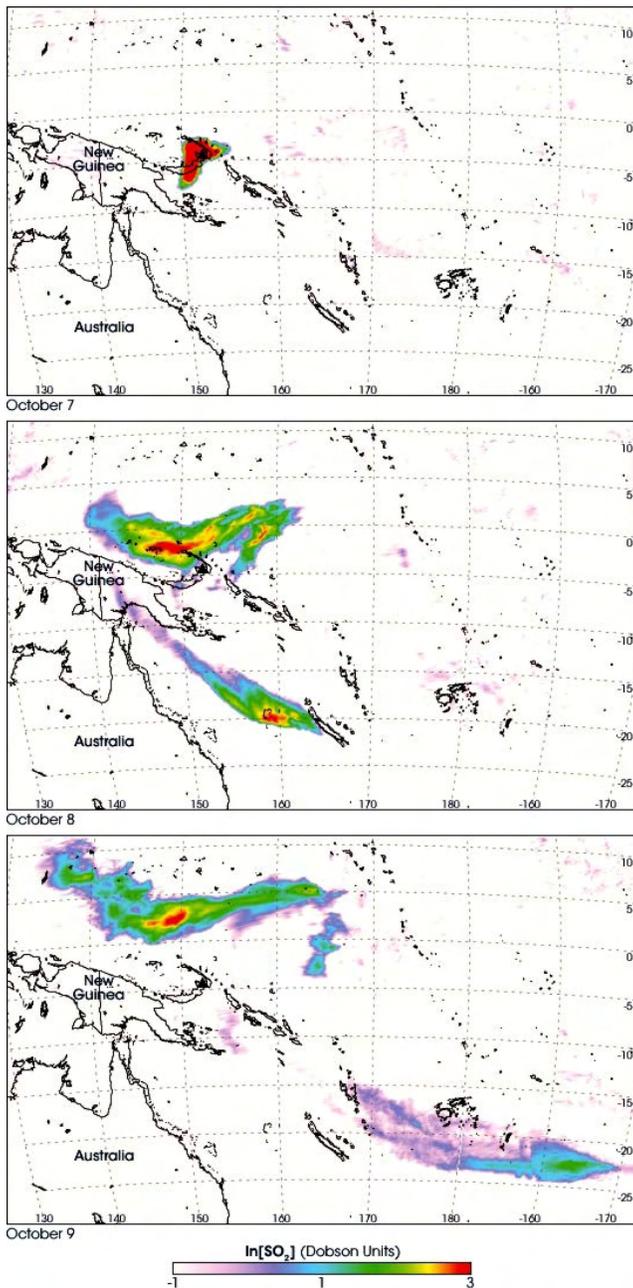


Figure 14. The Rabaul eruption injected SO₂ into the atmosphere and measurements from satellite spectrometers led to creation of this series of images mapping the SO₂ concentrations over the region during 7-9 October 2006. Data are from the Ozone Monitoring Instrument on NASA's Aura satellite. On 7 October, high SO₂ concentrations lingered over New Britain. By 8 October, the original plume had split into two clouds, one spreading NW, the other, SE. On 9 October, the SO₂ had diffused more, but a core of elevated concentration-pathlength values remained in the northern plume. Courtesy of NASA Earth Observatory and Simon Carn, University of Maryland Baltimore County.

Date	Time (UTC)	Number of Pixels	Satellite (A=aqua, T=Terra)
07 Oct 2006	1140	4	T
08 Oct 2006	0000	2	T
08 Oct 2006	1220	6	T
08 Oct 2006	1520	4	A
10 Oct 2006	1210	2	T
11 Oct 2006	0035	1	T
11 Oct 2006	1250	1	T
15 Oct 2006	1230	1	T
15 Oct 2006	1525	3	A
17 Oct 2006	1215	1	T
22 Oct 2006	0015	2	T
22 Oct 2006	1535	1	A
24 Oct 2006	1220	2	T

Table 1. MODIS thermal anomalies for Rabaul volcano for 7-17 October 2006. Courtesy of Hawai'i Institute of Geophysics and Planetology.

Geologic Summary. The low-lying Rabaul caldera on the tip of the Gazelle Peninsula at the NE end of New Britain forms a broad sheltered harbor utilized by what was the island's largest city prior to a major eruption in 1994. The outer flanks of the 688-m-high asymmetrical pyroclastic shield volcano are formed by thick pyroclastic-flow deposits. The 8 x 14 km caldera is widely breached on the east, where its floor is flooded by Blanche Bay and was formed about 1,400 years ago. An earlier caldera-forming eruption about 7,100 years ago is now considered to have originated from Tavui caldera, offshore to the north. Three small stratovolcanoes lie outside the northern and NE caldera rims of Rabaul. Post-caldera eruptions built basaltic-to-dacitic pyroclastic cones on the caldera floor near the NE and western caldera walls. Several of these, including Vulcan cone, which was formed during a large eruption in 1878, have produced major explosive activity during historical time. A powerful explosive eruption in 1994 occurred simultaneously from Vulcan and Tavorvur volcanoes and forced the temporary abandonment of Rabaul city.

Information Contacts: Steve Saunders and Herman Patia, Rabaul Volcanological Observatory (RVO), Department of Mining, Private Mail Bag, Port Moresby Post Office, National Capitol District, Papua, New Guinea (Email: hguria@global.net.pg); Andrews Tupper, Darwin Volcanic Ash Advisory Centre (VAAC), Bureau of Meteorology, Darwin, Australia (Email: A.Tupper@bom.gov.au); Peter Webley, ARSC/UAF, 909 Koyukuk Drive, Fairbanks, Alaska (Email: pwebley@gi.alaska.edu); Simon Carn, Joint Center for Earth Systems Technology (JCET), University of Maryland Baltimore County (UMBC), 1000 Hilltop Circle, Baltimore, MD 21250, USA (Email: scarn@umbc.edu); National Aeronautics and Space Administration Earth Observatory (URL: <http://earthobservatory.nasa.gov/NaturalHazards/>); RSAM definition (URL: http://vulcan.wr.usgs.gov/Monitoring/Descriptions/description_RSAM_SSAM.html); HIGP MODIS Thermal Alert System, Hawai'i Institute of Geophysics and Planetology (HIGP), University of Hawaii at Manoa, 168 East-West Road, Post 602, Honolulu, HI 96822, USA (URL: <http://modis.higp.hawaii.edu/>).

Bamus

New Britain, SW Pacific
5.20°S, 151.23°E; summit elev. 2,248 m
All times are local (= UTC +10 hours)

According to the Papua New Guinea Department of Mining (DOM), reports coming from Biialla Local Level Government (LLG) indicated that Bamus showed signs of unusual activity. At 1010 on 12 July 2006 observers saw white vapor coming out at the summit. The emission was forceful at about 1110 that day, with a tint of gray color in the emission. The vapor-rich plume blew inland to the SSE. No ashfall was reported.

Officials from Biialla LLG together with a DOM observer witnessed the activity, as did Max Benjamin from Walindi Resort (~ 40-50 km away). Benjamin called the Rabaul Volcano Observatory to report the activity. No satellite-detected thermal anomalies at the volcano were reported by the MODIS website for this time frame.

Geologic Summary. Symmetrical 2,248-m-high Bamus volcano, also referred to locally as South Son, is located SW of Ulawun volcano, known as the North Son. These two volcanoes are the highest in the 1,000-km-long Bismarck volcanic arc. The andesitic Bamus stratovolcano is draped by rainforest and contains a breached summit crater filled with a lava dome. A satellitic cone is located on the southern flank, and a prominent 1.5-km-wide crater with two small adjacent cones is situated halfway up the SE flank. Young pyroclastic-flow deposits are found on the volcano's flanks, and villagers describe an eruption that took place during the late-19th century.

Information Contacts: Rabaul Volcano Observatory (see Rabaul).

Sulu Range

New Britain, SW Pacific
5.50°S, 150.942°E; summit elev. 610 m

On 31 October 2006 the Rabaul Volcanological Observatory (RVO) issued a followup report to the eruptive activity in the Sulu Range through much of October. Sulu Range was previously discussed in *BGVN* 31:07, but that report was ambiguous on the nature of the activity that had taken place during July 2006. This report and personal communications establishes that RVO staff are doubtful that the most energetic events were magmatic in character. Furthermore, RVO reported that in the weeks that followed, seismicity continued to decline.

The seismic unrest that began on 6 July declined from over 2,000 daily volcano-tectonic (VT) events to below 50 daily VT events during October (figure 15).

The number fluctuated between 35 and 50 from late September to early October and between 5 and 25 during the third week of October.

RVO noted that about two to three felt earthquakes with intensity 2 continued to be felt daily at irregular intervals within the Biialla area and that white steam emissions from the Silanga Hot Springs were still visible from Biialla. In addition, a moderately strong sulfur smell from the Silanga and Talopu hot springs continued to be reported.

An analysis by RVO scientists concluded that at no point did magma reach the surface. The declining trend in seismic activity from early to late October may indicate that the new magma that apparently intruded to shallow levels in July is beginning to stall.

A permanent seismic station will be installed at Kaiamu in December 2006 to provide continuous monitoring of activity from the Sulu Range and surrounding areas.

In an extension of elevated regional tectonic seismicity, a strong earthquake, $M \sim 6.5$, struck the S side of central New Britain on 17 October. The USGS computed the focal depth as ~ 60 km, with epicenter ~ 50 km S of the Sulu Range. According to a USGS machine-generated shaking and intensity map, the Sulu Range lies within the zone of highest computed intensity (VI).

Geologic Summary. The Sulu Range consists of a group of partially overlapping small stratovolcanoes in north-central New Britain off Bangula Bay. The 610-m Mount Malopu forms the high point of the basaltic-to-rhyolitic complex at its SW end. Lava Point (also known as Lara Point) forms a peninsula of volcanoclastic-covered lava flows with a small lake extending about 1 km into Bangula Bay at the NW side of the Sulu Range. The Walo hydrothermal area, consisting of solfataras and mud pots, lies on the coastal plain west of the SW base of the Sulu Range. Prior to 2006, no historical eruptions had occurred from the Sulu Range, although some of the cones display a relatively undissected morphology.

Information Contacts: Rabaul Volcano Observatory (see Rabaul); USGS Earthquakes Hazard Program (URL: <http://earthquakes.usgs.gov/>)

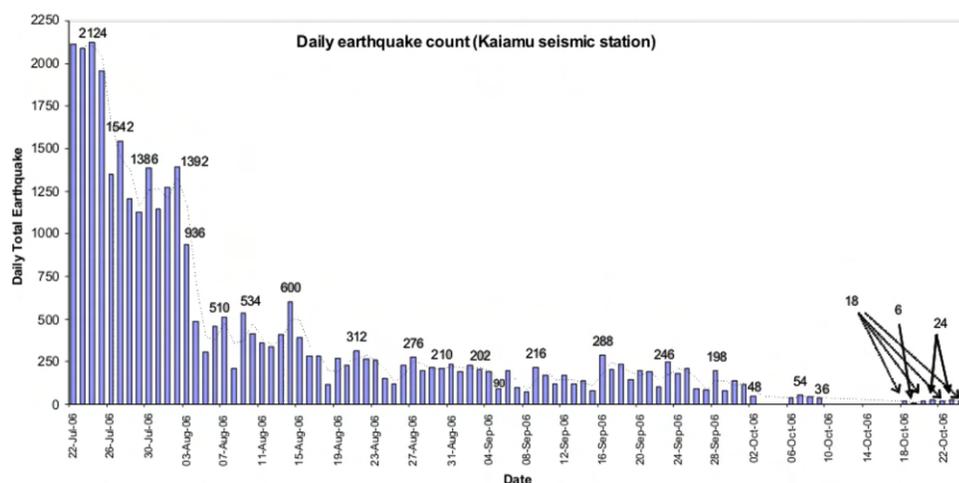


Figure 15. Sulu Range seismicity plot of daily VT earthquakes from 22 July 2006 to 24 October 2006 at the Kaiamu Seismic Station. The station did not operate on the days that lack earthquakes. Courtesy of RVO.

Barren Island

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

Our last report on Barren Island discussed events through much of January 2006 (*BGVN 31:01*); since that time we have only found sporadic reports of activity.

According to a news article by *The Indo-Asian News Service*, a team of scientists that visited Barren Island around 12 March 2006 found that the volcano was still very active. The height of the volcanic cone had increased by 50 m since eruptive activity began in May 2005. In addition, lava flows covered the NW side of the island.

Since March 2006 there have been only a few satellite images and pilot reports of continued activity. Based on a pilot report and satellite imagery, the Darwin VAAC reported that an ash plume was emitted during 5-6 April that did not rise higher than 4.6 km altitude. On 19 April a low-level plume extending W was visible on satellite imagery.

On 2 May satellite imagery detected a plume from Barren Island near 3.7 km altitude. The following day low-level ash plumes extended N. Based on a pilot report, the Darwin VAAC reported an ash plume at 1230 on 26 May that remained below 3 km altitude and drifted N.

On 23 September a news report in *The Hindu* stated that Indian Coast Guard officials indicated that the continuing eruption at Barren Island was decreasing in intensity. The news piece cited a surveillance report statement that there was less lava but more “smoke” from the volcano.

Geologic Summary. Barren Island, a possession of India in the Andaman Sea about 135 km NE of Port Blair in the Andaman Islands, is the only historically active volcano along the N-S-trending volcanic arc extending between Sumatra and Burma (Myanmar). The 354-m-high island is the emergent summit of a volcano that rises from a depth of about 2,250 m. The small, uninhabited 3-km-wide island

contains a roughly 2-km-wide caldera with walls 250-350 m high. The caldera, which is open to the sea on the W, was created during a major explosive eruption in the late Pleistocene that produced pyroclastic-flow and -surge deposits. The morphology of a fresh pyroclastic cone that was constructed in the center of the caldera has varied during the course of historical eruptions. Lava flows fill much of the caldera floor and have reached the sea along the western coast during historical eruptions.

Information Contacts: *The Hindu* (URL: <http://www.hinduonline.com>); *Indo-Asian News Service (IANS)* (URL: <http://www.eians.com/>); *Geological Survey of India*, 27 Jawaharlal Nehru road, Kolkata 700 016, India (URL: <http://www.gsi.gov.in/barren.htm>); *Indian Coast Guard*, National Stadium Complex, New Delhi 110 001, India (URL: <http://indiancoastguard.nic.in/indiancoastguard/>); *Darwin Volcanic Ash Advisory Center*, Bureau of Meteorology, Northern Territory Regional Office, PO Box 40050, Casuarina, Northern Territory 0811, Australia (URL: <http://www.bom.gov.au/info/vaac/>).

Bulusan

Luzon, Philippines
12.770°N, 124.05°E; summit elev. 1,565 m
All times are local (= UTC + 8 hours)

On 19 March 2006, the Philippine Institute of Volcanology and Seismology (PHIVOLCS) raised the status of Bulusan from Zero Alert (no alert) to Alert Level 1 to reflect elevated seismic, fumarolic, and other unrest (*BGVN 31:05*). From that date until an ash explosion on 28 June 2006, 10 explosions were recorded (see table 2).

After the ash explosion of 28 June 2006, Bulusan's monitored parameters gradually decreased to near baseline levels. The daily count of volcanic earthquakes was very low, and SO₂ emission rates and ground-deformation data

Date (2006)	Local time	Plume Altitude (km)	Drift Direction	Comments
19 Mar	—	—	—	Seismic swarm which lasted until 21 Mar; Alert Level raised to 1
21 Mar	2258	1.5	N, W, SW	1st explosion-type (E-type) earthquake lasted 20 min; total of 4 E-type earthquakes recorded
08 Apr	2000	—	—	Lahar at Cogon spillway
09 Apr	1036-1058	—	—	Lahar at Cogon spillway
29 Apr	1044	1.5	WSW, NW	2nd E-type earthquake; total of 3 E-type earthquakes recorded
25 May	2117-2130	cloud-covered summit	—	3rd E-type earthquake; ash deposits, trace to 2 mm thick in Juban, Irosin
31 May	1617	1.5	W, WNW	4th E-type earthquake
07 Jun	2017-2030	2.0	N, W, SW	5th E-type earthquake; smaller E-type earthquake at 0225 on 8 Jun; Alert Level raised to 2
10 Jun	1218	1.0	NE, E	6th E-type earthquake, lasting 25 min
13 Jun	1904	1.5	NW	7th E-type earthquake, lasting 13 min
18 Jun	1556	1.5	W	8th E-type earthquake
20 Jun	2013	cloud-covered summit	—	9th E-type earthquake — mild; event not observed; seismic signal recorded for 17 min; rains generated some lahars
24 Jun	2300	—	—	Lahar at Cogon spillway
28 Jun	0206	cloud-covered summit	—	10th E-type earthquake; the associated volcanic event was not observed but seismic signal recorded as E-type earthquake lasted 4 min
29 Jun	0800	—	—	Continuous decline in Bulusan activity; Alert Level lowered to 1

Table 2. Summary of significant events through late July 2006 at Bulusan. Numbering of explosion-type (E-type) quakes began 21 March 2006. Courtesy of Philippine Institute of Volcanology and Seismology (PHIVOLCS).

revealed the volcano's deflated condition, indicating the absence of active magma ascent. Ash emission stopped and steaming from the active vents and fissures gradually returned to normal levels. Due to the decline in activity, on 29 July PHIVOLCS lowered the status of Bulusan from Alert Level 2 to 1.

On 10 October 2006 at 1256 UTC, the Tokyo Volcanic Ash Advisory Center announced that an eruption plume from Bulusan was visible on satellite imagery reaching altitudes of 3 km and drifting SW and SSE.

Unlike nearby Mayon volcano (~ 70 km NW) (see *BGVN* 31:08), no thermal anomalies were detected at Bulusan by satellite or recorded by the Hawai'i Institute of Geophysics and Planetology (HIGP) MODIS/ MODVOLC web site from the beginning of 2006 to 10 October 2006.

Geologic Summary. Luzon's southernmost volcano, Bulusan, was constructed along the rim of the 11-km-diameter dacitic-to-rhyolitic Irosin caldera, which was formed about 35,000-40,000 years ago. Bulusan lies at the SE end of the Bicol volcanic arc occupying the peninsula of the same name that forms the elongated SE tip of Luzon. A broad, flat moat is located below the topographically prominent SW rim of Irosin caldera; the NE rim is buried by the andesitic Bulusan complex. Bulusan is flanked by several other large intracaldera lava domes and cones, including the prominent Mount Jormajan lava dome on the SW flank and Sharp Peak to the NE. The summit of 1,565-m-high Bulusan volcano is unvegetated and contains a 300-m-wide, 50-m-deep crater. Three small craters are located on the SE flank. Many moderate explosive eruptions have been recorded at Bulusan since the mid-19th century.

Information Contacts: *Philippine Institute of Volcanology and Seismology (PHIVOLCS)*, University of the Philippines Campus, Diliman, Quezon City, Philippines (URL: <http://www.phivolcs.dost.gov.ph>); *Tokyo Volcanic Ash Advisory Center (VAAC)* (URL: <http://www.jma.go.jp/jma/jma-eng/jma-center/vaac/index/html>); *HIGP MODIS Thermal Alert System*, Hawai'i Institute of Geophysics and Planetology (HIGP), University of Hawaii at Manoa, 168 East-West Road, Post 602, Honolulu, HI 96822, USA (URL: <http://modis.higp.hawaii.edu/>).

Cleveland

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

Cleveland's commonly observed activity consisting of short duration explosions, such as those seen earlier in the year on 6 February 2006 (*BGVN* 31:01) and on 23 May 2006 (*BGVN* 31:07), continued during August and October 2006. This report will cover the 24 August and 28 October eruptions.

At 1955 on 24 August a brief eruption was seen by mariners on a passing ship. The eruption was unconfirmed by satellite data. Video footage sent to the Alaska Volcano Observatory (AVO) on 28 August showed that an ash cloud rose to an approximate altitude of 3 km and produced minor ashfall. Shortly after the eruption, minor steaming was observed from the vent on additional footage. In response to the eruption, the AVO raised the level of Concern Color

Code from 'unassigned' to 'Yellow' on 7 September. A weak thermal anomaly in the summit crater was present in subsequent satellite images.

Clouds obstructed visibility through most of September and October.

A pilot reported that a minor eruption started at 1345 on 28 October. Satellite data confirmed the presence of an ash cloud drifting ENE of the volcano. The height of the cloud was estimated at an altitude of 6 km using the satellite imagery. One pilot reported the plume top at an altitude of 9 km. The AVO raised the alert level to 'Orange' during 28-29 October. On 30 October the AVO lowered the level to 'Yellow' because of no further evidence of activity.

Geologic Summary. Beautifully symmetrical Mount Cleveland stratovolcano is situated at the western end of the uninhabited, dumbbell-shaped Chuginadak Island. It lies SE across Carlisle Pass strait from Carlisle volcano and NE across Chuginadak Pass strait from Herbert volcano. Cleveland is joined to the rest of Chuginadak Island by a low isthmus. The 1730-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; Geophysical Institute, University of Alaska, P.O. Box 757320, Fairbanks, AK 99775-7320, USA; and Alaska Division of Geological & Geophysical Surveys, 794 University Ave., Suite 200, Fairbanks, AK 99709, USA (URL: <http://www.avo.alaska.edu/>).

Fourpeaked

Alaska Peninsula, USA
58.770°N, 153.672°W; summit elev. 2,105 m
All times are local (= UTC - 9 hours [or 8 hours early April-late October])

Until the eruption of Fourpeaked on 17 September, evidence for eruptive activity in the past 10,000 years was uncertain. The volcano is largely glacier covered with only isolated outcrops (figure 16). This report discusses the initial observation of plumes and subsequent activity until the end of October 2006. Fourpeaked is in S Alaska ~ 320 km SW of Anchorage. It is SW of the mouth of Cook Inlet and within NE Katmai National Park (figure 17).

On the evening of 17 September, AVO received several reports of two discrete plumes rising from the Cape Douglas area. The plumes were photographed at an un-stated time on 17 September from the town of Homer (figure 18). At this stage, neither Douglas nor Fourpeaked had devoted seismic instruments.



Figure 16. Fourpeaked volcano, the glacier-covered peak at the upper left is one of a group of poorly known volcanoes NE of Katmai National Park. In the foreground of this photo is Kaguyak caldera, which hosts a 2.5-km-wide lake. Pre-eruption photo at uncertain date taken by Chris Nye (Alaska Division of Geological and Geophysical Surveys, Alaska Volcano Observatory).

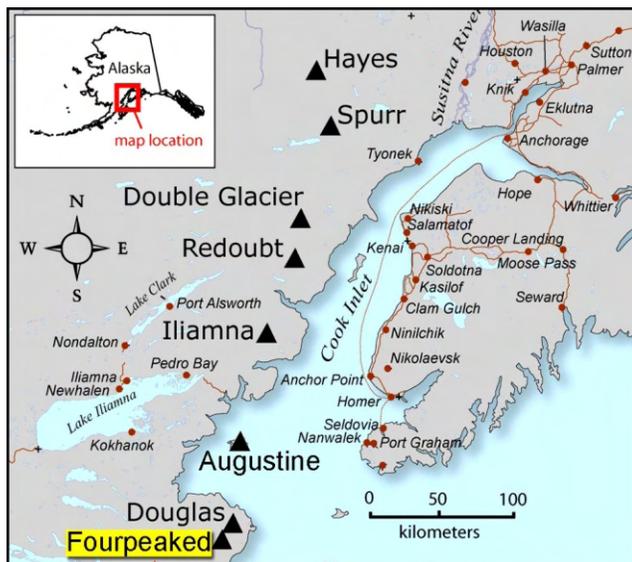


Figure 17. A map showing the location of Fourpeaked and Douglas volcanoes, Cook Inlet, and adjacent settlements including the city of Homer on the SW Kenai Peninsula. Created by Seth Snedigar and Janet Schaafer, AVO-ADGGS.

Retrospective analysis of data from the NEXRAD Doppler radar in King Salmon showed an unusual cloud starting at 1200 on 17 September. The maximum cloud height determined by radar during the first hour of the event was 6 km altitude. The radar return from the cloud continued until at least 2145 (figure 19).

A cloud of sulfur dioxide gas was observed by colleagues at the Volcanic Emissions Group at the University of Maryland Baltimore. They used data collected at 1500 by the Ozone Monitoring Instrument (OMI) on NASA's Aura satellite (figure 20).

On the basis of the suite of visual, radar, and satellite observations, all the 17 September clouds were inferred volcanic in origin. Although satellite data did not detect ash during this event, AVO received reports of a trace of ashfall at Nonvianuk Lake outlet (110 km WNW) and near Homer (150 km NE). Field observers saw deep scouring of a glacier flowing W from the summit, indicating flooding, probably from the 17 September event.

In the caption to a 20 September AVO photo by K.L. Wallace there was noted a "continuous layer of discolored snow and ice above [\sim 1 km elevation,] \sim 3,000 feet asl on the NE flank of Fourpeaked volcano (S of Douglas volcano). Could possibly be ash from the 9/17/06 event."

Both fixed-wing and helicopter overflights in the Cape Douglas area on 20 September confirmed the source of volcanic activity to be Fourpeaked volcano. AVO raised the Level of Concern Color Code from "Not

Assigned" to YELLOW on 20 September.

A 23 September observation flight conducted in relatively good weather permitted the first look at the summit since the event of 17 September. Observers saw a linear series of vents running N from the summit for about 1 km. Most of these vents vigorously emitted steam and other volcanic gases. Gas measurements indicated abundant quantities of sulfur dioxide, hydrogen sulfide, and carbon dioxide. Thermal measurements of up to 75°C were recorded at the vents, although steam was likely obscuring hotter areas. Adjacent glacial ice had been disrupted and showed signs of subsidence. Airborne gas measurements taken on 23, 24, and 30 September again documented high emission rates of



Figure 18. A photograph of the eruption of Fourpeaked on 17 September 2006. The photo was taken from Main Street in Homer at an unstated time. Copyrighted photograph by Lanny Simpson, Alaska High Mountain Images (shown on AVO's website).

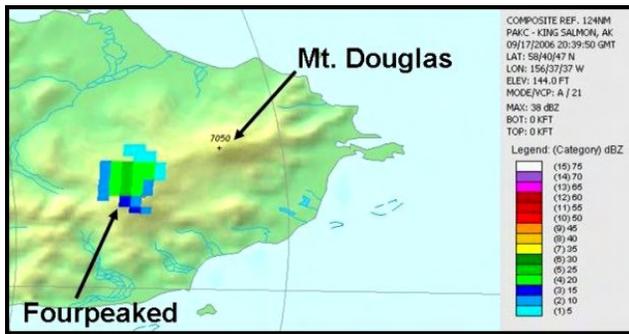


Figure 19. Image from the King Salmon NEXRAD weather radar showing the volcanic cloud at Fourpeaked on 17 September 2006 at 1240 (2040 UTC). In color the radar reflectivity ranges from light blue (low) to dark green (moderate), which corresponds to greater numbers and/or sizes of particles. It cannot be determined whether the signal is due to large water droplets, ice particles, coarse-grained ash, or a mixture. Image created by Dave Schneider, AVO/USGS, using data and software from the NOAA National Climatic Data Center.

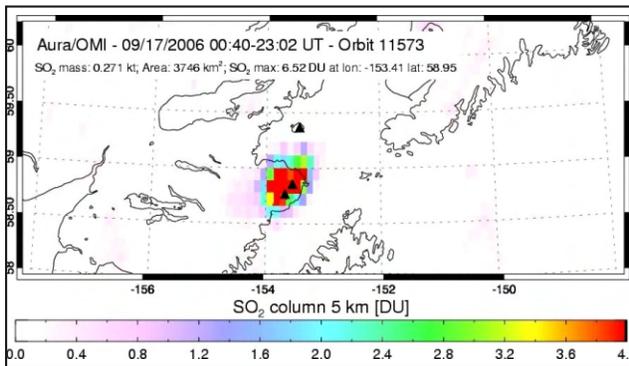


Figure 20. Image showing the total amount of sulfur dioxide over Fourpeaked on 17 September 2006 as measured by the Ozone Monitoring Instrument on NASA's Aura satellite. Sulfur dioxide is displayed in Dobson Units (DU, a measure of the number of molecules in a unit area of the atmospheric column). Image created by the Volcanic Emissions Group at the University of Maryland Baltimore County.



Figure 22. A 4 November 2006 photograph documenting steaming on the uppermost section of the northern flank of Fourpeaked volcano. Courtesy of Jennifer Adleman (AVO/USGS).

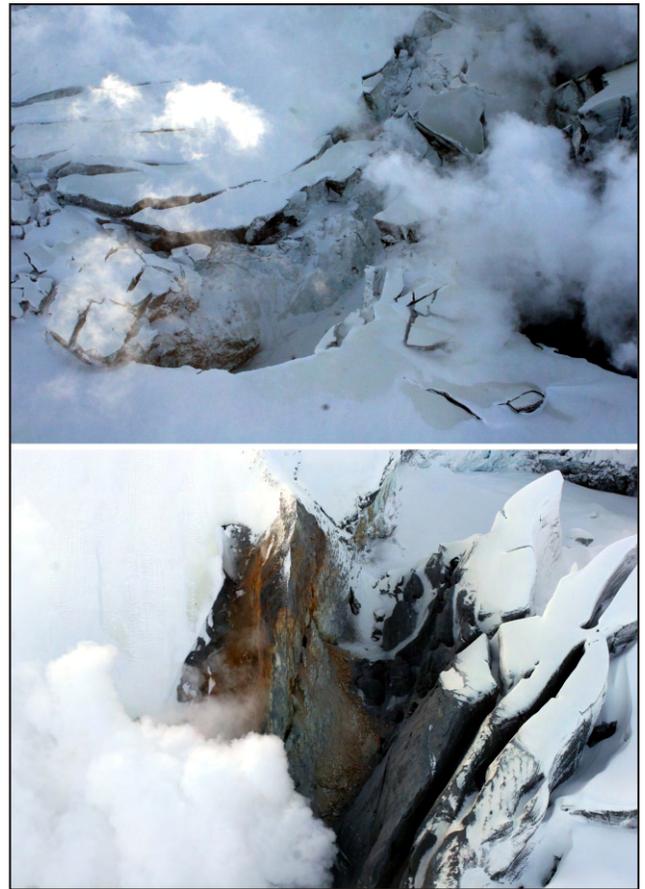


Figure 21. Photographs of the steaming vent area at Fourpeaked volcano on 15 October 2006. Courtesy of Kate Bull (AVO-ADGGS).

sulfur dioxide, hydrogen sulfide, and carbon dioxide, and a distinct sulfur smell was evident up to 50 km from the summit. An AVO status report on 3 October noted that cloudy conditions had prevented visual or satellite observations, but limited seismic data being received did not indicate significant volcanic activity.

The AVO reported that volcanic unrest continued at Fourpeaked during 30 September-24 October. A seismometer installed on 25 September indicated ongoing low-level seismicity. Due to the limited number of seismometers, earthquake epicenters were not located. Emission rates of sulfur dioxide were high during 4-10 October and on 27 October. Observations were hindered due to cloud cover, but on 12 October AVO staff reported that two prominent vents were emitting steam and gas. Figure 21 shows several shots illustrating the enlarged opening in the ice on 15 October.

On 20 October, field crews installed a web camera located 16 km (10 miles) N of Fourpeaked.

Steam plumes originating from vents along the summit were visible via the web camera on 27 and 30 October. Steaming continued through at least 4 November (figure 22).

Geologic Summary. Poorly known Fourpeaked volcano in NE Katmai National Park consists of isolated outcrops surrounded by the Fourpeaked glacier, which descends eastward almost to the Shelikof strait. The orientation of lava flows and extensive hydrothermal alteration of rocks near the present summit suggest that it probably marks the vent of Fourpeaked volcano (Swanson, in Wood and Kienle 1990).

Information Contacts: *Alaska Volcano Observatory* (see Cleveland); *S.A. Carn, N.A. Krotkov, A.J. Krueger, and K. Yang*, Joint Center for Earth Systems Technology (JCET), University of Maryland Baltimore County (UMBC), 1000 Hilltop Circle, Baltimore, MD 21250, USA (Email: scarn@umbc.edu).

Soufrière Hills

West Indies

16.72°N, 62.18°W; summit elev. 915 m

All times are local (= UTC - 4 hours)

Since the 20 May 2006 dome collapse, the lava dome at Soufrière Hills has continued to grow. Only weeks after the collapse, the alert level was raised to 4 as a result of increased seismic activity. At approximately 1300 on 30 June, the lava dome partially collapsed again, producing pyroclastic flows that traveled E. According to the Washington VAAC, a pilot reported an ash plume that reached ~ 3 km altitude and drifted NW. At 1830 on 30 June, Montserrat Volcano Observatory (MVO) indicated a second dome collapse that also generated ash plumes to an altitude of 3.0-3.5 km (figure 23). According to MVO, on 27 June (prior to the collapse on 30 June) the lava dome had an estimated volume of 27 million cubic meters.



Figure 23. A photo taken on 30 June 2006 of Soufrière Hills as viewed from the Montserrat Volcano Observatory showing the first partial dome collapse of the day. The partial collapse began just before 1300 local time and lasted ~ 20 minutes, generating ash clouds to an altitude of ~ 3.5 km that drifted WNW. Pyroclastic flows (left side of picture) were confined to the Tar River valley and ultimately reached the sea. Most of the lava dome remained intact. Photo courtesy of MVO.

On 7 July, the alert level was lowered from 4 to 3. Increased rockfall activity and dome growth to the NE were observed on 21 July, and the post-collapse dome developed an asymmetric profile owing to a blocky spine on the NE. On 18 July the spine's summit stood at ~ 895 m elevation. As the dome continued to grow during July (figure 24), visual observations revealed that the still intact blocky spine began leaning E.

During August the dome lost spines from its crest, giving it a more symmetrical profile as it continued to grow E. Heightened activity during the last week of August included an increase in seismicity and pyroclastic flows. On 29 August, pyroclastic flows reached the Tar River valley and generated a steam-and-ash cloud that reached an altitude of ~ 9 km. Heavy rainfall produced mudflows around the base of the volcano.

At 0300 on 31 August, two vigorous ash-and-steam vents opened on the W and N flanks of the dome (figure 25). The venting episode was audible at times from the town of Salem and the surrounding areas. MVO noted the continued dome growth and the opening of these vents when on 31 August they raised the alert level to 4.

Heightened activity continued in September. The dome continued to develop substantially with a majority of growth on the W side. The vents that opened on 31 August remained active, with the vent above Gage's wall emitting a plume of hot gases and the N vent on the dome producing mainly ash-and-steam (figure 26). The opening of these vents coincided with high lava extrusion rates and consequent dome growth.

At 0100 on 10 September, the vent above Gage's wall became more vigorous throughout the day, broadening the vent and generating a wide vertical ash column. By 1300 the venting there became violent and explosive with black jets of ash rising ~ 100 m. Pyroclastic flows traveled down the Gages valley for ~ 1 km (figure 27). The vent formed a crater in the Gages wall, reducing its height compared to that of Chances Peak by 30-50 m. By 11 September, pyroclastic flows from vent emissions had ceased, but vigorous ash venting continued. At 0830 an overhanging lava lobe that developed on the NE collapsed sending a pyroclastic flow almost to the sea at the end of the Tar River valley.



Figure 24. A photo of Soufrière Hills taken on 25 July showing spines at the summit of the lava dome as viewed from the NE. Photo courtesy Greg Scott of Caribbean Helicopters.

Although volcanic tremor ended early on 16 September, an intense episode of volcanic tremor lasting just half an hour started at 1400 on 19 September. It was accompanied



Figure 25. Photos showing activity at Soufrière Hills on 31 August 2006. (top) Emissions from the vigorous new vent inside Gages wall (Gages Mountain to the left of the vent and Chances Peak to the right). (bottom) N-looking photo showing the N crater wall, lava dome, and the new vigorous ash vent on the N side of the lava dome. Courtesy of MVO.



Figure 26. A photo showing lava-dome glow viewed from the S at MVO at 2200 on 7 September 2006. Incandescent rocks can be seen tumbling down all flanks of the lava dome on this clear night. A faint glow is visible from the very hot and active gas vent just inside the Gages wall (just right of the dome in the picture). Photo courtesy of MVO.

by intense rockfall activity giving rise to minor pyroclastic flows down the N and NE flanks of the lava dome. On 21 September the alert level was reduced to 3.

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 4,000 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/>).



Figure 27. A photo showing explosive ash venting from a spot above Gages valley at 1530 on 10 September. Pyroclastic flows can be seen advancing into Gages valley in the foreground. Photo courtesy of MVO.

San Cristóbal

Nicaragua

12.702°N, 87.004°W; summit elev. 1,745 m

All times are local (= UTC - 6 hours)

San Cristóbal was last reported on in *BGVN* 28:10, covering intermittent gas and ash emissions between August 2002 and September 2003. The Instituto Nicaragüense de Estudios Territoriales (INETER) noted that low seismicity and minor gas and ash emissions characterized the period from October 2003 to June 2004.

On 7 June 2004 a lahar flowed more than 600 m. On 13 June 2004, an eruption caused ash to fall in the communities of Las Rojas, El Chonco, and El Viejo.

On 20 July 2004 at 1430, an M 4.3 earthquake occurred to the N of the volcano at a depth of less than four km. The earthquake was felt in the regions of Carlos Fonseca, Villa 15 de Julio, La Suiza, Las Rojas, Mocerón, San Jose del Obraje, Santa Carlota, San Antonio, Rancheria, and bordering regions. Some houses were damaged and the population was alarmed. The earthquake was felt in Matagalpa and Ocotol, and San Cristóbal emitted abundant gases for the following two days. During the rest of July, 95 aftershocks were registered; residents felt two more earthquakes, which occurred on 23 and 30 July.

During August to early December 2004, minor seismicity and ash and gas emissions were the norm. Ash explosions occurred on 3, 4, and 7 December. According to local people, ash fell in Chinandega and El Viejo.

The next available report discussed 16-22 November 2005. INETER detected an increase in seismicity beginning on 19 November. Increased tremor was interpreted as being related to gas and ash emissions. Ash fell W of the volcano and near the town of Chinandega, ~ 15 km SW of the volcano. The amount of tremor decreased later.

According to an Associated Press news report, explosions on 6 March 2006 produced columns of ash and gas that rose above the volcano. The activity ceased by 8 March and there were no evacuations.

INETER noted that phreatomagmatic eruptions began at San Cristóbal on 21 April 2006. Seismic tremor increased the same day around 1300. Small explosions produced gas-and-ash plumes during 21-23 April that deposited small amounts of ash in nearby towns.

Geologic Summary. The San Cristóbal volcanic complex, consisting of five principal volcanic edifices, forms the NW end of the Marrabios Range. The symmetrical 1,745-m-high youngest cone, named San Cristóbal (also known as El Viejo), is Nicaragua's highest volcano and is capped by a 500 x 600 m wide crater. El Chonco, with several flank lava domes, is located 4 km to the west of San Cristóbal; it and the eroded Moyotepe volcano, 4 km to the NE of San Cristóbal, are of Pleistocene age. Volcán Casita, containing an elongated summit crater, lies immediately east of San Cristóbal and was the site of a catastrophic landslide and lahar in 1998. The Plio-Pleistocene La Pelona caldera is located at the eastern end of the San Cristóbal complex. Historical eruptions from San Cristóbal, consisting of small-to-moderate explosive activity, have been reported since the 16th century. Some other 16th-century eruptions attributed to Casita volcano are uncertain and may pertain to other Marrabios Range volcanoes.

Information Contact: Virginia Tenorio, Emilio Talavera, and Martha Navarro, Instituto Nicaragüense de Estudios Territoriales (INETER), Apartado Postal 2110, Managua, Nicaragua (Email: ineter@ibw.com.ni; URL: <http://www.ineter.gob.ni/geofisical/>); Associated Press, (URL: <http://www.ap.org/>).

Montagu Island

South Sandwich Islands

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

All times are local (= UTC - 2 hours)

Matthew Patrick reported that the month of October represents the 5-year anniversary of the start of the still-on-going eruption at Mount Belinda on Montagu Island. The first satellite thermal alert for the volcano occurred on 20 October 2001, and was the first definitive record of historical volcanic activity on the island (*BGVN* 28:02) (Patrick and others, 2005). The MODVOLC monitoring system uses MODIS (Moderate Resolution Imaging Spectroradiometer) satellite data processed at the University of Hawai'i-Manoa. Current MODVOLC results, shown in figure 28A, indicate more-or-less persistent activity throughout the 5-year period, with radiant heat flux apparently peaking in late 2005 and early 2006.

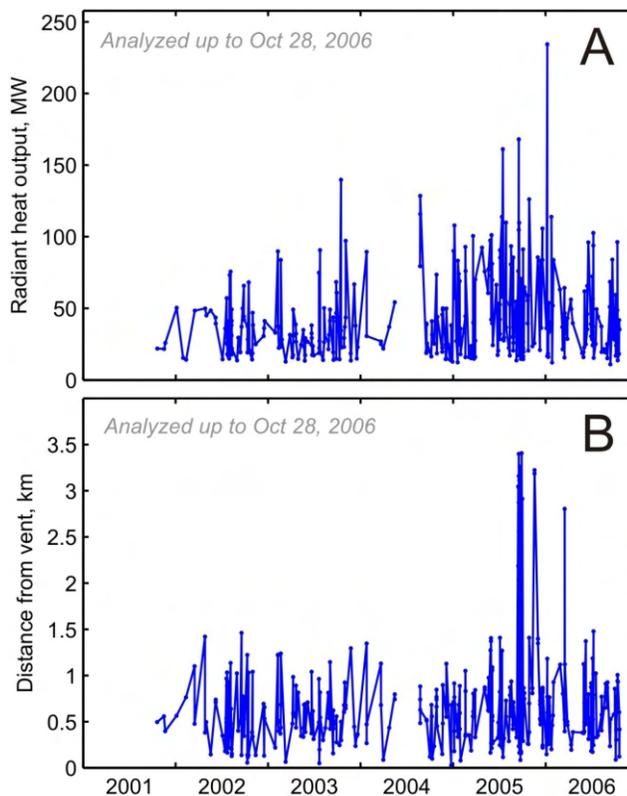


Figure 28. Plots of MODVOLC data at Belinda volcano on Montagu Island from 2001 to October 2006. (A) Chronological graph of radiant heat output from Mount Belinda measured from satellite sensors. (B) Chronological plot showing the distance of satellite-measured thermal anomaly pixels from the Mount Belinda vent. Courtesy of HIGP Thermal Alerts Team.

Landsat and ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) imagery has shown that the eruption consisted of central vent activity producing lava flows. Small-scale explosive activity has also commonly blanketed the E side of the island. Three effusive events have been observed in ASTER/Landsat imagery, with the most recent (September-October 2005) producing a lava flow that traveled 3.5 km and reached the sea to build a 500-m-wide delta of lava (*BGVN* 30:09 and 30:11).

Figure 28B shows relative location (distance from the vent) comparing Mount Belinda's vent with the locations of MODVOLC alert pixels. This plot clearly shows longer flows during the September 2005 effusive event. Following this period, there were several other long-distance events. It is unclear if these reflect additional effusive events.

In addition, the first two effusive events observed in the ASTER/Landsat images do not appear on the MODVOLC plot (figure 28B), due either to cloud cover or their short flow lengths. Since the beginning of 2006, no cloud-free ASTER images have been available.

Geographic terminology. The nomenclature of volcanic features on Montagu Island, particularly in regard to Mount Belinda, has been quite variable. Although the name Montagu has been applied to the major volcanic edifice forming the island (LeMasurier and Thomson, 1990), the name Mount Belinda has been variously applied to the entire volcano, the currently active young cone on the northern side of the island, the 6-km-wide summit caldera, and a peak on the southern caldera rim that is the island's high point. In consultation with John Smellie of the British Antarctic Survey, we have used Montagu to refer to the volcano forming the island and Mount Belinda for the currently active cone.

References. LeMasurier, W.E., and Thomson, J.W. (eds.), 1990, *Volcanoes of the Antarctic Plate and Southern Oceans*: Washington, D C: American Geophysical Union, 487 p.

Patrick, M.R., Smellie, J.L., Harris, A.J.L., Wright, R., Dean, K., Izbekov, P., Garbeil, H., and Pilger, E., 2005, First recorded eruption of Mount Belinda volcano (Montagu Island), South Sandwich Islands, *Bulletin of Volcanology*, v. 67, no. 5, p. 415-422.

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.

Information Contact: *Matthew Patrick*, Dept. of Geological and Mining Engineering and Sciences, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931, USA (Email: mpatrick@mtu.edu; URL: <http://www.geo.mtu.edu/~mpatrick/>); *HIGP MODIS Thermal Alert System*, Hawai'i Institute of Geophysics and Planetology (HIGP), University of Hawaii at Manoa, 168 East-West Road, Post 602, Honolulu, HI 96822, USA (URL: <http://modis.higp.hawaii.edu/>); *John Smellie*, British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB3 0ET, United Kingdom (URL: <http://www.anarctica.ac.uk/>, Email: jtsm@bas.ac.uk).