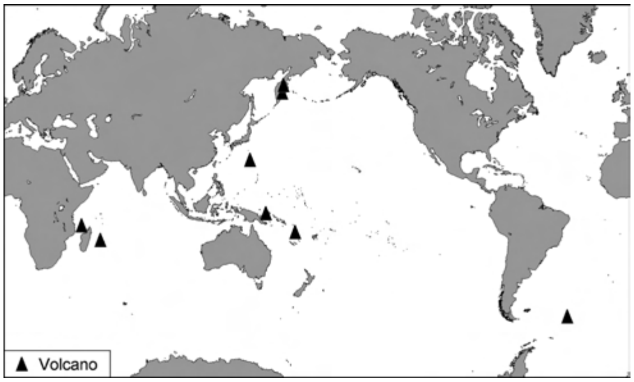
Bulletin of the Global Volcanism Network



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Karthala

Grand Comore Island, Comoros, Western Indian Ocean
11.75°S, 43.38°E; summit elev. 2,361 m
All times are local (= UTC + 3 hours)

The last eruption at Karthala occurred in April 2005 (*BGVN* 30:04); this report discusses the second large eruption of the year, on 24-25 November 2005. Karthala is a volcano with a lava lake and well-known for episodic outbursts. This report begins with imagery and maps, discusses satellite images of the 24-25 November ash plume, and then summarizes press and United Nations reports.

Satellite imagery. Elements of Karthala geography appear in figure 1. This and many other figures were produced by a United Nations consortium of public and private organizations, UNOSAT, which provides satellite imagery and geographic information to the humanitarian community. The islands capital, Moroni, lies on the coast directly W of the summit complex.

Perspective on the eruption's impact can be seen on figure 2, containing images from both pre- and post-eruption time frames (13 July 2004 and 5 December 2005). Conspicuous new deposits at distance from the summit area were imaged on 5 December. Some new deposits resided in what appear as channels to the N of the craters, suggesting that freshly deposited tephra may have entered and followed the drainage systems: see channels on figure 2, heading NE. These tentative inferences by *Bulletin* editors were not discussed in available ground-based reports, so confirmation is lacking. No reports were yet available discussing the morphology or potential hazards of these new deposits.

Ash clouds. Charles Holliday (US Air Force Weather Agency, AFWA) assessed the 25 November 2005 Karthala eruption plume using a NASA Terra MODIS image at 1010 local time (0710 UTC; figure 3). He measured the overall E-W extent of eruptive clouds as ~ 150 nautical miles (~ 280 km). The W margin of the brown clouds lie up to 30-50 km W and NW of the volcano. The light-colored clouds were blown SE, and they became far less optically dense towards the E where they extended over the vicinity of reef-fringed Mayotte Island. The image shows light-colored (nearly white) clouds above and centered SE of the visible brown clouds. Holliday interpreted this to represent a brown zone composed of dominantly ash with a higher lighter-colored zone of ash and ice particles. The tallest clouds reached FL 380 ('Flight Level 380,' a height of 38,000 feet or ~ 11.6 km altitude).

Fred Prata (CSIRO) processed both MODIS and AIRS images for the 25 November eruption (figures 4 and 5). Both instruments are part of NASA's Earth Observing System: MODIS stands for Moderate Resolution Imaging Spectro-Radiometer (flying onboard the Terra (EOS AM-1) satellite); AIRS stands for Atmospheric Infrared Sounder (which uses a grating spectrometer on the Aqua satellite).

Prata used the MODIS image to estimate the 25 November eruption's mass loading. This resulted in an estimate of fine ash amounting to 83 kilotons (kt) in the grain-size ranges indicated. Analysis of SO_2 from the MODIS data for 0710 on the 25th yielded 2.85 kt.

Prata also downloaded and processed the AIRS data available from 25 November but found only one good image (figure 2). Prata commented that the reason for the shortage of AIRS data stems from a compromise in instrument design, whereby when acquiring images at low latitudes, polar-orbiting satellites frequently lack sufficient overlap in their scanners to obtain full coverage. The one available satisfactory AIRS image, ~ 13 hours later than the MODIS image, showed a different plume configuration that included two separate zones of SO_2 concentration rather than one. The mass of the SO_2 measured by the AIRS instrument for the 25th was 2.0 kilotons. This value about the same as Prata obtained in a MODIS retrieval for the same 25 November eruption. In addition, the zones of elevated concentrations on both images stood in roughly the same place–except for the blob near 11°S detected by AIRS and not by MODIS.

Regarding his analysis of the 25 November Karthala eruption, Prata goes on to say that "assuming my fine ash loading of 83 kt is right and (big assumption now) this represents ~ 1% of the total erupted mass, then the volume of erupted ash would be ~ 0.006 km^3. This suggests a VEI ~ 2. If the 1% estimate is robust (I've seen this quoted in Bill Rose's work) then the fine ash estimates from remote sensing may be quite helpful [in] assessing the 'size' of an eruption. Coupled with cloud-height estimates we may be moving towards some nice tools for volcanologists."

Prata further commented that he had hoped to image an algal bloom in the ocean where the Karthala ash had fallen. Recent work on ocean chemistry and biology (Boyd and

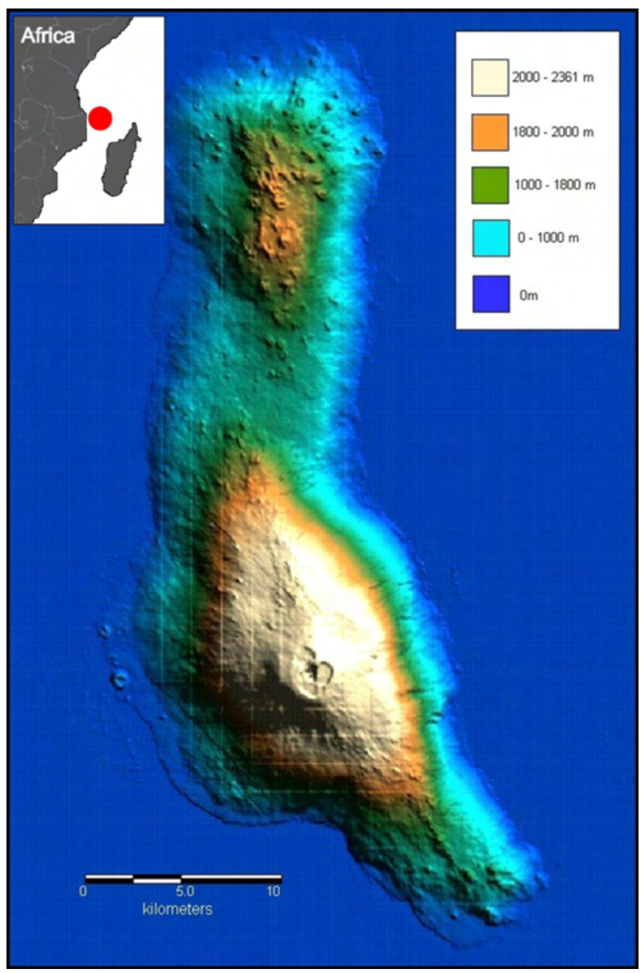

Figure 1. A shaded relief map portrays the island of Grand Comore, with Karthala's summit complex (the cratered, highest-elevation area) on the S. Courtesy of UNOSAT and their partner organizations.

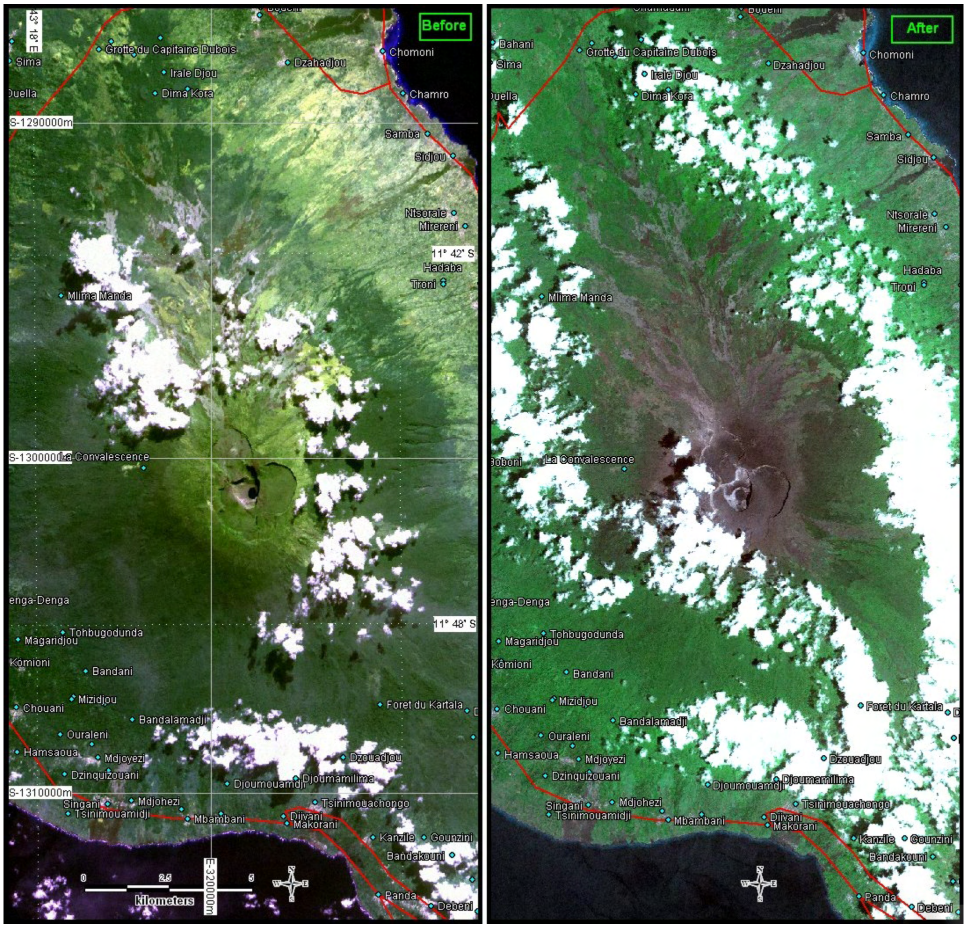

Figure 2. Karthala portrayed in two images (both with 10-m resolution; bands 321 + IR (RGBI)). Both images are at nearly, though not exactly, the same scales. The image at left is from before the eruption; taken by SPOT4 on 13 July 2004. The image at right is from after the eruption; taken by SPOT5 on 5 December 2005. Both images are partly masked by weather clouds. Large, clearly visible areas of new deposits appear in and around the summit crater area. Courtesy of UNOSAT and partner organizations.

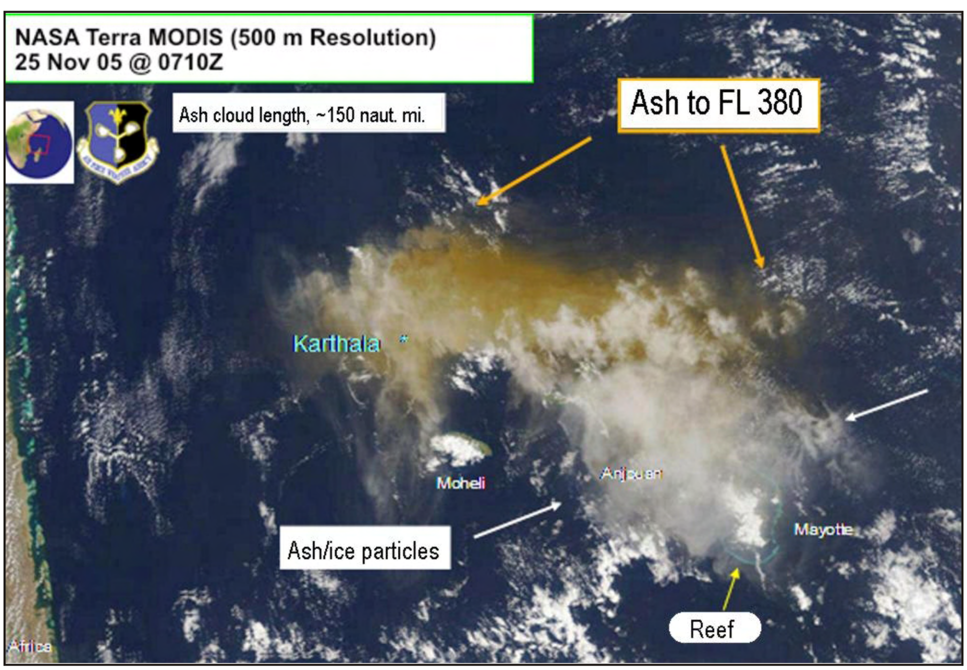

Figure 3. An image of the Karthala 25 November 2005 ash plume from NASA Terra MODIS. The image was centered over the Comoros islands, with the islands Mayotte, Anjouan, and Moheli labeled, and Grand Comore under ash clouds but the location of Karthala is indicated. For scale, the distance from Karthala to the S end of Mayotte island is ~240 km. The image shows AFWA interpretations of the ash cloud. Courtesy of Charles Holliday (AFWA).

others, 2000) point to iron enrichment as a means of ocean fertilization. As briefly discussed on the NASA Earth Observatory website, Anatahan plumes had recently been suggested to have triggered such blooms; however, with available remote-sensing data Prata was unable to confirm that the Karthala eruption triggered such a plume.

UN and related reports. The following appeared in a 28 November 2005 report of the United Nations Office for the Coordination of Humanitarian Affairs.

"The Karthala Volcano forms most of the landmass of Grande Comore (also called Ngazidja), the main island of the Union of the Comoros. The volcano is one of the largest volcanoes in activity in the world. Over the last two hundred years, it has erupted every eleven years on average. In April 2005, a volcanic eruption projected ashes and volcanic debris on the eastern part of the island, affecting as many as 40,000 people.

"[Karthala] had an eruption for the second time this year in the night of . . . 24 November, spilling ashes and smoke over the southeastern and southwestern parts of Grande Comore Island, and the Comoros capital, Moroni.

"During Friday 25, the projections of ashes and smoke receded. However, seismographic data collected by the Karthala Volcano Observatory has shown that the seismic activity is continuing. According to the observatory, a lava lake is in formation in the crater, as of yet confined within the crater. According to the local authorities, approximately 2,000 people fled from their villages in the region of Bambao in the central part of the island, and sought refuge in less exposed areas, such as Mitsamiouli, Mboudé, and Oichili."

"Concerns exist regarding the availability of potable water in the areas exposed to smoke and ashes. Preliminary results from the assessment indicate that as many as 118,000 persons living in 75 villages may be affected by the contamination of water tanks. A further assessment of the water tanks is underway to ascertain the

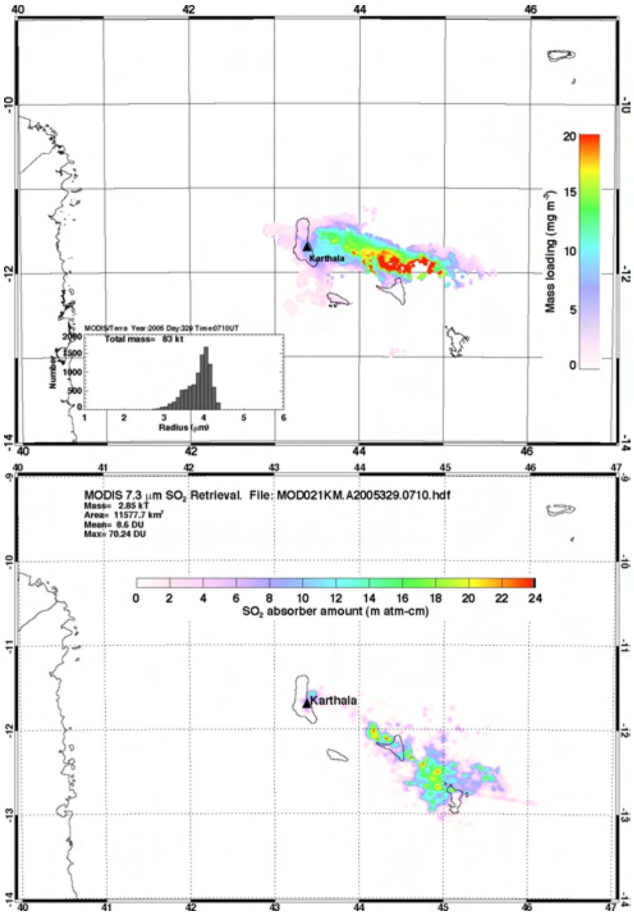

Figure 4. MODIS satellite images of the Karthala eruption plume on 25 November 2005 at 0710 UTC. The top image maps the computed atmospheric mass loading associated with the ash cloud; inset portrays the ash grain-size estimates in the same cloud. The bottom image maps the SO_2 burden in the cloud, contoured in Dobson Units; the total mass of SO_2 on this image was 2.85 kilotons. For distance scales, 1° of latitude (distance N-S) equates to ~111 km. Courtesy of Fred Prata, CSIRO.

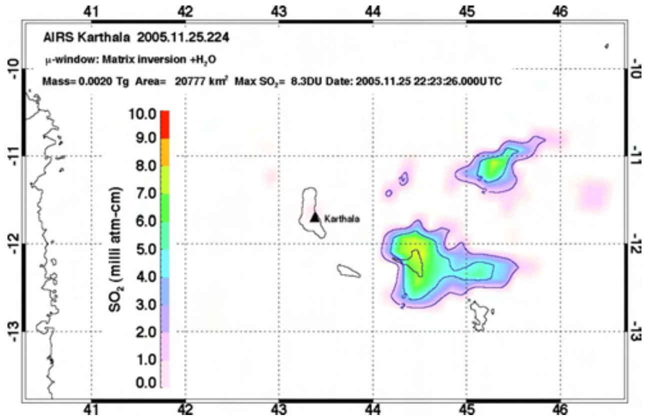

Figure 5. An AIRS image of the Karthala eruption's SO_2 content for 25 November at about 2223 UTC. The measured mass total for SO_2 was ~2.0 kilotons. Courtesy of Fred Prata, CSIRO.

exact scope of the needs. Concerns also exist regarding the impact of the pollution by volcanic debris on agriculture and livestock."

A 28 November news report by Agence France-Presse (AFP) also noted some of the above details, but added some new points. They said that the eruption had the effect of ". . .killing at least one infant, infiltrating homes, shops and offices and contaminating water in cisterns during the height of the dry season. 'We have two problems with water: one, we are in the dry season and two, the reserves in many private cisterns are now polluted,' minister of state for defense Abdu Madi Mari told AFP."

"He said cistern water supplies for about 120,000 residents mainly from rural villages near the volcano had been contaminated by the ash, which has also raised fears of respiratory ailments."

"Authorities on Grand Comore, the largest of the three semi-autonomous islands in the Comoros, had appealed for international assistance to help in distributing potable water to those in need, Mari said."

The AFP news report stated the eruption sent only "about 500 villagers fleeing from their homes in the shadow of the mountain." and said that despite continued tremor reported by the observatory, "almost all have now returned."

In a 9 December report the World Food Program estimated that the 24 November Karthala eruption affected 245,000 people. They briefly mentioned the issue of potentially contaminated drinking water but noted that, although minor eruptions continued, abundant rain in the weeks that followed helped reduce the potential water and air contamination problems. As noted above, no reports were found discussing problems from ash-choked drainages (lahars).

Background. The southernmost and largest of the two shield volcanoes forming Grand Comore Island (also known as Ngazidja Island), Karthala contains a 3 x 4 km summit caldera generated by repeated collapse. Elongated rift zones extend to the NNW and SE from the summit of the Hawaiian-style basaltic shield, which has an asymmetrical profile that is steeper to the south. The lower SE rift zone forms the Massif du Badjini, a peninsula at the SE tip of the island. Historical eruptions have modified the morphology of the compound, irregular summit caldera. More than twenty eruptions have been recorded since the 19th century from both summit and flank vents. Many lava flows have reached the sea on both sides of the island, including during many 19th-century eruptions from the summit caldera and vents on the northern and southern flanks. An 1860 lava flow from the summit caldera traveled ~ 13 km to the NW, reaching the western coast north of the capital city of Moroni.

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Piton de la Fournaise

Western Indian Ocean
21.229°S, 55.713°E; summit elev. 2,631 m
All times are local (= UTC +4 hours)

Increased seismicity and ground deformation from late June 2004 through 9 August preceded the third eruption of 2004, which started on 13 August (*BGVN* 29:12). During that eruption ~ 750 m of National Road 2 was overrun by lava. Eruptive activity ceased on the morning of 7 September 2004 (*BGVN* 29:12). Eruptions occurred again during February and October-December 2005.

Eruption during February 2005. A new period of heightened seismicity began on 17 February 2005 around 1300, consisting of about 100 seismic events within 90 minutes. After that, the number of events decreased, but recommenced at 1638 with several hundred events. Strong deformation was recorded at the same time by tiltmeters and the extensometer network. Eruption tremor began around 2035, becoming strong at 2050. The eruption site seemed to be situated close to Nez Coupé de Sainte Rose (on the N side of the volcano), and lava flows were observed in the Grand Brûlé area.

After a period of relative quiet on 19 February, eruption tremor increased to high levels again on 21 February. Two eruption sites were active: the principal vent at 1,600-m elevation above the Plaine des Osmondes, and a vent at about 1,200-m elevation in the Plaine des Osmondes. The principal vent released a volcanic plume and several pahoehoe lava flows, but no lava fountains were visible. The second vent also released a very fluid pahoehoe lava flow. The flows covered a large area within the Plaine des Osmondes, and smaller lava flows traveled to about 600-m elevation in the Grand Brûlé.

On 24 February, shallow seismicity began beneath Dolomieu crater. It increased over time and by 26 February, several hundreds of seismic events up to M 3 occurred. According to the Observatoire Volcanologique du Piton de la Fournaise (OVPDLF), these events may have indicated formation of a new pit crater within Dolomieu crater. On 24 February, visible signs of activity stopped within the Plaine des Osmondes, while eruption tremor slowly increased.

On the evening of 25 February, a lava flow from Plaine des Osmondes traveled down the Grandes Pentes, cutting the National Road on its way to the sea. The lava flow covered a distance of ~ 5 km in about 2 hours. At the same time, seismicity increased on the NE rift zone above Bois Blanc, and a new vent opened within the Trou de Sable on the N border of the caldera at 450-m elevation. This vents lava flow stopped about 100 m from the National Road.

Eruptions during October-December 2005. Another eruption started on 4 October 2005 at 1426 after 4 months of almost continuous inflation and increased seismicity. The eruption was immediately preceded by a 56-minute-long sequence of seismicity and strong summit inflation. A low-intensity eruption at Dolomieu crater produced pahoehoe lava flows that covered a small area of the western part of the crater.

Immediately after the end of the 4 October eruption at Dolomieu crater, the permanent GPS network and extensometer network continued to show strong surface deformation, which was a precursor for a new eruptive event. On 29 November 2005 at 0559 a seismic crisis began, and at 0625 tremor indicated the beginning of an eruption. A vent opened in the western part of Dolomieu crater and another vent opened on the N flank. Very little projected volcanic material was visible. A large, fast-moving lava flow traveled down the N flank in the direction of Piton Kapor. Inclement weather prohibited further observations. The Toulouse VAAC reported that ash from the eruption was not visible on satellite imagery.

Following the 29 November eruption, further summit inflation was recorded by the permanent GPS network. On 26 December at 1444 a seismic crisis started beneath Dolomieu crater. Within the next 2 hours seismic activity shifted to the NE, towards Nez Coupé de Sainte Rose. A first fissure opened at 1715 at the NE base of Piton de la Fournaise; at 2200 eruptive fissures opened in the caldera wall about 500 m E of Nez Coupé de Sainte Rose and lava flowed into the Plaine des Osmondes. By 28 December, eruptive activity was almost constant. An aa-type lava flow crossed the Grandes Brûlé and reached a point 3 km upslope from the national road.

Background. The massive Piton de la Fournaise basaltic shield volcano on the French island of Réunion in the western Indian Ocean is one of the world's most active volcanoes. Much of its >530,000 year history overlapped with eruptions of the deeply dissected Piton des Neiges shield volcano to the NW. Three calderas formed at about 250,000, 65,000, and less than 5000 years ago by progressive eastward slumping of the volcano. Numerous pyroclastic cones dot the floor of the calderas and their outer flanks. Most historical eruptions have originated from the summit and flanks of Dolomieu, a 400-m-high lava shield that has grown within the youngest caldera, which is 8 km wide and breached to below sea level on the eastern side. More than 150 eruptions, most of which have produced fluid basaltic lava flows, have occurred since the 17th century. Only six eruptions, in 1708, 1774, 1776, 1800, 1977, and 1986, have originated from fissures on the outer flanks of the caldera. The Piton de la Fournaise Volcano Observatory, operated by the Institut de Physique du Globe de Paris, monitors this very active volcano.

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Montagu Island

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

MODVOLC radiant heat-flux data and ASTER high-resolution satellite imagery revealed discharging lava flows that traveled N to the sea where they constructed a lava delta. The large effusive episode described in *BGVN* 30:09 had ceased, followed by a smaller episode in Novem-

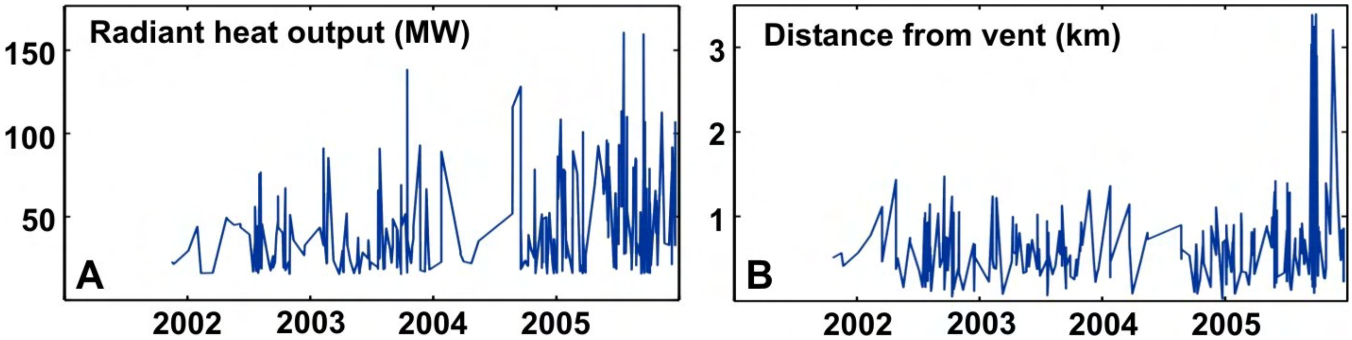

Figure 6. Plots of MODVOLC data at Belinda volcano on Montagu Island. Courtesy of Matt Patrick, HIGP.

ber. MODVOLC responses were most intense during 14 September to 4 October 2005. Figure 6a shows the radiant heat flux for the volcano since the start of the eruption in October 2001, providing rough idea eruptive intensity. Figure 6b indicates the distance of each alert pixel from the vent, giving insights into the timing of significant effusive episodes.

As figure 6b suggests, the September-October 2005 episode was likely the largest effusive episode of the eruption in that it involved the only sustained occurrence of alert pixels (i.e. active lava) more than 2 km from the vent. Following 4 October 2005, a single alert pixel appeared more than 3 km from the vent on 17 November 2005, but subsequent alert pixels were all near-vent. It is not yet clear if this 17 November anomaly represents the start of a substantial additional episode of lava effusion.

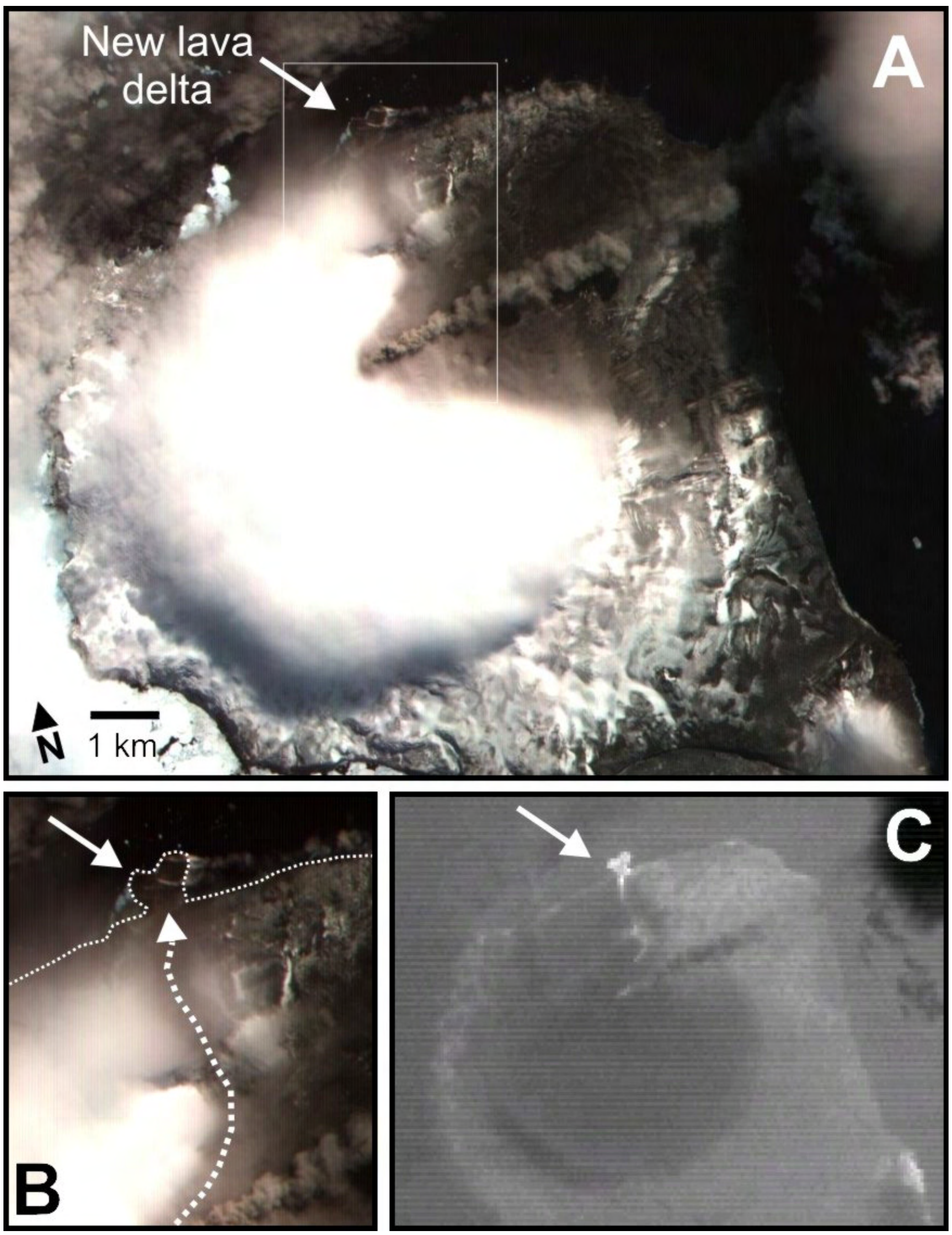

Figure 7. An ASTER image and enlargement on Montagu Island showing Belinda as it appeared in visible wavelength data on 3 November 2005 (a and b). An ASTER thermal-infrared image was obtained of the island on the same date (c). Courtesy of Matt Patrick, HIGP.

An ASTER image collected on 3 November 2005, shows the result from the September-October 2005 effusive episode (visible wavelength image shown in figure 7a). The shortwave infrared anomaly in this image (not shown) is minor compared to the 23 September 2005 image (*BGVN* 30:09), suggesting that any effusion had dropped to low levels by early November. The 3 November image indicates that a significant lava delta had formed on the N shore of the island during the September-October effusive phase (see arrow in figure 7a). The delta comprises two major lobes, and is approximately 400-500 m in width and length, equating to approximately 0.2 km^2. An enlarged view of the visible image is provided in figure 7b, where the approximate path of the September-October 2005 lava flow is shown by the dotted arrow. The current coastline is shown by the dotted line, with the lava delta (denoted by solid arrow) clearly jutting out. Note the faint steam wisps extending E from delta's eastern margin. The thermal infrared image (band 14, at 11-micron wavelength) of the island is shown in figure 7c, and clearly indicates the anomalously warm delta.

A Royal Air Force overflight on 11 October 2005, captured an oblique photograph of the delta (not shown). The lava flow appears to have steeply cut through thick ice approaching the shore, producing a broad and relatively flat delta that is vigorously steaming from the delta margins in the photograph.

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

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Aoba

Ambae Island, Vanuatu
167.83°E, 15.40°S; summit elev. 1,496 m

A new eruption began on 27 November 2005 when vapor plumes and ash columns were observed originating from Lake Voui, a crater lake at the summit of Aoba (figure 8). The volcano is also referred to locally as Manaro or Lombenben. Prior to this activity, the most recent reported volcanism consisted of phreatic explosions from the lake during March 1995 (*BGVN* 20:01, 20:02, and 20:08). Bathymetry conducted by ORSTOM in 1996 showed that the vent feeding gases and magma into Lake Voui had a depth of about 150 m and a diameter of about 50 m. The volume of water in the lake (1 x 2 km) totals some 40 million cubic meters, with a mean pH of 1.8. Lake Voui and the Manaro Ngoro summit explosion craters and cones formed ~ 420 years ago (figure 9). Lake Manaro was formed by the accumulation of water in a low-lying area of the Manaro summit caldera.

Starting on 3 December a team of volcanologists from the Vanuatu Department of Geology, Mines, and Water Resources (DGMWR), the French Institut de recherche pour le développement (IRD), the New Zealand Institute of Geological & Nuclear Sciences (GNS), and New Zealand's Massey University began collaborating on observations and monitoring. The amplitude of tremor recorded by DGMWR instruments from 30 November to 3 December was lower than during the March 1995 activity.

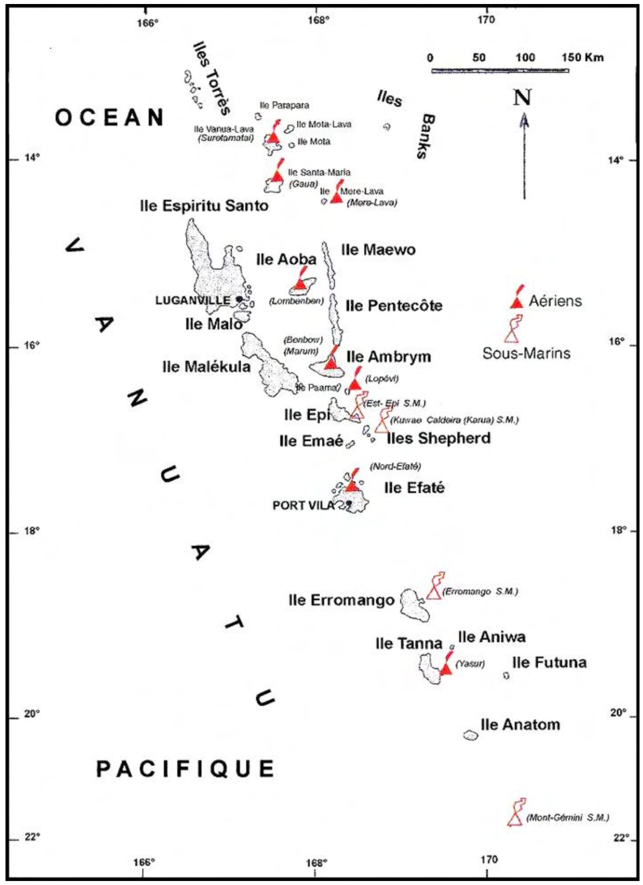

Figure 8. Map showing the location of volcanoes, including Aoba, in Vanuatu. Open triangles indicate submarine volcanoes. Modified from a map by IRD.

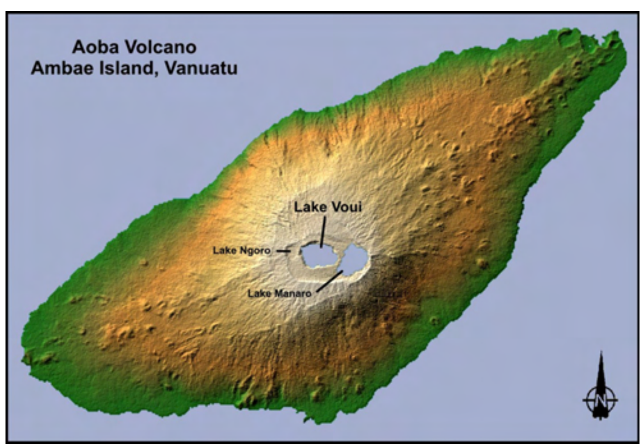

Figure 9. Digital image of Aoba created by combing shading and color coding of topographic height. The shading indicates direction of the slopes; NW slopes appear bright, while SE slopes appear dark. Color coding shows height, with green at the lower elevations, rising through yellow and tan, to white at the highest elevations. The flattened-looking summit shows that the newest crater is actually nested within older, larger craters. Elevation data used in this image were acquired by the Shuttle Radar Topography Mission (SRTM) aboard the Space Shuttle Endeavour, launched on 11 February 2000. Annotations added by Smithsonian editors. Courtesy of NASA.

Figure 10. Photograph showing a telephoto view of an explosive eruption from Lake Voui at Aoba, 4 December 2005. View is approximately towards the east from the crater rim. Courtesy of Philipson Bani, IRD.

Figure 11. Photograph showing an explosive eruption from Lake Voui at Aoba on 4 December 2005. View is approximately toward the E from the crater rim. A large steam plume can be seen rising above the darker zone containing pyroclastic material. Three small islands formed prior to this eruption can also be distinguished, with the active vent area closest to the western-most island. Courtesy of Philipson Bani, IRD.

Scientists who visited the lake on 4 and 5 December (figures 10 and 11) observed a similar style of eruptive activity on both days, but some individual explosions appeared larger on the 5th. It was not possible to reach the lake to collect a water sample. There appeared to be two active vents, side by side, in the lake. One was producing eruptions of mud, rocks, and water, and the other appeared to be the source of the large continuous steam plume rising above the crater; the plume did not contain ash. There were no reports of ash falling on the island since the start of the eruptions the previous week. The team estimated that the cone being built in the lake, at an estimated height of more than 20 m on the 4th, was about 70% complete around the

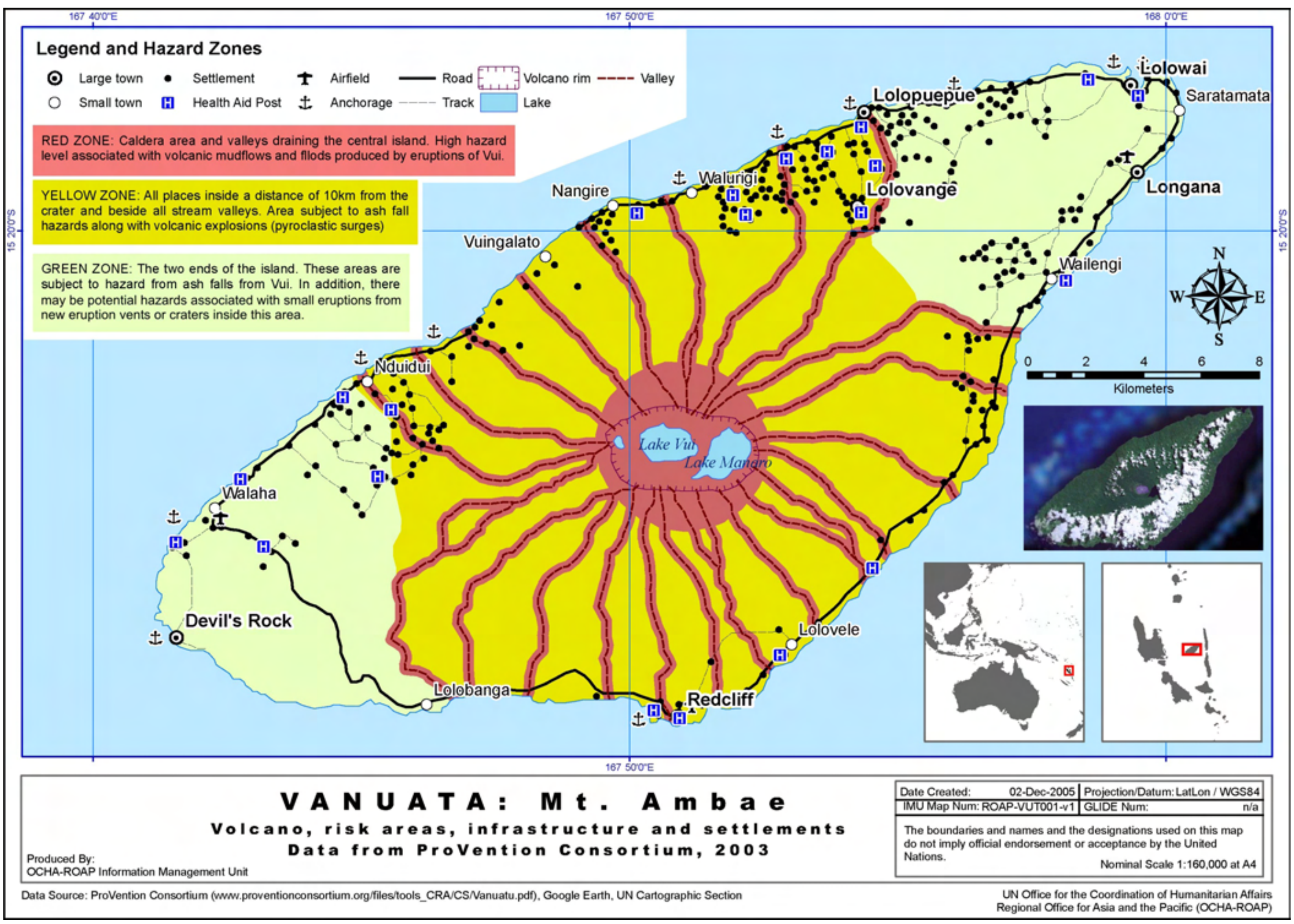

Figure 12. Hazard map of Aoba, showing risk areas, infrastructure, and settlements. See Cronin and others (2004) for additional details. Map produced by the United Nations, OCHA-ROAP Information Management Unit, 2 December 2005.

Figure 13. Aerial photograph showing a steam plume rising from Lake Voui at Aoba, 8 December 2005. Courtesy of Forces Armées en Nouvelle Calédonie (FANC).

active vents, and grew 5-10% higher between 4 and 5 December. Continuous tremor was recorded during this time, and the level of eruptive and seismic activity seemed to be fairly stable.

Cloud cover and rain prevented a visit to the lake on 6 and 7 December. Earthquake recorders from the GNS were installed at the Provincial Centre at Saratamata, the Longana Peoples Centre (Lovonda village), and at Tahamamavi ("place of warm sea") (figure 12). On 7 December, a final recorder from the IRD was installed near Nduidui on the SW side of the island. Over 6-7 December continuous moderate-level volcanic tremor was recorded, with no significant change in its level; there was no other significant seismic activity.

On 8 December, the group noted that small-scale eruptions continued in Lake Voui, building a volcanic cone in the lake and producing a tall (2.4-3.0 km) steam-and-gas plume. Afternoon observations showed the cone growing taller and surrounding three sides of the active vents. However, the cone was not complete on its E side, allowing lake water to react with the rising magma. Though the resulting explosions became further apart and slightly larger, the total energy involved appeared similar to 4-5 December. There continued to be two active vents, one producing the small explosions, and the second the steam and gas emissions. Seismic recorders continued to record volcanic tremor, but very few local earthquakes. No volcanic ash was present in the plume. The eruption had no immediate effect beyond Lake Voui. The Volcanic Alert Level remained at Level 2. The level of seismic activity seemed to be stable. No other significant seismic activity was recorded.

While departing by air on the evening of 8 December, the group clearly saw the active vents (figure 13). The cone had grown to the W, joining and partly burying one of the old islands. All eruptions occurred from inside the cone. The largest individual eruptions threw material 150-200 m above the lake. There was also a gas-and-steam vent present within the cone, W of the other vent. The level of the lake appeared unchanged.

On 10 December, the small-scale volcanic eruption continued from active vents within the summit crater lake (Lake Voui). Molten material entered the crater lake and reacted with the water to produce small explosive eruptions and a plume of steam and gas. The eruption built a cone around the active vents, enclosing them on three sides, forming an island about 200 m across and 50-60 m high. There were two vents, one erupting water, rocks and mud, and the other producing a tall column of steam and gas. The eruption had little effect outside the crater lake (minor ashfall occurred only in the first three days of the eruption). Five days of seismic recordings show a moderate level of seismic activity (mostly volcanic tremor).No change was noted in the level of Lake Voui, and there was also no evidence of ground uplift or fractures near the lake.

Sulfur dioxide measurements. SO_2 data collected using a DOAS spectrometer on the Islander planes of Unity Air Lines (3 December) and Air Vanuatu (5 December). On 3 December the flux was 32.6-33.6 kg/s (~ 2,900 metric tons/day). By 5 December the flux had decreased about 25%, to 24.7-26.4 kg/s (~ 2,300 metric tons/day). SO_2 was clearly detected by the OMI (ozone monitoring instrument) sensor on the NASA Aura satellite (figure 14). One measurement of the volcanic gas output on 10 December showed a moderate level of sulfur dioxide (SO_2) gas (about 2,000 t/d) from the active vents.

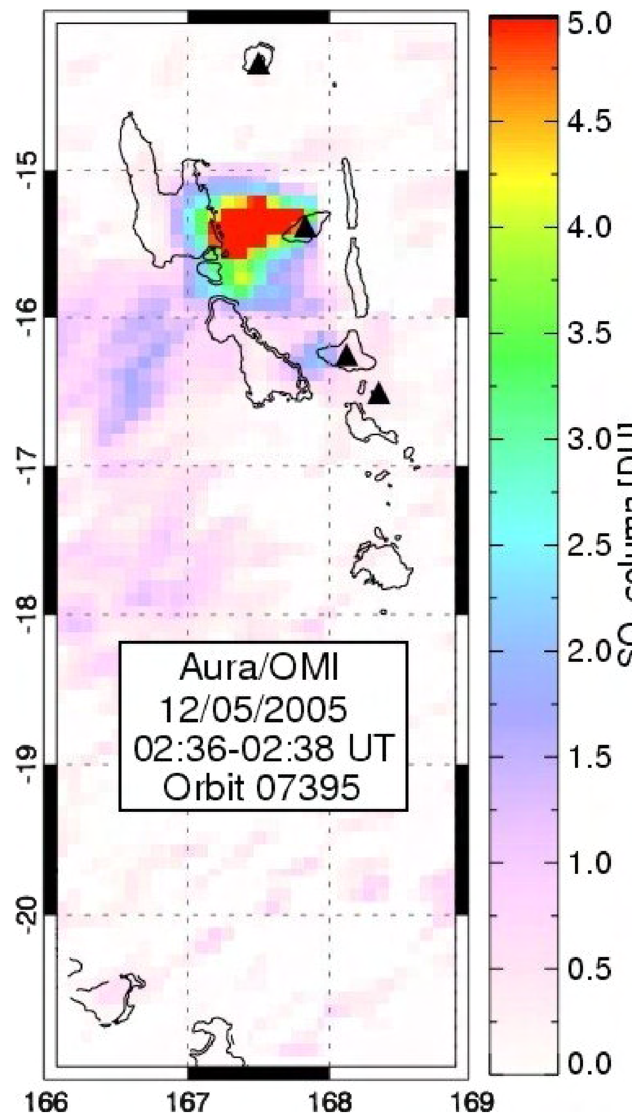

Figure 14. SO_2 data from the Ozone Monitoring Instrument (OMI) on the Aura satellite, 5 December 2005. Courtesy of NASA, the KNMI MOI Science Team, and Simon Carn, University of Maryland-Baltimore County.

Lake temperatures. A monitoring station for continuous measurements of water temperature at Lake Voui was installed in October 1998. The station used a satellite ARGOS transmission system and recorded the last heating episode of 2001 (figure 15), but failed after three years due to the harsh acid environment. ASTER thermal infrared images can also be used for monitoring lake surface temperatures, and Aoba has a freshwater lake (Manaro Lakua) which can be used to remove the seasonal/diurnal variations in atmospheric temperatures. Unfortunately, the top of the volcano is frequently covered by clouds and few ASTER images are exploitable. The most recent ASTER image clearly showing both lakes was collected on 9 July 2005. Difference in temperatures between lake Voui and Lakua was 4.0°C, slightly above background values during 2002-2003. Maximum background temperatures measured with ASTER during the September 2002-October 2005 were at 26.3°C. The last ASTER images before the eruption, on 5 October 2005, showed no unusual temperatures at Lake Voui.

MODIS satellites have a more frequent coverage than ASTER but their spatial resolution is only 1 km. The surface area of Lake Voui (2.1 km^2) is too small for an accurate measurement of lake temperature, but MODIS can detect rough temperature changes or an increased thermal anomaly. The MODIS pixel footprint is about 1 km along track and 2 km across track, so the measured temperatures are a mixed signal corresponding to the lake and some signal from the adjacent tropical forest (much colder than the lake at night at this elevation). MODIS SST imagery showed a strong thermal anomaly on 21 November 2005 (figure 15). Approximate lake temperatures, likely a minimum, were 30.4°C on 20 November and 29.5°C (Terra)/

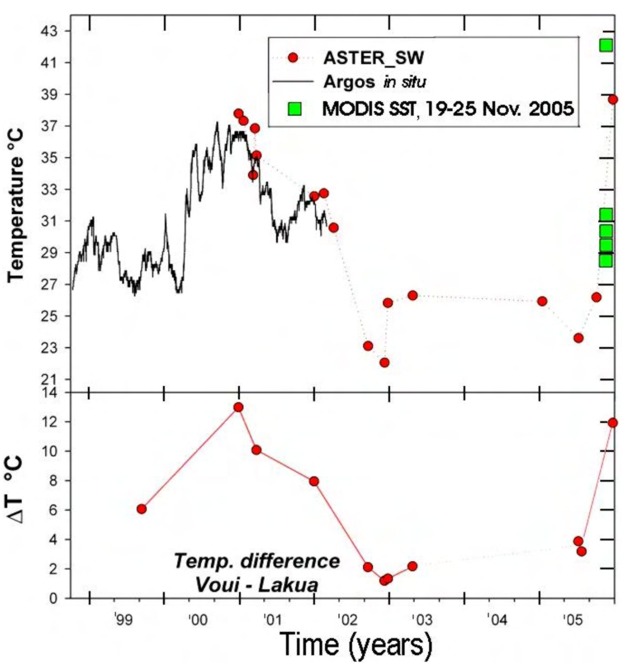

Figure 15. Temperature data from Lake Voui at Aoba, October 1998-December 2005, from in-situ measurements, ASTER satellite imagery, and MODIS satellite data. Delta T represents the thermal anomaly calculated as the temperature differences between the two lakes. The figure includes the first post-eruption ASTER data (24 December 2005). ARGOS data from Michel Halbwachs (Université de Savoie) and Michel Lardy (IRD). Courtesy of Alain Bernard.

31.4°C (Aqua) on 21 November. On 25 November the temperature jumped to about 42°C.

Background. Aoba is a massive 2,500 km^3 basaltic shield volcano. A pronounced NE-SW-trending rift zone dotted with scoria cones gives the 16 x 38 km island an elongated form. A broad pyroclastic cone containing three crater lakes is located at the summit of the Hawaiian-style shield volcano within the youngest of at least two nested calderas, the largest of which is 6 km in diameter. Post-caldera explosive eruptions formed the summit craters of Lake Voui (also spelled Vui) and Lake Manaro Ngoru about 360 years ago. A tuff cone was constructed within Lake Voui about 60 years later. The latest known flank eruption, about 300 years ago, destroyed the population of the Nduindui area near the western coast.

Reference: Cronin, S.J., Gaylord, D.R., Charley, D., Alloway, B.V., Wallez, S., and Esau, J.W., 2004, Participatory methods of incorporating scientific with traditional knowledge for volcanic hazard management on Ambae Island, Vanuatu: Bulletin of Volcanology, v. 66, p. 652-668. (URL: http://www.proventionconsortium.org/files/tools_CRA/CS/Vanuatu.pdf)

Information Contacts: *Esline Garaebiti*, *Douglas Charley*, *Morris Harrison*, and *Sandrine Wallez*, Department of Geology, Mines, and Water Resources (DGMWR), Port-Vila, Vanuatu (Email:esline@vanuatu.com.vu); *Michel Lardy*, *Philipson Bani*, *Jean-Lambert Join*, and *Claude Robin*, Institut de recherche pour le développement (IRD), BP A5, 98 848 Nouméa CEDEX, New Caledonia (URL: http://www.mpl.ird.fr/suds-en-ligne/fr/volcan/vanu_eng/aoba1.htm; Email: lardy@noumea.ird.nc, bani@noumea.ird.nc, join@noumea.ird.nc, crobin@cec.uchile.cl); *Brad Scott* and *Steve Sherburn*, Institute of Geological & Nuclear Sciences (GNS), Wairakei Research Center, Taupo, New Zealand (Email: b.scott@gns.cri.nz, s.sherburn@gns.cri.nz); *Shane Cronin*, Institute of Natural Resources, Massey University, Palmerston, New Zealand (Email: s.cronin@massey.ac.nz, k.nemeth@massey.ac.nz); *Alain Bernard*, IAVCEI Commission on Volcanic Lakes, Université Libre de Bruxelles, Brussels, Belgium (URL: http://www.ulb.ac.be/sciences/cvl/aoba/Ambae1.html); *NASA Earth Observatory* (URL: http://earthobservatory.nasa.gov/); *United Nations*, Office for the Coordination of Humanitarian Affairs (OCHA), Regional Office for Asia and the Pacific.

Garbuna Group

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

This report concerns Garbuna volcano's first historically witnessed eruption. That occurred in mid-October 2005 after a felt earthquake. This report contains a section by members of the Rabaul Volcano Observatory (RVO) and another by Rodger Wilson, a NOAA meteorologist , who made an unofficial visit in November.

Setting. Garbuna is part of the 23 x 15 km Krummel-Garbuna-Welcker complex (a volcanic field with these major topographic highs located in S-to-N progression; figure 16). The field resides at the S end of New Brit-

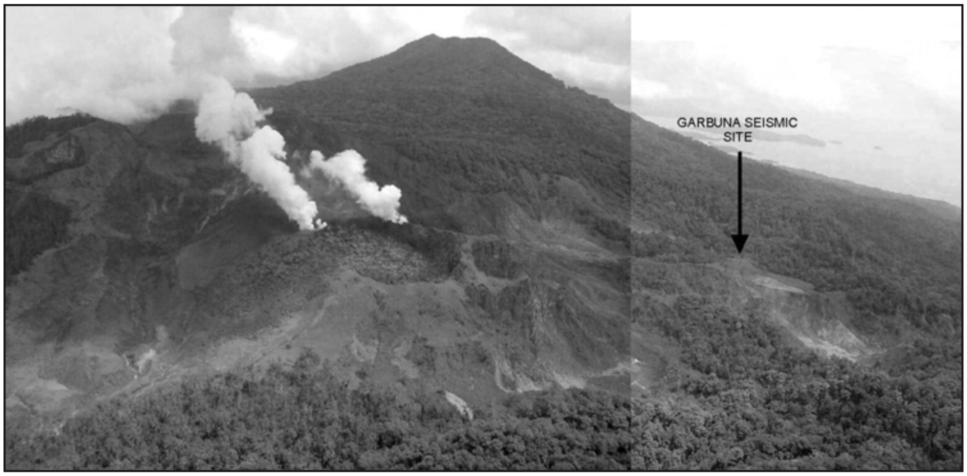

Figure 16. Photograph of Garbuna taken on 19 October 2005 from the SSE. View is northward along the Krummel-Garbuna-Welcker ridge, across the general area of Garbuna with Welcker on skyline; Krummel is behind the camera. The two fuming vents can be seen on the periphery of an old lava dome. The bare geothermal nature of the area is apparent. The incised cone to the left is what locals refer to as Mount Garbuna. Photo by Steve Saunders provided courtesy of RVO.

ain island's Willaumez (Talasea) peninsula, a narrow projection jutting well N from the island's W-central region. The peninsula and some local reefs and islands are known for volcanoes and hydrothermal features (including, from N to S, Dakatua caldera and its large lake, Bola stratovolcano, Garua Harbour volcanic field, and the Garbuna complex). In addition to young volcanics found at the complex's three summit (ridge) centers and their associated domes and craters, there have been prior flank and eccentric eruptions, most notably Numundo Maar. The complex's products are mostly high-SiO_2 andesites to high-SiO_2 dacites with more mafic eruptives from Krummel and Numundo Maar. (McKee and others, 2005). Only 5-6 km to the E and W of the volcanic field are some inhabited and intensively cultivated strips along the coast.

Garbuna and Welcker volcanoes were thought to have had a latest significant/datable eruption at ~ 1,800 BP. Garbuna in particular was very geothermally active, with the central area containing 4 km^2 of fumaroles, solfataras, hot and bubbling mud and water springs, and patches of hot ground. Conspicuous from the barren, sulfurous and geothermally altered, clay-rich areas was a timber-covered but undated lava dome (or alternately, a short, thick lava flow to the S, a feature sometimes described as a coulée). This dome shows little geothermal alteration, appears very youthful, and is not obviously mantled by the regional tephras from Witori or Dakataua, all features suggesting a comparatively young age. The low cone hosting the dome stands ~ 500-600 m in diameter.

Events surrounding the eruption. The RVO team reported this section and noted that the complex was not instrumentally monitored. A single, locally felt earthquake occurred around midday on 16 October 2005. Jet-like noises were noticed about 2342 that night, rumbling noises started soon after, and at about midnight ash emissions began. The eruption continued and by morning pale to dark gray ash clouds were being driven forcefully into the sky. By 1000 a 3-4-km-high eruption column was visible; the main plume drifted NW with a thin veil of falling material below it. The eruption began to wane between midnight and the morning of 18 October, reducing to slow pale-gray emissions, with only white vapor by the end of the day. A second vent opened quietly during the night of the 18-19 October, with two white vapor plumes visible at dawn on the 19th.

Aerial inspections on 19, 20, and 26 October showed the two vents situated in the central low area of Garbuna, historically an area of high geothermal activity. Both vents are located on or close to the edge of the youthful lava dome mentioned above. The center of the dome is at 05° 26' 48" S, 150° 01' 36" E, with the active vents aligned SW-NE at across a NW sector of the old cone. Both active vents are 60-75 m in diameter and emitted low to moderate amounts of white fume, the southerly plume being more voluminous. On the first two visits fume billowed out gently.

The SW vent seems to have been the source of the initial October emissions. Before the 19th a small incomplete cone had formed around it. Within a kilometer of this vent several ten's of centimeters of ash/mud had been deposited, which thinned very rapidly away from the vent. Old records did not indicate the existence of the SW vent or other conspicuous feature prior to the onset of this eruption.

The second, or NE, vent became active on the night of 18-19 October. Photographs from 1996 showed that prior to the eruption this vent was a small, wooded, funnel-shaped pit, with some evidence of instability on its western side and visible un-vegetated scars.

Although ashfall was reported to the NW, images of the eruption at first light on the 17th showed the fallout to resemble rain rather than dry ash. Vegetation damaged by the fallout had brown blotches rather than uniform discoloration, leading to the conclusion that the initial column was made up primarily of acidic water and mud.

It appears that the NE vent is predominantly a collapse feature, surrounded by a small apron of brownish-gray mud, with a jagged edge and bright red/yellow walls. Following a locally felt earthquake, summit observations on the 20th showed that the NE vent had increased ~ 10-20 m by concentric collapse since the previous day and was 50-60 m deeper. At this time it contained a boiling mud lake ~ 60-70 m below the rim.

Observations on the 26th showed the ash cone around the SW vent had all but disappeared as it had increased in size by collapse. The resulting pit was irregular in shape. Quite vigorous steam emissions occurred and some ash was visibly mixed with the fume and dropping out as fine droplets of dilute mud. Impact craters from projectiles were evident around the vent, especially to the SW. Near the vent these small projectiles were visible and block-like. Up to 500-600 m to the SW small impact craters could still be seen but the projectiles themselves were not apparent.

Close study of the old dome, on whose periphery the vents have opened, suggests that it has undergone little or no movement during the onset of this eruption. Foliage-stripped trees are mainly up-right, and no fresh cracks or heaved boulders are evident. Thermal imagery also showed no hot cracks in the dome, suggesting that the eruption was not preceded by intense surface deformation, and that the vents are now enlarging by concentric collapse.

A large area of grass N of the vents gave the impression of having been flattened in a uniform direction. Trees and shrubs, although stripped of leaves, did not show this flattening. This may suggest that floods of water were responsible for the flattened grass, rather than blast effects. To the S, flooding is also suggested by the apparently recent incising of the valley floor (headwaters of the Garu-Haella sulfur stream). The edge of the jungle also shows undercutting with trees having fallen toward the vents.

Since the start of the eruption changes in the amount of discharge, along with unusual discoloration and dying fish were seen in the streams draining from Garbuna. On 26 October, aerial observers followed one of the Garu thermal streams from the Plantation-Garu village road on its ascent to the summit. At higher elevations the stream's water level dropped markedly, until within a few kilometers of the summit, it dried out completely. The stream was not blocked or dammed, and the falling levels of streams and drying of springs appeared to be related to the drying of the summit, or fracturing, allowing water to percolate into the mountain rather than flow off the geothermally produced clay-rich area. At first light on the morning of 29 October, the watercourse commonly known as the Walindi river was milky white with a blue tinge. It was odorless, of normal temperature, and tasted simply of clayey water with no bitterness. This is the first recorded case of one of the eastern drainage systems exhibiting this behavior, although it is common in the W and SW regions.

A few locally felt earthquakes and sulfur odors were reported from areas not traditionally affected by the complex's sulfatara emissions. On several occasions explosions or booming noises from the Garbuna area were heard at Garu Plantation.

Two seismic stations were installed on 18 October. A 3-component digital recorder was located at Garu Plantation ~ 5.5 km SW of the active vents. An analog recorder was installed at Sisi near Walindi, ~ 5.6 km E of the vents. Notable seismicity was recorded on 20, 21, and 22 October. On the 20th a $M_L \sim 2.5$ local volcano-tectonic earthquake was felt, which was followed by a dozen smaller VT earthquakes between 1300 and 1500. Starting about 0500 on 21 October many very small ($M_L < 0.5$) VT earthquakes began to occur. These events continued throughout 21 October and ceased about 1600 on 22 October. Random VT earthquakes numbering 1-4 per day were recorded on 23, 25, and 28 October. Other volcano-related earthquakes recorded included some small low-frequency earthquakes on 22 October by the Sisi station. Continuous tremor was recorded immediately when a new telemetered seismometer was installed about 0.9 km NE of the active vents. At the end of the month the tremors were continuing.

The West New Britain Provincial Disaster Committee has ensured a smooth civic response to this unforeseen event with public education and preparations for a possible evacuation being well advanced.

Observations during mid-November 2005. Rodger Wilson submitted the following report of his visit to Garbuna with John Seach.

"We climbed Garbuna the first time on 14 November. We smelled H_2S(?) from at least three locations at lower elevations along the trek. Wind at the time was to the NE, so I don't believe we were sensing the summit gas plume. Also, there was an area that I jokingly referred to as, 'The Valley of Death,' where we all (four) felt nauseated (on both climbs at the same location, both coming and going), but did not detect any odor of gas. On the second climb, we found an immature parrot on the ground at the (SE?) edge of this area (we removed him from that area, and he seemed fine afterward). Again, we were unable to get a GPS fix there, but it occurs along a (NW to SE-running?) depression just prior to a steeper climb to the summit.

"Just before reaching the clearing at the summit, along a more N-S-running depression, we encountered an area where the trees appeared to have been 'sprayed' horizontally as evidenced by ash being 'plastered' to their N (crater) sides. Bark on many of the larger trees appeared to be at least lightly abraded, but not removed. Numerous smaller trees of approximately 6 cm or less in diameter had been neatly 'clipped' or sharply bent over at just less than 2 m height. There was no evidence of high temperature in connection with the physical damage. Our visit was restricted to along the S edge of the summit, bounded by the hydrothermal area on the W and the two old phreatic craters to the E. This area of damaged trees was, as far as we could see, the only significant damage to the surrounding forest (by a base surge or a cold density current?) in contrast to the more complete devastation suffered by the fewer trees and lower vegetation at the summit. Interestingly, the trees still standing at the summit, appeared to be stripped solely by vertically falling, not horizontally moving, debris.

"We exited the forest at the summit at about 1100, along a N-S bare ridge (old crater rim?), that is clearly visible in aerial photos of the area. Copious fume emanated soundlessly from the two new craters. White fume exited the western crater, with yellow-tinged fume rising from the eastern one. There was a fairly strong smell of H_2S, but not the eye-stinging or choking sensation I've felt with SO_2 at Etna and Stromboli. As we rested there, we noted the water in our bottles was in constant motion and once we made our way to the thermal area, we clearly felt frequent (several per minute) small shocks while we took temperatures at several spots there. The highest temperatures were all at 100°C. During the first couple of hours at the summit, we had two brief bands of rain showers pass overhead, but by about 1330 the rain became sustained and heavy. Run-off in most of the surrounding gullies had increased to several inches deep. We . . . were picking our way back toward the forest when, just as we left the southern edge of the thermal area, we heard a loud roar and witnessed a lahar issue from the gully draining the crater . . ..

"Changes we noted during the second visit 3 days later were [as follows]: a low rumble or rushing noise associated with the summit vents which was heard through most of the journey to the summit, although [they observed] a complete lack of detectable seismicity while at the summit. The interval between "huffs" of fume was shorter, on the order of maybe 4-5 minutes rather than the 8-10 minutes observed during the first visit. Fume leaving the western vent remained white, while ash was clearly visible as it fell over the E flank of the volcano from the eastern plume. That plume also had a more yellow cast as it issued from its source, compared with a few days before.

"We heard low booming rumbles from near Walindi at around 0530 on 17 November and loud roaring the next morning at about 0700 from the same location. The latter was preceded (by as much as 10 minutes) by dogs at our location being agitated and barking, simultaneously with others in the distance.

Background. The basaltic-to-dacitic Garbuna volcano group consists of three volcanic peaks, Krummel, Garbuna, and Welcker. They are located along a 7-km N-S line above a shield-like foundation at the southern end of the Willaumez Peninsula. The central and lower peaks of the centrally located 564-m-high Garbuna volcano contain a large vegetation-free area that is probably the most extensive thermal field in Papua New Guinea. A prominent lava dome and blocky lava flow in the center of thermal area have resisted destruction by thermal activity, and may be of Holocene age. The 854-m-high Krummel volcano at the S end of the group contains a summit crater, breached to the NW. The highest peak of the Garbuna group is 1,005-m-high Welcker volcano, which has fed blocky lava flows that extend to the eastern coast of the peninsula.

Reference: McKee, C.O., Patia, H., Kuduon, J., and Torrence, R., 2005, Volcanic Hazard Assessment of the Krummel-Garbuna-Welcker Volcanic Complex, Southern Willaumez Peninsula, WNB, Papua New Guinea: Geological Survey of Papua New Guinea–Report 2005/4.

Information Contacts: *Steve Saunders*, *Ima Itikarai*, and *Herman Patia*, Rabaul Volcano Observatory (RVO), P. O. Box 386, Rabaul, Papua New Guinea; *Rodger Wilson*, Meteorological Technician, US National Oceanic and Atmospheric Administration (NOAA) and National Weather Service (NWS), WSO, P.O. Box 1685, Valdez, AK 99686, USA (Email: rodger.wilson@noaa.gov).

Langila

Papua New Guinea
5.525°S, 148.42°E; summit elev. 1,330 m
All times are local (= UTC + 10 hours)

Rabaul Volcano Observatory (RVO) reported that during 22-28 August 2005, modest eruptive activity was observed at Langila's Crater 2. Occasional forceful emissions of ash produced plumes that rose ~ 1 km above the crater on 22 and 25 August, but reached only several hundred meters after that. The ash plumes drifted N and NW, resulting in fine ashfall in downwind areas, including the town of Kilenge. Seismicity was at low levels, consisting mainly of low-frequency earthquakes. The Darwin Volcanic Ash Advisory Centre (VAAC) reported that a plume was visible on satellite imagery on 30 August extending NNW.

During 12-18 September, Crater 2 continued to forcefully erupt ash at irregular intervals. The resultant ash plumes drifted NW and W. Incandescence and weak projections of volcanic material were visible on the evening of 13 September. There was no activity at Crater 3. Seismicity was at low levels at the volcano, consisting mainly of low-frequency earthquakes.

During 20-23 October, low-level plumes from Langila were occasionally visible on satellite imagery. On 29 October, a plume from Langila was visible on satellite imagery at an altitude of ~ 2.7 km.

During 11-12 November, low-level ash plumes emitted from Langila were visible. The heights of the plumes were not reported.

Background. Langila, one of the most active volcanoes of New Britain, consists of a group of four small overlapping composite basaltic-andesitic cones on the lower eastern flank of the extinct Talawe volcano. Talawe is the highest volcano in the Cape Gloucester area of NW New Britain. A rectangular, 2.5-km-long crater is breached widely to the SE; Langila volcano was constructed NE of the breached crater of Talawe. An extensive lava field reaches the coast on the north and NE sides of Langila. Frequent mild-to-moderate explosive eruptions, sometimes accompanied by lava flows, have been recorded since the 19th century from three active craters at the summit of Langila. The youngest and smallest crater (Crater 3) was formed in 1960 and has a diameter of 150 m.

Information Contacts: *Darwin Volcanic Ash Advisory Centre* (VAAC), Bureau of Meteorology, Northern Territory Regional Office, PO Box 40050, Casuarina, NT 0811, Australia (URL: http://www.bom.gov.au/info/vaac); *Rabaul Volcano Observatory* (RVO), P.O. Box 386, Rabaul, Papua New Guinea; *International Federation of Red Cross And Red Crescent Societies (IFRC)* (URL: http://www.reliefweb.int/).

Fukutoku-Okanoba

Volcano Islands, Japan
24.28°N, 141.485°E; summit elev. -14 m
All times are local (= UTC + 9 hours)

Notice of Fukutoku-Okanoba unrest in 2005 first came to *Bulletin* editors from Olivier Hyvernaud, information that was amplified by the Japanese Meteorological Agency (JMA) Volcanic Activity Reports of July and October 2005. The JMA reports contain information from the Japanese Marine Defense Forces as well as the Marine Security and Safety Agency and the Tokyo Institute of Technology. In addition, a Japan Coast Guard website (see URL below) contains a more extensive (and yet untranslated) table on recent events at Fukutoku-Okanoba, which includes photos and videos of the July eruption. That table clearly illustrates activity both earlier and later than the 2-3 July eruption, and several other details not discussed here, including the observation of numerous large and steaming blocks floating on the ocean surface at mid-day on 3 July. *Bulletin* editors hope to decipher this table and include more details in a later report.

The last five *Bulletin* reports discussing or mentioning Fukutoku-Okanoba appeared in *BGVN* 22:01, 24:11, 24:12, 25:05, and 28:06 (1997-2003). Note that the last four cases were considered ambiguous and grouped along with reports under the heading "Acoustic signals in 1999-2000 from unknown source, Volcano Islands, Japan" and only the first case was listed under the volcano name). A 3-d view of the volcano and its setting appears as figure 17.

JMA reported that at about 1745 on 2 July 2005, a white plume was witnessed at Fukutoku-Okanoba. During an investigation at 1900 that same day, a white plume reached ~ 1 km above the sea surface. A photo taken from considerable distance was included in the JMA report, showing the plume, but the image's limited contrast has led to its exclusion here. In addition to the plume, other evidence for an

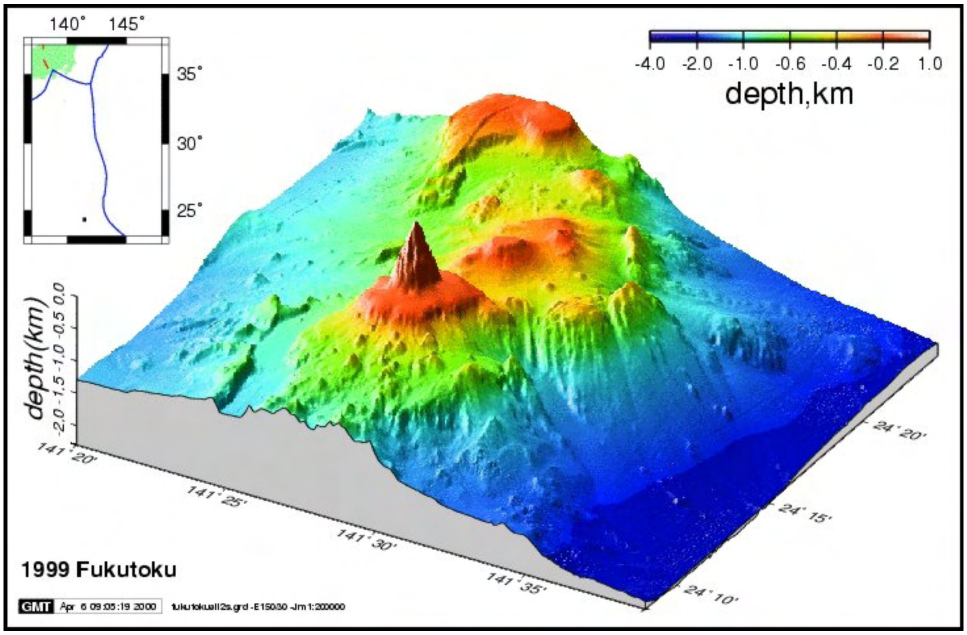

Figure 17. Fukutoku-Okanoba and vicinity shown in a 3-dimensional diagram, with shading (or color) representing various elevation ranges (see key above); vertical exaggeration is considerable but was not stated. The inset contains an index map showing the Volcano islands along the Bonin trench. The diagram represents data from 1999 and views the region from the SE. Fukutoku-Okanoba is a submarine vent ~ 5 km N of the island (Minami-Iwo-jima). Copyrighted image courtesy of the Japan Coast Guard.

eruption included debris on the sea surface. When seen on 2 July, the debris covered an area approximately 100 m wide and 300 m long.

JMA noted that 3 July aerial observations suggested that compared to the previous day, eruptive vigor and the height of the white plume had decreased. The key observation then was a zone of discolored seawater (figure 18).

JMA's report of 4 and 5 July aerial investigations noted the lack of a white vapor plume over the sea. In other words, the 2-3 July eruption had calmed, but fresh debris and seawater discoloration were still present. After that, aerial investigations on 15, 17, 20, and 21 July, again disclosed seawater discoloration, but not the presence of floating debris.

The Maritime Security and Safety Agency conducted an underwater topographical survey on 20-22 July 2005, the result of which was the discovery of two craters caused by the recent eruption. The results suggested that the topography just S of those craters was newly raised.

According to a 3 October aerial observer, the ocean surface near Fukutoku-Okanoba, then displayed a pale, blue-white discoloration, interpreted as indicative of volcanism. The area of discoloration extended ~ 300 m in length to the E and was ~ 50 m wide (N-S) at its widest point. However, in the surrounding area they saw no floating debris or plumes containing ash or steam. On 27 October, an aerial observation could not confirm the seawater discoloration.

Satellite data. M. Urai (2005) reported that three days after the 2 July 2005 eruption of Fukutoku-Okanoba, satellite remote sensing using ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) observed the discolored seawater and floating materials within 40 km of the submarine volcano. Some of this abstract follows.

"At the most dense discolored seawater area, reflectance of ASTER band 1 is 3% higher [than] the surrounding seawater. The floating materials are similar in ASTER VNIR [Very Near-Infrared Radiometer] reflectance spectra to clouds, however, the floating materials can be separated from clouds using their shape and stereo image features. The extensions of discolored seawater area and floating material detected by ASTER were 6.34 km^2 and 1.14 km^2, respectively. It is possible to estimate the scale of [a] submarine eruption using the quantitative data derived from satellite remote sensing."

Distant hydrophones. Robert Dziak and Haru Matsumoto monitor N Pacific volcano seismicity with the National Oceanic and Atmospheric Agency/Pacific Marine Environmental Laboratory (NOAA/PMEL). They initially learned of the eruption via the internet. Regarding the 2 July eruption, Dziak wrote to the *Bulletin* staff on 22 November 2005. Some of his messages follow.

". . . the [N] Pacific hydrophone array we use recorded seismicity during the Fukutoku-Okanoba eruption near Iwo Jima. I was aware of the eruption at the time [mid 2005] thanks to Haru [Matsumoto—he designed and built the instruments used there to record the T-wave events] forwarding a news image of the discolored water. Despite being only able to roughly locate the seismicity since it is way west of our array, I am pretty sure Fukutoku-Okanoba was the source because the arrival azimuths and timing of the signals were a match. The last earthquake activity we recorded from this area occurred on 25 September [2005] . . .. A few years ago I was contacting you [Smithsonian Institution] about our recording of harmonic tremor from a source

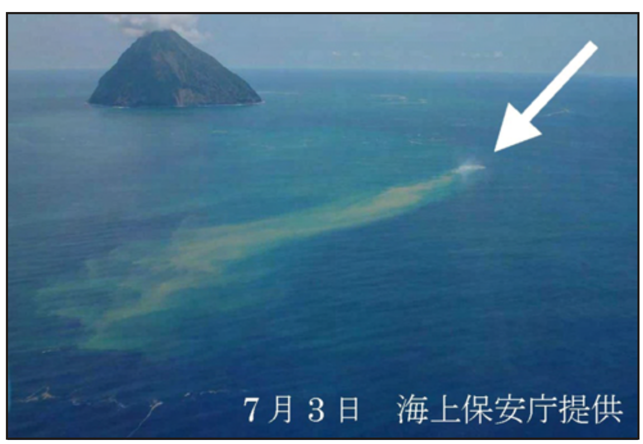

Figure 18. An aerial view of Fukutoku-Okanoba taken on 3 July 2005 as seen from the NE. Debris and discoloration extend from the arrow. Courtesy of the Maritime Security and Safety Agency.

in the Volcano Islands. The conclusion I published in JGR [Dziak and Fox, 2002] was that either Fukutoku-Okanoba or Funka-asane ([N] of Iwo Jima) was the probable source because of a history of submarine volcanic activity at both volcanoes. We have still been recording this tremor intermittently over the last few years and another pulse of it occurred during the Fukutoku-Okanoba eruption on July 2, 2005. The last occurrence was on August 22.

According to an Email from Dziak on 23 November 2005, "...I think the tremor is coming from [Fukutoku-Okanoba or Funka-asane]. I was only able to get synchronous data from the French Polynesian seismic net (Hyvernaud). They confirmed the signals but it did not help much with location because they were so far away. My thought is the source of earthquakes and tremor from these submarine volcanoes is at an ocean depth within the sound channel. This allows for very efficient seismic-acoustic coupling and acoustic propagation throughout the Pacific ocean basin."

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Background. Fukutoku-Okanoba is a submarine volcano located 5 km NE of the pyramidal island of Minami-Iwo-jima. Water discoloration is frequently observed from the volcano, and several ephemeral islands have formed in the 20th century. The first of these formed Shin-Iwo-jima ("New Sulfur Island") in 1904, and the most recent island was formed in 1986. Fukutoku-Okanoba is part of an elongated edifice with two major topographic highs trending NNW-SSE and is a trachyandesitic volcano geochemically similar to Iwo-jima.

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Karymsky

Kamchatka, Russia
54.05°N, 159.43°E; summit elev. 1,536 m
All times are local (= UTC +12 hours)

From December 2004 to June 2005 frequent explosions and plumes were detected at Karymsky (*BGVN* 30:06). In June 2005, the alert level was briefly lowered from Orange to Yellow because of a decrease in seismic and volcanic activity, but it was raised to Orange again on 23 June because of ash and gas plumes which rose to 3 km above the crater.

Karymsky remained at Concern Color Code Orange and seismicity remained above background levels throughout August-December 2005.

Throughout July 2005 ash-and-gas plumes frequently may have risen to 1-3 km above the crater. During 8-15 July, 450-600 shallow earthquakes occurred daily. On 11 July, an ash-and-gas plume extended about 11 km SE. During 15-22 July, 350-700 shallow earthquakes occurred daily. On 22 July, a weak thermal anomaly and a short E-drifting ash-and-gas plume were visible on satellite imagery.

Seismic activity during August indicated frequent possible ash-and-gas plumes up to 4 km altitude. A MODIS satellite thermal anomaly was registered on 2 August. On 22 August, three ash plumes reached heights around 3-4 km altitude and extended ~ 130 km E. An ash plume was visible at an altitude of ~ 5.8 km on 27 August.

Small ash and gas plumes continued to be emitted in September. A thermal anomaly was visible at the volcano on satellite imagery on 15 September.

Visual observations on 17 October revealed that the lava dome in the volcano's crater had been partially destroyed. Based on seismic data, three ash-and-gas plumes may have risen to 2.5-4 km altitude during 14-16 October. Five ash-and-gas plumes may have reached heights of 2.5-3.5 km altitude on several days during the last week of October 2005. A thermal anomaly at the volcano was visible on satellite imagery.

The lava dome inside the volcano's crater continued to grow during November 2005. Based on seismic data, three gas plumes containing some ash possibly rose 3-3.8 km altitude during 29-31 October and 1 November. Ash plumes were visible on satellite imagery extending NE on 31 October and 2 November. During 4-11 November five gas-and-steam plumes with some ash may have reached heights of 3-3.5 km altitude.

No seismic data were available after 10 November. A thermal anomaly was visible at the volcano on 15 and 17 November. According to seismic data, many weak shallow earthquakes and possible gas-steam plumes with some amount of ash up to 2.5 km altitude were registered on 20-23 November. A thermal anomaly was noted over the volcano during the last week of November and the first week of December. According to satellite data from Russia and USA, ash clouds moving to the SE from the volcano were noted on 6-7 December.

After 3 December the availability of seismic data became very erratic. A thermal anomaly was registered on 9-11 December and 14-15 December. According to satellite data, ash plumes and clouds were noted on 9 and on 10 December, moving SW and SE, and SE and E, respectively.

During the third week of December, many weak shallow earthquakes and possibly ten ash plumes up to 3.6 km altitude were registered. According to Kamchatka Volcanic Eruptions Response Team (KVERT) volcanologists who work near Karymsky, ash explosions rose up to 2.5-3 km altitude on 17-21 December 2005, and extended WSW and ENE. A thermal anomaly was registered over the volcano on 15-21 December. Seismicity indicated that ash explosions from the summit crater continued.

Many weak shallow earthquakes were registered during the last week of December. Ash plumes rose up to 2.5-4 km altitude on 24 December and 26-27 December and extended mainly E and SE from the volcano, and occasionally SW. According to KVERT volcanologists, a new cone approximately 60-80 m in diameter was formed at the summit of Karymsky volcano. A small lava dome 20-30 m in diameter was seen in the cone's crater. According to satellite data from the USA and Russia, a thermal anomaly was registered over the volcano all week.

Background. 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 2,000 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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Bezymianny

Kamchatka, Russia
55.978°N, 160.587°E; summit elev. 2,882 m
All times are local (= UTC + 12 hours)

This report mentions a series of noteworthy events during mid-January through late December 2005. On 11 January 2005 an explosive eruption was inferred from seismic data; it was thought to have produced an ash column to 8-10 km altitude (*BGVN* 30:03). Seismic activity returned to background levels following this eruption and the Concern Color Code was lowered from Orange to Yellow on 14 January and remained at Yellow until the end of November 2005.

On 6-7 May 2005, weak gas-and-steam plumes were observed, but clouds frequently obscured the volcano. Thermal anomalies at the dome were detected in satellite imagery on 6-8, 10, and 12 May.

On 30 November, KVERT reported that seismicity at Bezymianny had increased during the previous two weeks. Seismic signals indicated that hot avalanches from the lava dome had begun on 29 November and the intensity of the thermal anomaly at the dome had increased. Strong fumarolic activity was captured on video of 29 November. An explosive eruption began on 30 November at 2400 according to seismic data. Ash plumes were subsequently seen in satellite imagery extending SW at an altitude of about 6 km. The Concern Color Code was raised to Orange.

After the eruption on 30 November, seismic activity at the volcano decreased to background levels. On 2 December the Concern Color Code was reduced from Orange to Yellow. On 9 December, KVERT reported that based on past experience with Bezymianny, a viscous lava flow was probably active at the summit lava dome and there were no indications that an explosive eruption was imminent.

A gas-steam plume was visible on 9-11 December and fumarolic activity at the lava dome continued through December. Thermal anomalies were registered at the dome on 9, 17, 21, 24-25, and 27-29 December.

Background. Prior to its noted 1955-56 eruption, Bezymianny volcano had been considered extinct. The modern Bezymianny volcano, much smaller in size than its massive neighbors Kamen and Kliuchevskoi, was formed about 4,700 years ago over a late-Pleistocene lava-dome complex and an ancestral volcano that was built about 11,000-7,000 years ago. Three periods of intensified activity have occurred during the past 3,000 years. The latest period, which was preceded by a 1,000-year quiescence, began with the dramatic 1955-56 eruption. This eruption, similar to that of Mount St. Helens in 1980, produced a large horseshoe-shaped crater that was formed by collapse of the summit and an associated lateral blast. Subsequent episodic but ongoing lava-dome growth, accompanied by intermittent explosive activity and pyroclastic flows, has largely filled the 1956 crater.

Information Contacts: KVERT and AVO (see Karymsky).