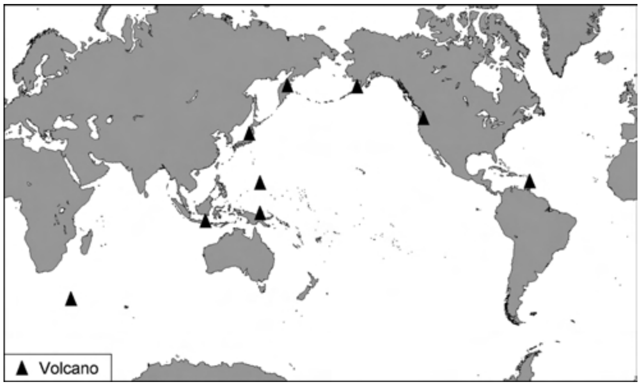
Bulletin of the Global Volcanism Network



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Manam

Papua New Guinea
4.10°S, 145.061°E; summit elev. 1,807 m
All times are local (= UTC + 10 hours)

On 24 October 2004 a strong eruption occurred at Manam (*Bulletin* v. 29, no. 10). Several more significant eruptions followed in late 2004 (*Bulletin* v. 29, no. 11), leading to the most severe and damaging one, which took place on 27 January 2005. That event occurred in conditions favorable to satellite imagery, enabling Andrew Tupper of the Darwin Volcanic Ash Advisory Centre (VAAC), and colleagues, to confirm that the associated ash cloud reached to over 20 km altitude, well into the stratosphere.

Satellite remote sensing documented 5 eruption plumes ascending to over 15 km during this issue's reporting interval, 23 October 2004-28 January 2005. One additional plume may have been missed by remote sensing in adverse weather conditions. Various images from the 2004 and 2005 eruptions are on the Darwin VAAC website (see Information Contacts, below). Sulfur dioxide is discussed there as well as on websites of the OMI-TOMS Volcanic Emissions Group and related sites.

The *Bulletin* has benefitted from reports by the Rabaul Volcano Observatory (RVO), the media, and the Darwin VAAC. Although the 27 January eruption received comparatively little press coverage, it caused several injuries and one death. RVO staff working at Manam faced challenging, hazardous conditions. The island had been home to ~ 9,500 now-displaced residents.

Summary of RVO observations. During the reporting interval both lava flows and pyroclastic flows reached the sea at various times (*Bulletin* v. 29, nos. 10 and 11). The main pathways were the NE and SE valleys (table 1, figures 1 and 2). Intervals of tremor were common.

Eruption on 27 January 2005. RVO reported that eruptive activity during the evening of 27 January was more severe than previous eruptions of the current eruptive period. As indicated on table 1, during 27-28 January there were 14 people injured and one person killed at Warisi village. RVO's monitoring base at Warisi was completely destroyed, taking out its HF radio, seismograph, and a satellite phone, thus preventing RVO from providing information on the current level of activity. The phone had been donated by an airline just a few weeks prior, provided as a means of aiding eruption-warning efforts. The station sat on the E flank at Warisi village (figures 1 and 2). RVO later recovered the station's seismograph and installed it on the island's NW side; they also restored radio communications.

According to the Papua New Guinea (PNG) news source, *The National*, some people had returned on 27 January from the displacement camps on the mainland to gather food from their island gardens, only to have their boat destroyed by impacts from erupted rocks. *The National* also reported that many of the residents of the island who were originally evacuated in November 2004 had returned. There were reports of several houses that had burned down from hot emissions and others that collapsed under the weight of ash and pyroclastic material. It was reported that after the large eruption on 27 January, local authorities planned to evacuate about 2,000 residents.

Ash fell at ~ 230 km W of Manam (in Ambunti district, East Sepik province, PNG). Tupper recognized NW monsoon winds that took low-level ash SE. Thus, the ash that fell in Ambunti must have traveled at a higher altitude, which Tupper estimated to be above 6 km altitude.

Date	Event at Manam
24 Oct 2004	Pyroclastic flows reached the sea and lava flowed 600 m down the SE valley.
31 Oct 2004	Three lobed lava flow in NE valley, and possibly a small flow in the NW valley.
11 Nov 2004	Lava in NE valley.
23-24 Nov 2004	Lava in NE valley. "The flow that headed towards Bokure 1 terminated about 100 m away from the main road . . . the Kolang lava flow had reached the sea" (reported by Warisi observer Herman Tibong). Ash on roofs caused a number of houses to collapse.
19-20 Dec 2004	Lava and pyroclastic flows in SE valley. Pyroclastic flows stopped 200 m from the sea on the 19th (no report on what happened on the 20th).
27-28 Jan 2005	14 injured and 1 dead at Warisi; debris voluminous and widespread on the island; ashfall reported ~230 km W of Manam.

Table 1. A summary of RVO observations involving lava flows and pyroclastic flows associated with Manam's eruptions during 23 October 2004-28 January 2005. Andrew Tupper (of the Darwin VAAC) compiled this list from available RVO reports and communications with RVO staff.

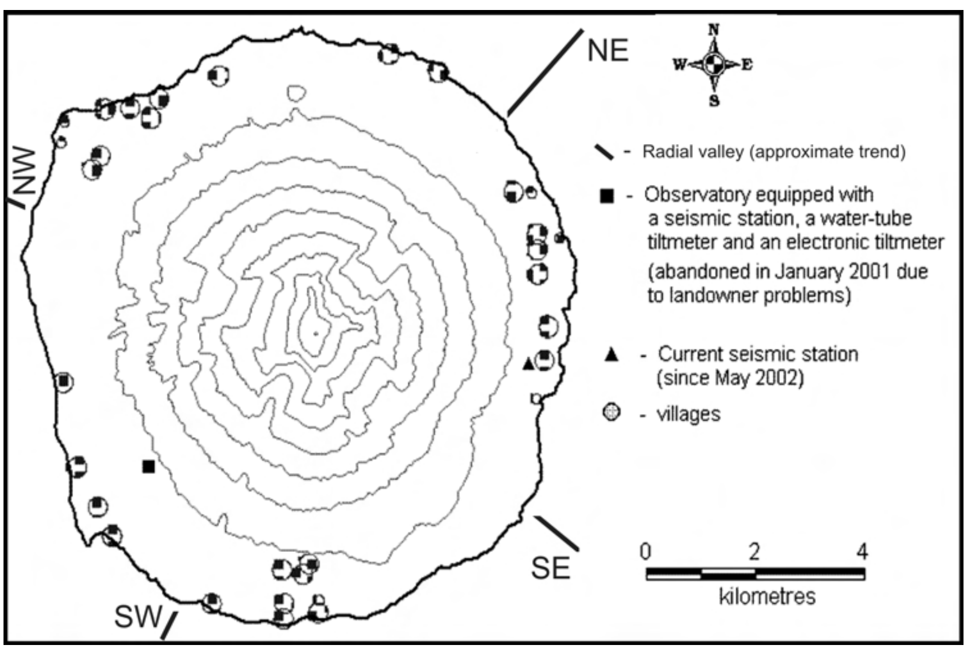

Figure 1. Map of Manam island made or updated circa 2002 (contour interval, 200 m). A temporary observatory was at Warisi (triangle, 'current seismic station') on the island's E side, but the eruption on 27 January 2005 destroyed it. Approximate trends of radial valleys were added by *Bulletin* editors. Courtesy of RVO.

The October-January eruptive sequence. Figure 3 plots eruption heights versus time during 23 October 2004 to late January 2005. Three kinds of eruption-height estimates appear: those from pilot reports, RVO's estimates (ground-based observations), and Tupper's post-analysis studies of satellite data. In a descussion below, Tupper mentions the differences between the three height-estimate techniques. The line showing alert level corresponds to the right-hand scale. Six eruptive clouds are clear on the graph.

The 24 October eruption at Manam occurred just before the Terra and Aqua satellites passed over. The data from those satellites, and from AVHRR and GOES satellites, indicated a very ice-rich cloud. Associated with Manam's eruption on 24 October, the coldest temperature measured from the high-level cloud was about 204 K (a couple of hours after the eruption), which translated to an altitude of about 15-18 km (a height supported by the ash cloud's subsequent dispersion, including wind trajectories consistent with the ~ 18 km altitude plotted on figure 3). There was no evidence of significant stratospheric penetration. Pilot reports for the cloud's top were generally lower, as is usual for large eruptions (Tupper and Kinoshita, 2003).

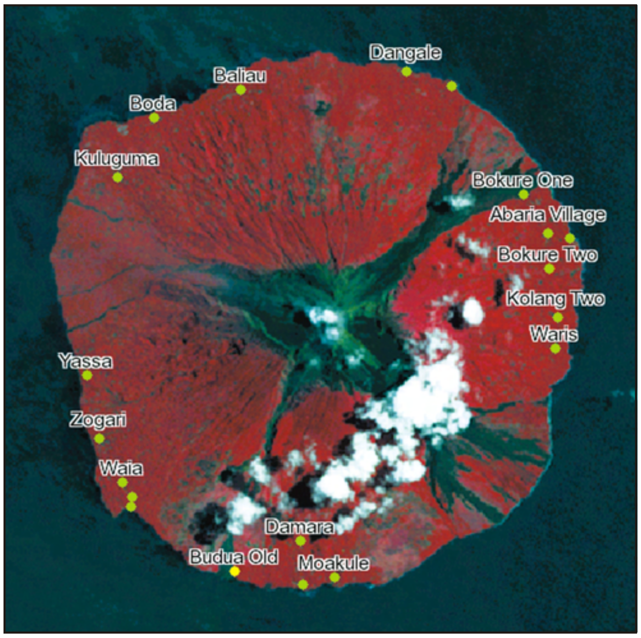

Figure 2. Annotated image of Manam indicating village and other place names on a false-color satellite photo (note the cloud cover; for scale, compare to previous figure). Source details are unknown. "Waris," is more commonly spelled "Warisi" in RVO reports. Courtesy of the PNG Mapserver website.

Figure 4 presents a photo of the 11 November eruption plume as seen by Air Niugini pilot David Innes. He estimated the visible portion of the plume height at "30,000 feet" (~ 9 km), but the cloud probably ascended at least a bit higher as it entered into masking cirrus clouds from a tropical disturbance to the N, so the pilot's estimate might be stated as 'above 9 km.' RVO's ground observer estimated a plume at ~ 8 km slightly earlier in the eruption, on about 10 November. The satellite-based analysis was thwarted by the cirrus cloud cover during this eruption.

From 20 December until just before the 27 January eruption, no plumes or hot spots were visible. Few plumes were reported by RVO, and none were seen by pilots (table 1). The 27 January eruption began about 1400 UTC; and an Aqua/MODIS image from 0507 UTC is shown as figure 5.

The Darwin VAAC initially estimated the 27 January eruption cloud's maximum height as 21 km altitude, but later analysis found the range 21-24 km a better estimate. Infrared 11-µm imagery from GOES-9 at 1440 UTC and Aqua/MODIS at 1539 UTC on 27 January showed 'warm' spots in the middle of the umbrella cloud of 215.4 K and 210.4 K, respectively, indicating a substantial overshoot of the cloud top into the warmer stratosphere (tropopause temperatures were around 187 K). The GOES-9 temperature may be less useful because of poorer satellite resolution and calibration, and because at that stage the cloud may not have come into equilibrium with its environment. Comparing these temperatures to a temperature sonde taken from nearby Manus Island at 0000 UTC on 28 January suggests a cloud altitude of 21-24 km. Tupper plotted the more conservative (smaller) value on figure 3.

The 27 January eruption cloud was extremely difficult to track, as it was ice-rich and mixed with monsoonal storms, but dispersion models and satellite analysis suggest that a mid-tropospheric portion spread quite quickly W over Irian Jaya, while higher cloud remained near the eruption site for some time. The best 'tracer' for the cloud in operations turned out to be the strong 'ice' signature in split-window imagery¾ similar to the Hekla (Iceland) eruption in the year 2000.

Another large eruption occurred around 2300 on 28 January. That plume's height plots at 18 km altitude (figure 3).

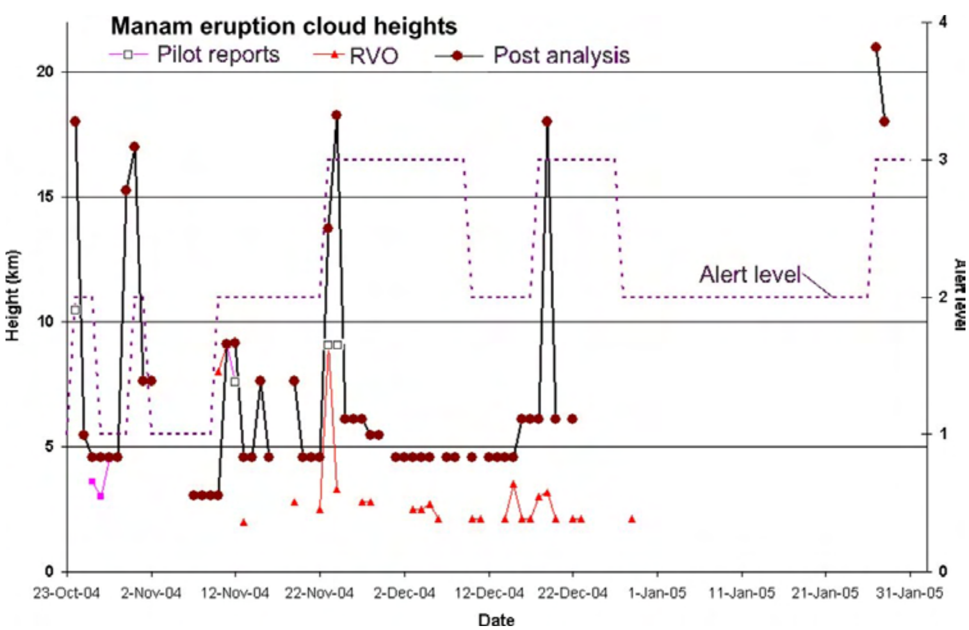

Figure 3. A graph of Manam's cloud heights from 23 October 2004 to late-January 2005, as determined from various means (see key along top). The dashed line corresponds to the right-hand scale of the graph, which displays alert levels reported by RVO (0-4, with 4 as the highest). Courtesy of Andrew Tupper, Darwin VAAC.

Preliminary synopsis. Tupper wrote that he and his group were aware of five or six major events

Figure 4. A N-looking aerial photo showing Manam's plume at 0630 local time on 11 November 2004. The plume extends to ~9 km before disappearing into higher weather clouds. Photo by David Innes of Air Niugini; used here with his permission.

"during these [Manam] eruptions that have generated high (over 10 km altitude) eruption clouds—23-24 October 2004, 31 October 2004, 10-11 November 2004, 23-24 November 2004, 19-20 December 2004, and 27-28 January 2005 [figure 3]. On each of these occasions a high and sometimes persistent cloud has developed over a stronger phase of the eruption. The largest event by far has been the 27-28 January event, which was the only one to clearly penetrate into the stratosphere.

"Attached is a graph [figure 3] showing the heights reported by ground observers, by local pilots, and derived from satellite analysis. Some major differences of perspective are evident. I believe that, in general, the ground observer heights are most accurate for the lower eruptions, pilot reports can be accurate or quite inaccurate depending on the pilot and the viewing angle, and satellite estimates are most accurate for the larger eruptions.

"The cold-point tropopause generally occurs at around 16-18 km at this time of year in Papua New Guinea, and scores of thunderstorms reach these altitudes every day in the area. Consequently, it is not surprising that the larger eruptions are easily able to reach these altitudes. The tropopause is also the major dynamical limit on the rise of the larger eruption clouds. The eruption of 27 January clearly penetrated into the stratosphere, to altitudes of 21-24 km, based on the warmth of the central umbrella cloud, and the subsequent dispersion of the ice-cloud, and the SO_2 from the eruption."

"All of the eruption clouds have been water/ice rich, and difficult to track using satellite techniques. The ash signal at altitudes above the freezing level has been overwhelmed by the ice signal in infrared split-window imagery. Similarly, in visible and true-colour imagery, even where the lower level clouds have shown an ash signal, the higher clouds have been a brilliant white and have only been revealed as volcanic in short-wave infrared (3.7 µm) imagery and with SO_2 retrievals. For example, [in *Bulletin* (v. 29, no. 11, the first of two satellite photos)] the large brilliant white cloud to the N of Manam (overlying the dark ash cloud) derives from the same 24 October eruption."

Background. The 10-km-wide island of Manam, lying 13 km off the northern coast of mainland Papua New Guinea, is one of the country's most active volcanoes. Four large radial valleys extend from the unvegetated summit of the conical 1807-m-high basaltic-andesitic stratovolcano to its lower flanks. These "avalanche valleys," regularly spaced 90 degrees apart, channel lava flows and pyroclastic avalanches that have sometimes reached the coast. Five small satellitic centers are located near the island's shoreline on the northern, southern, and western sides. Two summit craters are present; both are active, although most historical eruptions have originated from the southern crater, concentrating eruptive products during the past century into the SE avalanche valley. Frequent historical eruptions have been recorded at Manam since 1616. A major eruption in 1919 produced pyroclastic flows that reached the coast, and in 1957-58 pyroclastic flows descended all four radial valleys. Lava flows reached the sea in 1946-47 and 1958.

References: Tupper, A., and Kinoshita, K., 2003, Satellite, air and ground observations of volcanic clouds over island of the Southwest Pacific: South Pacific Study, v. 23, no. 2, p. 21-46.

Information Contacts: *Andrew Tupper*, Darwin Volcanic Ash Advisory Centre, Australian Bureau of Meteorology (URL: http://www.bom.gov.au/info/vaac); *Rabaul Volcano Observatory (RVO)*, P.O. Box 386, Rabaul, Papua New Guinea; *National Disaster Centre*, Department of Provincial Affairs and Local Level Government (Ministry of Inter-Government Relations), PO Box 4970, Boroko, National Capital District, Papua New Guinea (URL: http://www.pngndc.gov.pg/); *The National Online*, Lot 13 Section 38, Waigani Drive Hohola, PO Box 6817 Boroko, National Capital District, Papua New Guinea (URL: http://www.thenational.com.pg/1206/); *Papua New Guinea Mapserver (Mapu)*, EDF 8/9 EU-SOPAC Reducing Vul-

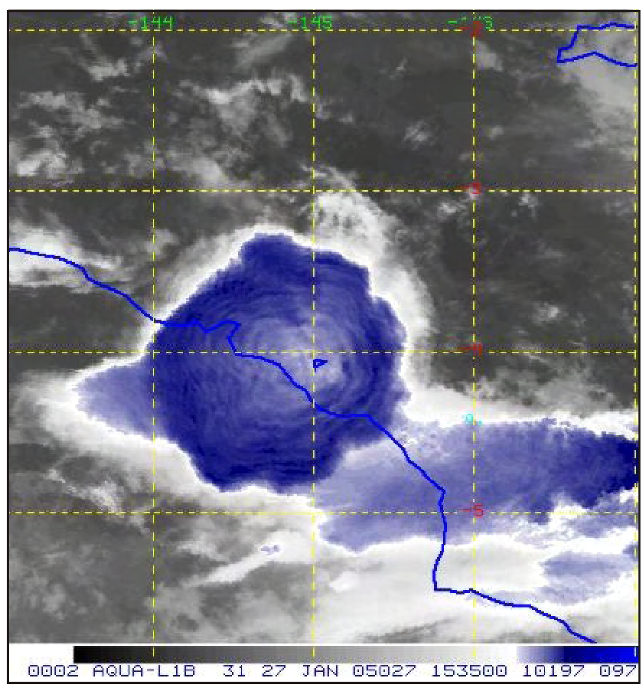

Figure 5. An infrared Aqua/MODIS image of the umbrella cloud from the 27 January 2005 Manam eruption (taken at 1535 UTC on the night of the 27th). The image is enhanced to show the 'warm spot' in the centre of the cloud (warm because of the stratospheric intrusion) and the gravity waves in the cloud. The lobate structure at the fringes of the cloud is similar to other observed umbrella clouds, such as the 1991 Pinatubo cloud. At this stage the cloud had a diameter of approximately 180 km. Courtesy of Andrew Tupper.

nerability of Pacific ACP States Project (see TikiMap map link at URL: http://map.mineral.gov.pg/tiki/tiki-index.php?page=MANAM+PAGE); *David Innes*, Flight Safety Office, Air Niugini, P.O.Box 7186, Boroko, Port Moresby, National Capital District, Papua New Guinea (Email: dinnes@airniugini.com.pg or deejayinnes@yahoo.com, URL: http://www.airniugini.com.pg/); *Simon Carn*, TOMS Volcanic Emissions Group, University of Maryland, 1000 Hilltop Circle, Baltimore, MD 21250, USA (Email: scarn@umbc.edu; URL: http://skye.gsfc.nasa.gov/).

Rinjani

Lesser Sunda Islands, Indonesia
8.42°S, 116.47°E; summit elev. 3,726 m

Rinjani had increases in some monitored parameters and hazard status during this report interval, covering much of 2004 through 30 January 2005. An eruption occurred on 1 October 2004. We previously presented a brief aviation report concerning an unconfirmed ash cloud from Rinjani in September 1995 (*Bulletin* v. 20, no. 10). In their text associated with recent reporting used here, The Directorate of Volcanology and Geological Hazard Mitigation (DVGHM) noted that Rinjani's last explosions occurred during 4 June 1994-January 1995. Those explosions came from Barujari volcano (see Background for morphologic information).

On 27 September 2004 a DVGHM report noted the decision to increase Rinjani's hazard status to Alert Level II (Yellow, on a scale with the most hazardous at IV). During the last third of 2004, the number of volcanic and tectonic earthquakes had increased. Their increase followed a rise in the number of tectonic earthquakes that began 18 August 2004. Tremor registered on 23, 24, 25, and 26 September 2004. Tremor amplitudes ranged between 12 and 13.5 mm, and the duration of the tremor stood between 94 and 290 seconds.

At 0530 on 1 October 2004 Rinjani clearly erupted. The observation station where visual monitoring occurs (Sembalun Lawang) lies in a spot where the caldera wall blocks views into the active zone, so a smaller eruption might have been missed. The eruption caused authorities to immediately raise the hazard status to Alert Level III (Orange). Further details have not emerged regarding the initial 1 October eruption. During the next few days of eruptions, the lake Segara Anak remained undisturbed.

During 2-5 October 2004 continued explosions sent ash columns ~ 300 to 800 m above the summit. Gray, thick ash columns drifted to the N. Detonation sounds accompanied every explosion. Successive explosions occurred at intervals of 5 to 160 minutes. Explosions vented on the NE slope of Barujari volcano. Some material also vented from Barujari's peak, however, and fell down around its edifice. A press report in the *Jakarta Post* indicated that evacuations were not considered necessary.

Available monthly seismic data appears in table 2. Seismicity was dominated by explosion earthquakes with maximum amplitudes of 30 mm. Explosion and emission signals were common during February and March 2004 and became absent or unreported after April 2004. Data were unavailable for October 2004 when known eruptions occurred.

During 24 to 30 January 2005, gas plumes remained less than 600 m tall. The tremor record had a maximum amplitude of 1.5 mm.

Background. Rinjani volcano sits on the island of Lombok and rises to 3,726 m, making it second in height among Indonesian volcanoes, only shorter than Kerinci volcano (Sumatra). Rinjani has a steep-sided conical profile when viewed from the E, but the W side of this compound volcano is truncated by the oval-shaped (6 x 8.5 km) Segara Anak caldera. The caldera's western half contains a 230-m-deep lake whose crescentic form results from growth of the post-caldera cone Barujari (also written Baru Jari) at the caldera's eastern end. Historical eruptions at Rinjani dating back to 1847 have been restricted to Barujari cone and consist of moderate explosive activity and occasional lava flows that have entered Segara Anak lake.

Information Contacts: *Directorate of Volcanology and Geological Hazard Mitigation (DVGHM)*, Jalan Diponegoro 57, Bandung 40122, Indonesia (Email: dali@vsi.dpe.go.id; URL: http://www.vsi.esdm.go.id/); *The Jakarta Post*, Indonesia (URL: http://www.thejakartapost.com/).

Date	Volcanic A	Volcanic B	Tremor	Emission	Explosion
10 Feb 2004	2	—	20	3	37
10 Mar 2004	3	3	16	5	32
10 Apr 2004	—	—	5	—	5
17-23 Jan 2005	20	28	11	—	—
24-30 Jan 2005	9	34	11	—	—

Table 2. Available seismicity at Rinjani during 10 February 2004 to 30 January 2005. The symbol " - " means not reported. Courtesy of VSI.

Anatahan

Mariana Islands
16.35°N, 145.67°E; summit elev. 788 m
All times are local (= UTC + 10 hours)

As discussed in our previous report (*Bulletin* v. 29, no. 12), Anatahan's third historical eruption began on 5 January 2005. Ongoing eruptions continued through at least 18 February 2005.

Anatahan lies in the Commonwealth of the Northern Mariana Islands (CNMI) ~ 120 km N of Saipan and ~ 320 km N of Guam. The first historical eruption of Anatahan began 10 May 2003 (Bulletin v. 28, nos. 4 and 5); after several hours of increasing seismicity, a phreatomagmatic eruption sent ash to over ~ 9 km (~ 30,000 feet) and deposited about 10 million cubic meters of material over the island and sea. A small craggy dome extruded in late May and was destroyed during explosions on 13 and 14 June, after which the eruption ceased. The second historical eruption began about 9 April 2004 after a week or so of increasing seismicity (Bulletin v. 29, no. 4). That eruption primarily comprised Strombolian explosions every minute or so and occasionally sent ash up to a few thousand feet. The eruption ended 26 July 2004.

Charles Holliday (US Airforce Weather Agency, AFWA) contributed a series of remotely sensed images showing plumes in February (table 3, figure 6). The plume in the 4 February Terra image (figure 6, top) contains a brownish tinge suggesting considerable ash. The Anatahan region was on the western edge of the Terra pass. The image contains an artifact reminiscent of Venetian blinds (commonly called the bow-tie effect), which arose due to pixel replication in the mapping/processing algorithm filling in for missing data on the edge of the scan.

Randy White of the U.S. Geological Survey noted that the energy release from seismic stations monitoring Anatahan dropped to near zero on 13 February 2005, yet a monitoring microphone continued to indicate considerable acoustic-energy release. Corresponding to this, a MODIS image clearly showed ash still being emitted early on 14

2005	Time (UTC)	Satellite and type of image	Predominant direction of plume and comments
03 Feb	2329	DMSP F16 (capturing visible data at 0.3 nanometer (nm) wavelength)	Steam and vog; seen at least 95 NM (~180 km) from Anatahan, trending slightly E of S.
04 Feb	*0105	NASA TERRA MODIS (250 m resolution)	Steam and vog; seen for at least 100 NM (~185 km) to the S.
06 Feb	0050	NASA TERRA MODIS (500 m resolution)	Steam and vog; 100 NM (~185 km) trending to WSW.
06 Feb	0043	NOAA 17 (visible, 0.5 nm wavelength)	Steam and vog; 175 NM (~320 km) to SW.
06 Feb	0335	NASA AQUA MODIS (500 m resolution)	Steam and vog; 150 NM (~280 km) trending to WSW.
08 Feb	2226	DMSP F15 (visible, 0.3 nm)	Steam and vog; 150 NM (~280 km) trending to SW.
09 Feb	0125	NASA TERRA MODIS (500 m resolution)	Steam and vog to the SSW; plume length undisclosed.
09 Feb	0442	NOAA 16 (visible, 0.5 nm and infrared (IR), 0.5 nm)	Steam and vog; 150 NM (~280 km) trending over a sector from SW to WSW.
09 Feb	2207	DMSP F16 (visible, 0.5 nm)	Ash and steam for ten's of kilometers; vog at greater distances, up to at least 130 NM (240 km) WSW.
10 Feb	0030	NASA TERRA MODIS (250 m resolution)	Ash and steam nearer volcano, blowing S to SSW; region interpreted as vog at distances of ten's of kilometers SW of volcano.
10 Feb	0052	NOAA 17 (0.5 nm)	Vog visible 220 NM (~410 km) to the WSW.
10 Feb	0330	NASA AQUA MODIS (500 m resolution)	Ash and steam nearer volcano, blowing SW; vog at distances ~150 NM (~280 km) WSW of volcano.
10 Feb	0423	NOAA 16 (IR, 0.5 nm)	Ash and steam; plume blown 100 NM (185 km) to W and WSW.
10 Feb	0423	NOAA 16 (visible, 0.5 nm)	Ash and steam; 475 NM (967 km) trending to WSW.
10 Feb	2251	DMSP F15 (visible, 0.3 nm)	Ash and steam for ten's of kilometers WSW from Anatahan; vog at greater distances visible up to at least 475 NM (967 km) from the volcano.
11 Feb	0110	NASA TERRA MODIS (1 km resolution)	One of the longer-extended plumes identified in this set, trending SW and reaching 525 NM (~972 km) from source to identified vog near the SW corner of the image. Ash and steam to ten's of kilometers from source.
11 Feb	0412	NOAA 16 (0.5 nm)	Ash and steam plume that gradually broadens as it drifts WSW. The plume was ultimately identified as vog in the more distal areas. Total length identified 505 NM (936 km).
11 Feb	0415	NASA AQUA MODIS (500 m resolution)	Plume clearer than on most other images in this set, with few weather clouds obscuring; SW-directed plume identified as ash and steam near source; vog in distal areas to ~150 NM (~280 km).
11 Feb	0702	GOES-9 (visible)	Longest-extending plume of this set; ash and steam WSW of volcano; vog detected at 850 NM (~1,600 km) from Anatahan.
12 Feb	0401	NOAA 16 (visible, 0.3 nm)	W-directed plume with ash/steam near source, vog at 355 NM (657 km).
12 Feb	2316	DMSP F16 (visible, 0.3 nm)	SW-directed plume, ~140 NM long (~260 km).
13 Feb	0100	NASA TERRA MODIS (500m resolution)	SW-directed plume, ~200 NM (~370 km) long.
13 Feb	0124	NOAA 17 (visible, 0.5 nm)	W-directed plume, ~360 NM long (~670 km).
13 Feb	1229	NOAA 17 IR (0.5 nm)	WNW-directed plume, 95 NM (180 km) long.
13 Feb	*2303	DMSP F16 (visible, 0.3 nm)	SW-directed plume, ash and steam for much of 140 NM (260 km) length (unusually clear conditions).
14 Feb	0101	NOAA 17 IR (0.5 nm)	Elongate ash-and-steam plume stretched SW to ~120 NM (~220 km).
14 Feb	0101	NOAA 17 (visible, 0.5 nm)	Ash and steam plume(s) near source; vog visible on image to over 400 NM (740 km).
14 Feb	0305	NASA AQUA MODIS (250m resolution)	SSW-directed plume with ash and steam, but length undisclosed.
14 Feb	0519	NOAA 16 (visible, 0.5 nm)	W-directed ash-and-steam plume in the near source, vog seen ~500 NM (~930 km) to the W.
15 Feb	0038	NOAA 17 (visible, 0.5 nm)	Gravity waves to the W for 25 NM (~45 km); faint vog seen to ~80 km (~150 km).
15 Feb	0045	NASA TERRA MODIS (500 m resolution)	(Similar to above)
15 Feb	0350	NASA TERRA MODIS (1 km resolution)	Ash and steam ~350 NM to the W to SW; faint vog in more distal areas.
15 Feb	0507	NOAA 16 (visible, 0.5 nm)	Plume directed WSW stretching 345 NM (640 km).
15 Feb	0812	NOAA 15 (IR, 0.5 nm)	Ash and steam directed WSW stretching 175 NM (326 km).

Table 3. A list of some of the satellite images recording Anatahan plumes during 3-15 February 2005. Those shown with an asterisk appear in the next figure. Date and time are both UTC; for example, 04 Feb 2005 @ 0105 is the date and time in UTC, in this example equivalent to 04 Feb 2005 at 1105 local time. Names affiliated with satellites are as follows: DMSP (Defense Meteorological Satellite Program), NOAA (National Oceanic and Atmospheric Administration), NASA (National Aeronautics and Space Administration). Courtesy of Charles Holliday, U.S. Air Force Weather Agency.

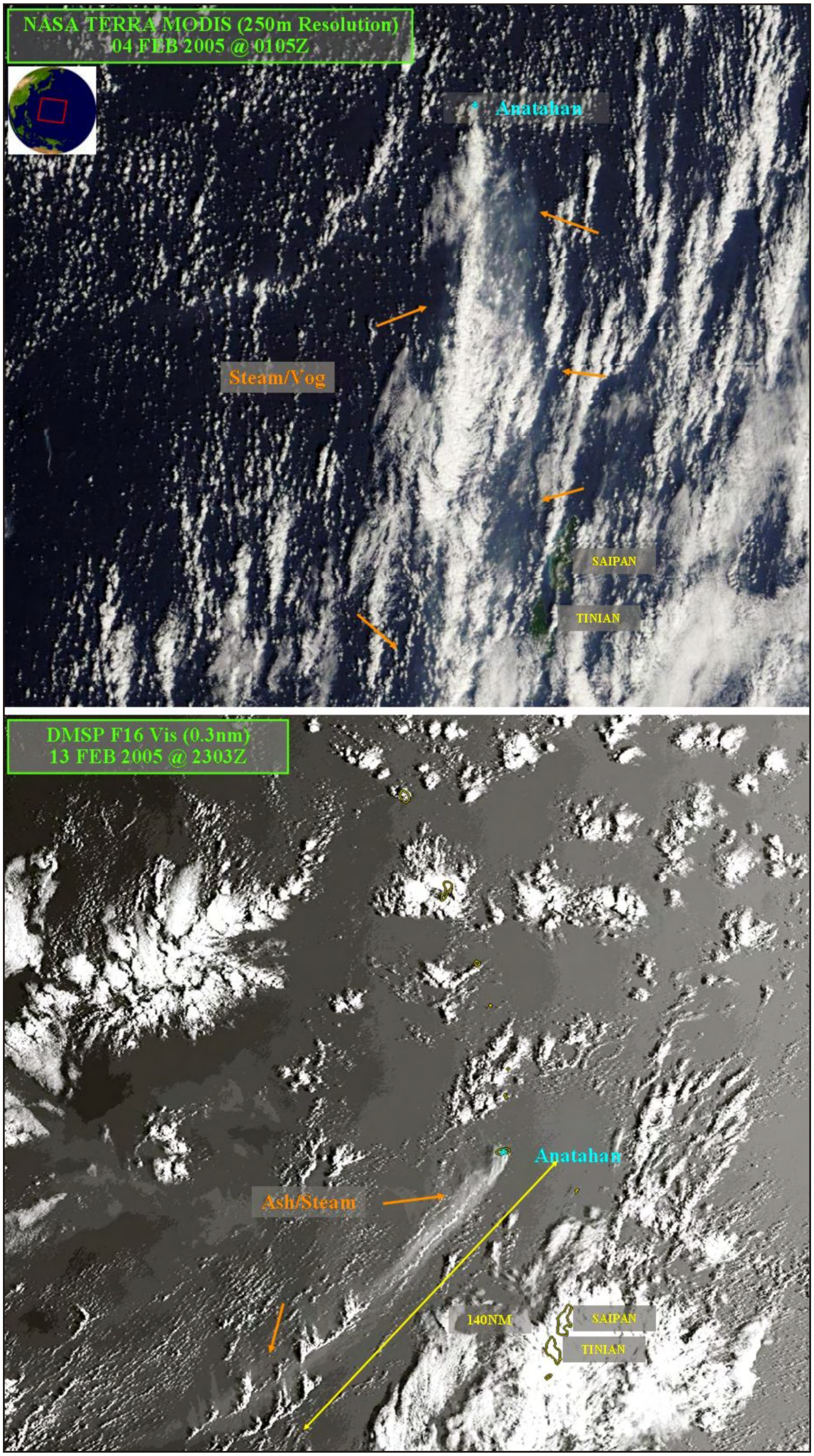

Figure 6. Two remotely sensed images of Anatahan plumes during February 2004 (N is upwards). (top) S-blown steam and vog on 4 February at 0105 UTC clearly identifiable to Saipan and Tinian islands; reported as the source of health problems in Guam news reports (see text). (bottom) A modest ash/steam plume in unusually clear conditions, imaged at 2303 UTC on 13 February (DMSP F16 visible) reached 260 km (140 NM). Courtesy of Charles Holliday, U.S. Air Force Weather Agency.

February (see table 3). In other words, the seismicity failed to accurately portray the eruption's vigor.

Reporters Katie Worth and Natalie Quinata wrote in the 5 February 2004 issue of the *Pacific Daily News* that many students in school on Guam had been sent home after experiencing dizziness or nausea because of the foul-smelling 'vog' or volcanic smog hovering over the island from the eruption. Guam lies ~ 320 km S of Anatahan.

John Ravelo wrote a news article for the *Saipan Tribune* published on 15 February with the title "Anatahan ash cloud continues to hinder flights." Ravelo said that, "An aircraft coming from Manila to Saipan experienced zero visibility before landing at the Francisco C. Ada-Saipan International Airport yesterday morning, prompting the carrier's pilots to fly around the island and search for a clearer approach to the runway. The passenger aircraft landed safely at the airport, but the hazy condition delayed its arrival."

At about 0909 on 14 February, the Washington Volcanic Ash Advisory Center (VAAC) reported that a plume of ash extended SW of the volcano at an altitude of 4.3 km. The plume was 18-28 km wide. Later in the afternoon, the Washington VAAC reported an ash plume below an altitude of 2.7 km that extended SW of the volcano for about 460 km. The VAAC also forecasted that the plume would shift to a more westerly direction within the next 12 hours.

According to Ravelo's 15 February Saipan Tribune article, the CNMI Emergency Management Office and the U.S. Geological Survey "said in a joint report that the magnitude of the volcanic eruption declined during the past few days." During the eruption's peak on 26 January and 1 February 2005, however, the article stated that both agencies noted that the volcano sent ash to about 4.6-6.1 km altitude.

A message from Holliday filed at 0100 UTC on 17 February 2005 included a series of remarks, mainly from unnamed scientists on the scene in the field. As background prior to presenting those remarks, we note that the term 'RSAM' (real-time seismic amplitude) signifies estimates the average amplitude of ground shaking. RSAM values increase with increases in tremor amplitude or the rate of occurrence and size of earthquakes. The RSAM estimates the seismicity during intervals when many earthquakes might occur, times when rapid earthquake-magnitude assessments might become impractical. The remarks follow.

"Over the past 24 hours, the eruptive activity at Anatahan apparently continued to decline, with RSAM levels at the seismic station ANAT now only marginally above the levels recorded just before the 5 January eruption began. Microphone amplitudes have also dropped to similar levels.

"The 2003 crater floor is now essentially entirely covered by fresh lava [with] a diameter of about one kilometer. The current eruption peaked during the period between 26 January and 2 February [2005], during which the volcano sent ash as high as 15,000 to 20,000 feet a.s.l. [~ 5,000 to ~ 6,000 m] . . .. In the days following, ash blew as far as 100 nautical miles [185 km] and vog blew nearly 600 [nautical] miles [~ 1,100 km] downwind.

"The third historical eruption of Anatahan began on 5 January, after three days of precursory seismicity. On 6 January frequent strombolian explosion signals began and by the next day ash was rising to 10,000 feet [~ 3 km] and blowing 40 nautical miles [72 km] downwind. Bombs a meter in diameter were being thrown hundreds of feet in the air [1 foot = 0.305 m]. By January 20 explosions were occurring every 3 to 10 seconds and fresh ejecta and small lava flows had filled the innermost crater to nearly the level of the pre-2003 East Crater floor.

"The Emergency Management Office, Office of the Governor, CNMI, has placed Anatahan Island off limits until further notice and concludes that, although the volcano is not currently dangerous to most aircraft within the CNMI airspace, conditions may change rapidly, and aircraft should pass upwind of Anatahan or beyond 30 km downwind from the island and exercise due caution within 30 km of Anatahan."

Background. The elongated, 9-km-long island of Anatahan in the central Mariana Islands consists of two coalescing volcanoes with a 2.3 x 5 km, E-trending summit depression formed by overlapping summit calderas. The larger western caldera is 2.3 x 3 km wide and extends eastward from the summit of the western volcano, the island's 788-m-high point. Ponded lava flows overlain by pyroclastic deposits fill the caldera floor, whose SW side is cut by a fresh-looking smaller crater. The summit of the lower eastern cone is cut by a 2-km-wide caldera with a steep-walled inner crater whose floor is only 68 m above sea level. Sparseness of vegetation on the most recent lava flows on Anatahan indicated that they were of Holocene age, but the first historical eruption of Anatahan did not occur until May 2003, when a large explosive eruption took place forming a new crater inside the eastern caldera.

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Asama

Honshu, Japan
36.40°N, 138.53°E; summit elev. 2,560 m
All times are local (= UTC + 9 hours)

Setsuya Nakada and Yukio Hayakawa provided follow-up information on events at Asama since our last report (*Bulletin* v. 30, no. 1). Asama's largest recent explosion occurred on 1 September 2004, and the second largest, on 14 November 2004. Subsequent eruptions have been absent except for a small one in early December 2004.

The eruption that started on 1 September 2004 was characterized by an increase in the number of A-type earthquakes occurring during and after the main phase of explosions (based on data collected by the University of Tokyo's Earthquake Research Institute (ERI) and the Japan Meteorological Agency). Deep seismicity peaked at the end of 2004, but had subsequently remained moderate. GPS (global positioning system) instruments maintained ERI and the Geographical Survey Institute (GSI) disclosed inflation of the edifice. This inflationary trend has continued since mid-October 2004.

ERI undertook detailed analysis of earthquake hypocenters and the pressure source for the observed GPS data. This showed the existence of a dike-shaped magma reservoir trending WNW-ESE. The reservoir occurred just W of the summit and 1-2 km below sea level.

Around October 2004 the height of the lava filling the summit crater reached a maximum. Around that time the dome attained a height just ~ 70 m below the crater's lowest notch (an opening along the N rim). By the end of January 2005, in contrast, the center of the lava pool had deepened, possibly due to draining of the lava body back into the conduit.

A sequence of radar images provided glimpses into changeable features inside the steamy crater. Two images appear here, from 16 September and 15 December 2004 (figures 7 and 8). The former shows a flat-looking disk-shaped extrusion in the crater. The latter shows that the earlier extrusion had by this time become disrupted or perhaps buried.

Strong glowing at the summit was considered to be due to significant degassing after the main explosive phase. SO_2 flux peaked around October (at ~ 5,000 metric tons a day) and has continued at a relatively high level, as much as 2,000 to 3,000 metric tons a day.

The eruptions emitted andesite (SiO_2 ~ 61%), with high crystallinity, and containing partially melted sedimentary and other rock (felsic tuff?). The rock chemistry has re-

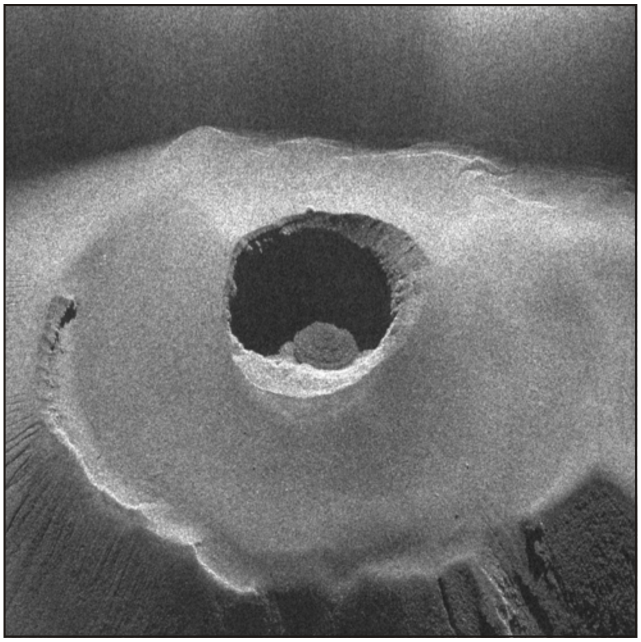

Figure 7. Radar image of Asama's summit crater taken from a Cessna airplane on 16 September 2004 by the Geographical Survey Institute, Japan. N is up. Radiated microwaves were transmitted from the N, at 4,290 m altitude, 2 km from the crater, with the off-nadir angle of 55 degrees. Courtesy of the Geographical Survey Institute.

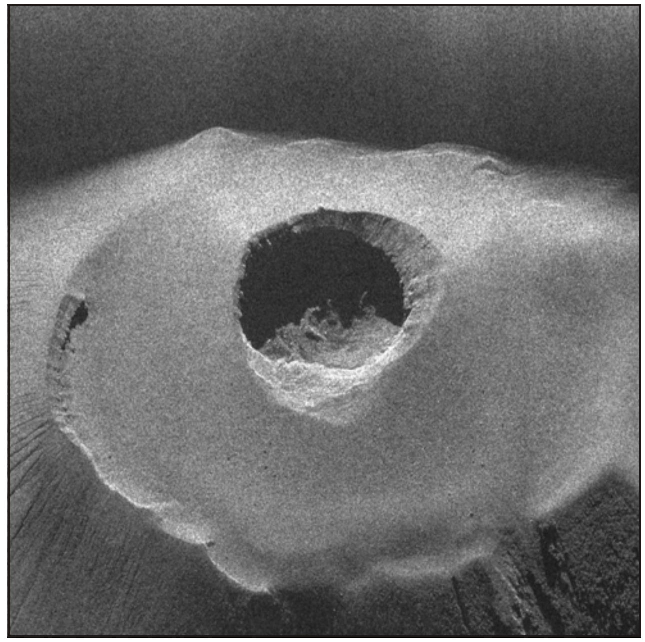

Figure 8. Radar image of Asama's summit crater taken from a Cessna on 15 December 2004 by the Geographical Survey Institute, Japan. N is up. Radiated microwaves were transmitted from the N, 2 km from the crater, with the off-nadir angle of 55 degrees. Courtesy of Geographical Survey Institute.

mained uniform throughout the eruptions of the past several thousand years, though the inclusion of melted sedimentary rock was absent in products erupted prior to 2004.

Yukio Hayakawa provided a composite isomass map of 2004 Asama tephra deposits (figure 9). By far the largest deposit of the year erupted on 1 September. The smallest documented deposit occurred on 10 October. Ash deposits from activity on 1 September drifted NE, deposits from 16 September drifted SSE; 23 September, NNE; 29 September, N; 10 October, NE; and 14 November, E.

Background. Asama, Honshu's most active volcano, overlooks the resort town of Karuizawa, 140 km NW of Tokyo. The volcano is located at the junction of the Izu-Marianas and NE Japan volcanic arcs. The modern cone of Maekake-yama forms the summit of the volcano and is situated east of the horseshoe-shaped remnant of an older andesitic volcano, Kurofu-yama, which was destroyed by a late-Pleistocene landslide about 20,000 years before present (BP). Growth of a dacitic shield volcano was accompanied by pumiceous pyroclastic flows, the largest of which occurred about 14,000-11,000 years BP, and by growth of the Ko-Asama-yama lava dome on the east flank. Maekake-yama, capped by the Kama-yama pyroclastic cone that forms the present summit of the volcano, is probably only a few thousand years old and has an historical record dating back at least to the 11th century AD. Maekake-yama has had several major plinian eruptions, the last two of which occurred in 1108 and 1783 AD.

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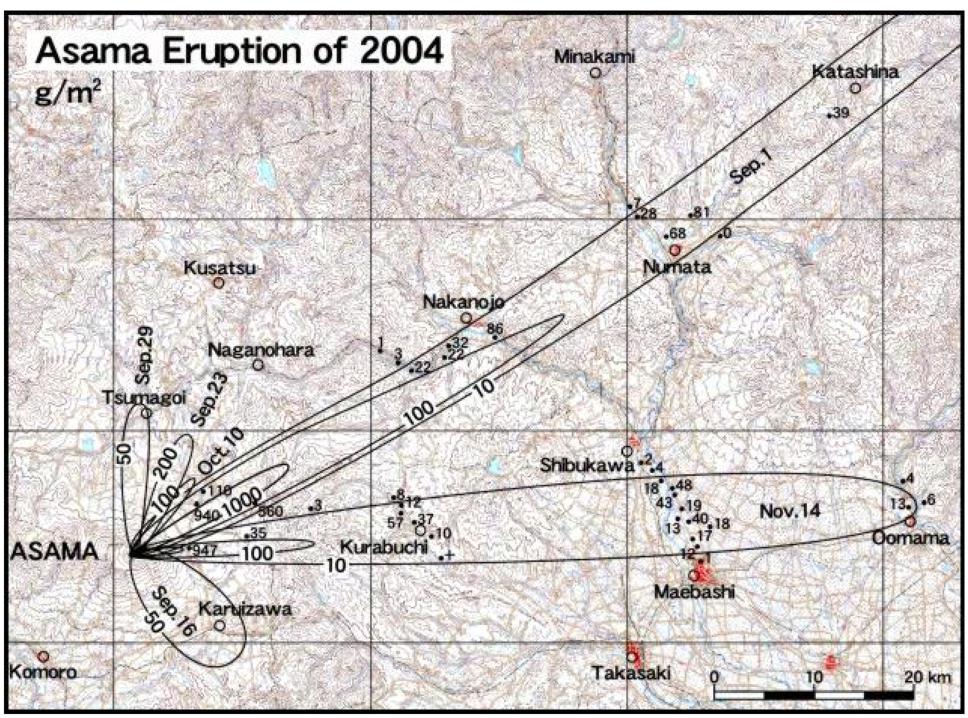

Figure 9. Isomass map of 2004 Asama tephra deposits erupted during September-November 2004. Open circles indicate cities; dots indicate sampling points where g/m^2 of ash were measured; contours are in the same units. Courtesy Yukio Hayakawa.

Hayakawa, Faculty of Education, Gunma University, Aramaki 4-2, Maebashi Gunma 371-8510, Japan (Email: hayakawa@edu.gunma-u.ac.jp, URL: http://maechan.net/hayakawa/asama/gankoran/, http://www.edu.gunma-u.ac.jp/~ hayakawa/English.html); *Geographical Survey Institute,* Ministry of Land, Infrastructure and Transport, 1, Kitasato, Tsukuba-shi, Ibaraki-ken 305-0811 Japan (URL: http://www.gsi.go.jp; URL with radar data (text in Japanese): http://www.gsi.go.jp/BOUSAI/ASAMA/); *Japan Meteorological Agency*, Otemachi, 1-3-4, Chiyoda-ku Tokyo 100-8122, JAPAN (URL: www.jma.go.jp/).

Shiveluch

Kamchatka Peninsula, Russia
56.653 N, 161.360 E; summit elev. 3,283 m
All times are local (= UTC + 12 hours [+13 hours in March-June])

The previous report on Shiveluch (*Bulletin* v. 29, no. 5) covered activity until 27 May 2004. From May 2004 until September 2004, seismicity at Shiveluch was above background, with many shallow earthquakes recorded 0-5 km beneath the active lava dome, and Shiveluch remained at Concern Color Code Orange. Periods of continuous spasmodic tremor were recorded in May, June, July, and October 2004. Gas-and-steam plumes rising to 3-6 km altitude were frequent, sometimes drifting up to 10 km or more. A small lava flow on top of the active dome, first observed on 21 May, continued to flow until 28 May. On 19 June, a likely ash cloud was seen 10-20 km S of the volcano. The lava dome continued to grow in Shiveluch's active crater.

On 6 September at 2054 an explosion produced small pyroclastic flows and an ash plume that rose to ~ 5.5 km altitude. According to satellite data, 1- to 12-pixel thermal anomalies were registered over the lava dome on 15-16 September 2004. During 23-29 September, 26 strong shallow earthquakes up to M 2.3 were recorded. An explosion on 25 September was accompanied by small pyroclastic flows. The Kamchatka Volcanic Eruptions Response Team (KVERT),again reported seeing a new lava flow at Shiveluch's lava dome around 26 October.

Figure 10. A dark plume of ash streamed from the Shiveluch at 0110 UTC on 20 October 2004, when the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite captured this image. MODIS observed several such plumes in October. Fainter plume(s) to the SW can be seen from Bezymianny or Kliuchevskoi, both of which were emitting ash plumes during the first week of October.

Based on interpretations of seismic data, possible ash-and-gas explosions up to 7 km altitude occurred throughout October (figure 10), November, and December 2004. Possible minor ash-and-gas explosions and hot avalanches also occurred. On 28 December a gas-and-steam plume extended as far as 50 km E.

During January and February 2005, seismicity decreased slightly at Shiveluch but remained above background levels, with weak shallow earthquakes occurring beneath the active dome. Possible weak ash-and-gas explosions and hot avalanches occurred throughout January and February, and gas-and-steam plumes rose up to 2-7 km altitude.

On 13 January, several ash explosions up to 5 km altitude and a pyroclastic flow probably occurred. The Tokyo Volcanic Ash Advisory Center (VAAC) reported an eruption of Shiveluch on 17 January at 1625 with a plume that rose to a height of ~ 4.5 km altitude. On 6 February a pyroclastic flow traveled ~ 2 km down the volcano's flank. On 17 February ash deposits were seen on the volcano's snow-covered lava dome extending to the SE and S.

A large eruption occurred at Shiveluch from 1825 on 27 February to 0100 on 28 February, leading KVERT to raise the Concern Color Code from Orange to Red (the highest level). Meteorological clouds obscured the volcano during the eruption. According to satellite data (NOAA 16 at 1656 UTC on 27 February), a 45-pixel thermal anomaly was registered near the dome (band 3). This anomaly was probably related to a large pyroclastic flow on the SW flank. At this time analysts detected a 45-km-long ash cloud on satellite imagery trending NW of the volcano. At 0900 on the 28th, ash deposits were noted in the town of Klyuchi, ~ 46 km from the volcano. Satellite imagery from 1205 on 28 February showed ash deposits W of Shiveluch covering an area of 24,800 km^2. Later that day, an ash cloud extending more than 360 km was centered over the western half of Kamchatka. On 1 March the Concern Color Code was reduced to Orange. Prior to the 27 February eruption, seismicity was above background levels and ash-and-gas plumes were seen on video rising to ~ 3 km above the lava dome.

Explosions deposited ash in Ust'-Hairyuzovo village, about 250 km to the W, on 27 and 28 February, and on 2 March. The seismic station at Shiveluch stopped working on 27 February. According to visual and video data on 2 March, part of a large pyroclastic flow was observed on the SW flank of the volcano. According to satellite data from the USA and Russia, a 2- to 23-pixel thermal anomaly was registered at the dome on 1-3 March. Clouds obscured the volcano at other times. Shiveluch remained at Concern Color Code Orange.

Background. The high, isolated massif of Shiveluch volcano (also spelled Sheveluch) rises above the lowlands NNE of the Kliuchevskaya volcano group. The 1,300 km^3 Shiveluch is one of Kamchatka's largest and most active volcanic structures. The summit of roughly 65,000-year-old Strary Shiveluch is truncated by a broad 9-km-wide late-Pleistocene caldera breached to the S. Many lava domes dot its outer flanks. The Molodoy Shiveluch lava dome complex was constructed during the Holocene within the large horseshoe-shaped caldera; Holocene lava dome extrusion also took place on the flanks of Strary Shiveluch.

At least 60 large eruptions of Shiveluch have occurred during the Holocene, making it the most vigorous andesitic volcano of the Kuril-Kamchatka arc. Widespread tephra layers from these eruptions have provided valuable time markers for dating volcanic events in Kamchatka. Frequent collapses of dome complexes, most recently in 1964, have produced debris avalanches whose deposits cover much of the floor of the breached caldera.

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Veniaminof

Alaska Peninsula, USA
56.17°N, 159.38°W; summit elev. 2,507 m
All times are local = UTC - 9 / 8 hours (winter / summer)

After a long period of quiescence, Veniaminof began exhibiting increased seismicity and possible low-level eruptive activity from September 2002 through mid-April 2003. Between mid-April 2003 and February 2004 no signs of activity were observed. From February 2004 until the end of June 2004 steam and ash emissions were observed and volcanic tremor and earthquakes recorded (*Bulletin* v. 29, no. 6).

Activity during July 2004. Throughout July 2004 short intervals of volcanic tremor continued. Small amounts of dark ash were seen in the ice-filled caldera on 27 June. During the second week of July, the Alaska Volcano Observatory (AVO) reported that the tremor correlated well with ash-and-steam plumes as high as 1.5 km altitude; during the rest of the month, these plumes may have reached as high as 3.7 km altitude. On 22 July at 1229, an AVO field crew witnessed a small ash burst rise a few hundred meters above the summit of the intracaldera cone (figure 11). This type of activity had prevailed at Veniaminof during the previous three months. During the last week of July, the cone produced variable amounts of white steam from at least two separate craters near its top. The snow-and-ice field over much of the caldera was covered with a discontinuous, 1- to 2-mm thick ash blanket. No visual observations of ash emissions were made after 22 July, although the recorded seismicity was similar to that observed during ash emissions in the previous few months. Veniaminof remained at Concern Color Code Yellow throughout July.

Activity during August 2004. Episodes of volcanic tremor continued throughout August. No visual observations of ash emissions were made from 22 July through the first week of August, although the recorded seismicity was similar to that observed during ash emissions in the previous weeks. Throughout the month, frequent small ash-and-steam emissions from Veniaminof were visible on the web camera in Perryville and confirmed by AVO geologists working in the area. Bursts of volcanic tremor recorded intermittently on 17 August were probably associated with low-level, short-term ash emissions. Veniaminof remained at Concern Color Code Yellow throughout August 2004.

Activity during September 2004. During the first three weeks of September both low-level tremor and intermittent bursts of tremor continued at Veniaminof. AVO scientists believed tremor episodes likely represented low-level ash-and-steam emissions similar to those observed during the previous two months. Minor emissions of ash and steam were occasionally seen on the web camera during clear weather. During the last week of September, low-level tremor and intermittent small tremor bursts may have occurred at Veniaminof, but high winds in the area caused considerable vibrational noise, masking the signal of interest, and making analysis of seismic records inconclusive. The winds were strong enough to hide evidence of low-level tremor. If the tremor episodes continued, they likely corresponded with low-level ash-and-steam emissions similar to those observed over the previous four months. Cloudy conditions obscured views of the volcano by web camera and satellite. Veniaminof remained at Concern Color Code Yellow throughout September.

Activity during October 2004. Low-level seismic tremor and intermittent small tremor bursts continued. These tremor episodes likely represented low-level ash and steam emissions similar to those observed over the past four

Figure 11. Veniaminof's intracaldera cone photographed on 22 July 2004 in a view to the SW. The ~330-m-high intracaldera cinder and spatter cone was the source of all known historical Veniaminof eruptions. The cone protrudes through glacial ice that fills the summit caldera. Although this photo was taken during an interval with occasional minor ash and steam emissions, at this moment only steam rises to a few hundred meters above the cone. A very faint dusting of ash has discolored the glacier's surface; however, some may be older, wind-blown ash rather than freshly erupted ash. Courtesy of K.L. Wallace, USGS.

Figure 12. Veniaminof intracaldera cinder cone, 11 January 2005. The elevation of the cone is 2,156 m and the ash plume is drifting to NE. Photo taken during an observational overflight. Image courtesy of K.L.Wallace, USGS.

months, although cloudy conditions obscured views of the volcano by web camera and satellite.

Low-level tremor during 8-15 October correlated with weak steaming of the intracaldera cone as observed on the web camera. No ash emissions were observed, although cloudy conditions over the caldera restricted viewing for much of the week. AVO lowered the Concern Color Code at Veniaminof on 26 October from Yellow to Green. Seismicity, which had been associated with ash emissions during the summer of 2004, decreased to levels that indicated ash, ash-and-steam, or steam emissions were no longer occurring on a regular basis. Since early September, no ash emissions were seen on the web camera and no evidence of ash was visible on satellite imagery. Also, AVO had received no recent reports of ash from pilots or ground observers. AVO considered the intermittent, low-level seismic tremor that continued to be recorded at the volcano to be part of the background activity.

Activity during January 2005. AVO raised the Concern Color Code at Veniaminof from Green to Yellow on 4 January because around that time several small ash emissions from the volcano's intracaldera cone were observed on the web camera in Perryville. Ash emissions were visible starting around 0938, but may have been obscured by meteorological clouds in previous images. The discrete ash emissions were small, rose hundreds of meters above the cone, and dissipated as they drifted E. Minor ash fall was probably confined to the summit caldera. Very weak seismic tremor was recorded beginning on 1 January, and increased slightly over the next 2 days. These seismic signals were similar to those recorded during steam-and-ash emissions in April to October 2004. However, there were no indications from seismic data that events significantly larger than those observed around 4 January were imminent.

AVO raised the Concern Color Code at Veniaminof from Yellow to Orange on 10 January as ash emissions from the volcano's intracaldera cone reached heights of nearly 4 km during 8-10 January (figure 12). Seismicity remained at elevated levels and satellite images showed a persistent thermal anomaly at the intracaldera cone. On 11 January, the Anchorage VAAC again reported emission of a thin ash cloud to ~ 3 km altitude visible on the Perryville web camera. On 12 January the Anchorage VAAC reported emission of a thin ash cloud, visible on the Perryville web camera, that rose to 3-4 km altitude, extended ENE, and dissipated within ~ 55 km of the volcano. On 14 January, a satellite image showed a thermal anomaly in the vicinity of the Veniaminof summit. Although the anomaly appeared less intense than when first detected on 8 January and volcanism seemed to have declined significantly since 12 January, activity still remained significantly higher than normal with occasional bursts of volcanic tremor.

During the rest of the month of January, seismic data, web camera views, and satellite images indicated that low-level ash emissions continued at Veniaminof. Seismicity was similar to levels observed during the previous week, consisting of low-amplitude volcanic tremor with occasional larger bursts. During clear weather, satellite imagery showed anomalous heat at the summit cone, consistent with hot blocks and ash being ejected from the active vent. In addition, the web camera showed intermittent ash plumes reaching as high as 3 km altitude. Occasional stronger bursts of seismic tremor during 20-21 January and around 28 January may have indicated plumes to higher levels, but not above 4 km altitude. Veniaminof remained at Concern Color Code Orange.

Activity during February 2005. On the evening of 3 February, Strombolian activity at Veniaminof was visible by residents of Perryville ~ 30 km from the volcano. Activity was also observed on web camera views and seen by satellite as an increase in radiated surface heat. An increase in seismicity suggested that Strombolian activity may have continued through 4 February while the volcano was obscured by clouds.

During 28 January to 4 February, seismicity at Veniaminof was similar to levels for the previous week, with low-amplitude tremor and occasional larger bursts. During clear weather, satellite imagery showed anomalous heat at the summit cone, consistent with hot blocks and ash being ejected from the active vent. The web camera showed intermittent ash plumes reaching as high as 3 km altitude. Veniaminof remained at Concern Color Code Orange.

Low-level Strombolian eruptive activity continued at Veniaminof during 4-11 February. On 9 February, an ash burst rose hundreds of meters above the intracaldera cone. Satellite images continued to show a thermal anomaly in the vicinity of the intracaldera cone, consistent with the presence of hot material at the vent. Seismicity remained above background levels at the volcano. On the morning of 10 February there was a distinct increase in the amplitude and frequency of earthquakes. The increase continued through 11 February. This activity was consistent with more energetic explosions from the active cone, but there were no indications that the bursts rose higher than 4 km altitude. Veniaminof remained at Concern Color Code Orange.

During 11-18 February, it was likely that low-level Strombolian eruptive activity continued at Veniaminof based on seismic data and satellite imagery. Cloudy conditions obscured web camera views of the volcano, and no ash emissions were observed above the cloud cover. Seismicity remained above background levels at Veniaminof. The character of the seismicity changed slightly during the report period, with frequent periods of continuous banded volcanic tremor occurring, but the amplitudes of earthquakes did not increase. This activity was consistent with explosions from the active cone; however, there was no indication that these bursts rose more than 4 km altitude. Veniaminof remained at Concern Color Code Orange.

Seismicity decreased substantially at Veniaminof during 18-25 February in comparison to previous weeks, leading AVO to decrease the Concern Color Code from Orange to Yellow. Periods of volcanic tremor diminished, and no discrete events associated with ash bursts had occurred for several days. Only minor steam emissions were seen. AVO received no reports of ash emissions from pilots or ground observers. AVO concluded that given the decline in seismicity, it appeared that the most recent episode of Strombolian eruptive activity at Veniaminof had ended.

Activity during March 2005. A further reduction in activity at Veniaminof during 25 February to 4 March led AVO to reduce the Concern Color Code from Yellow to Green, the lowest level. For more than a week seismic activity was at background levels, periods of volcanic tremor had ceased, and there were no discrete events associated with ash bursts. Only minor emissions of steam were observed on the web camera and satellite imagery. AVO received no reports of ash emissions from pilots or observers on the ground. They concluded that given the decline in seismicity it appeared that the most recent episode of eruptive activity had ended at Veniaminof.

Background. Massive Veniaminof volcano, one of the highest and largest volcanoes on the Alaska Peninsula, is truncated by a steep-walled, 8 x 11 km, glacier-filled caldera that formed around 3,700 years ago. The caldera rim is up to 520 m high on the N, is deeply notched on the W by Cone Glacier, and is covered by an ice sheet on the S. Post-caldera vents are located along a NW-SE zone bisecting the caldera. That zone extends 55 km from near the Bering Sea, across the caldera, and down the Pacific flank. Historical eruptions probably all originated from the westernmost and more prominent of two intra-caldera cones, which reaches an elevation of 2,156 m and rises about 300 m above the surrounding icefield. The other cone is larger, and has a summit crater or caldera that may reach 2.5 km in diameter, but is more subdued and barely rises above the glacier surface.

Information Contacts: *Alaska Volcano Observatory (AVO)*, a cooperative program of a) *U.S. Geological Survey*, 4200 University Drive, Anchorage, AK 99508-4667, USA (URL: http://www.avo.alaska.edu/; Email: tlmurray@usgs.gov), b) *Geophysical Institute, Univ. of Alaska*, P.O. Box 757320, Fairbanks, AK 99775-7320, USA (Email: eich@dino.gi.alaska.edu), and c) *Alaska Division of Geological & Geophysical Surveys*, 794 University Ave., Suite 200, Fairbanks, AK 99709, USA (Email: cnye@giseis.alaska.edu); *Kristi L. Wallace*, USGS/AVO, Alaska Tephra Laboratory and Data Center, 4230 University Drive, Suite 201, Anchorage, AK 99508, USA (Email: kwallace@usgs.gov).

St. Helens

Washington, USA
46.20°N, 122.18°W; summit elev. 2,549 m
All times are local (= UTC - 8 hours)

Growth of the new lava dome inside the crater of Mount St. Helens has continued since the last report (*Bulletin* v. 29, no. 10), accompanied by low rates of seismicity, low emissions of steam and volcanic gases, and minor production of ash. During such eruptions, episodic changes in the level of activity can occur over days to months. The eruption can also intensify suddenly or with little warning and produce explosions that may cause hazardous conditions within several kilometers of the crater and farther downwind. The current status is Volcano Advisory (Alert Level 2), and the aviation color code is orange.

A small, short-lived explosive event at St. Helens volcano began at approximately 1725 hours on 8 March 2005. Airplane pilot reports indicated that the resulting steam-and-ash plume reached an altitude of about 11 km above sea level within a few minutes and drifted NE.

Results from analysis of imagery by the U.S. Geological Survey of 21 February 2005 showed that the highest part of the new lava dome stands at an altitude of 2.3 km, 160 m higher than the old lava dome, and only 28 m below Shoestring Notch, a low point on the SE crater rim. Further analysis of recent aerial photos revealed that as of 1 February, the whaleback-shaped dome extrusion was about 470 m long and 150 m wide. The new dome and uplifted welt of crater floor and deformed glacier ice have grown to a combined volume of about 38 million m3, almost one-half the volume of the old lava dome.

Background. Prior to 1980, Mount St. Helens formed a conical, youthful volcano sometimes known as the Fuji-san of America. During the 1980 eruption the upper 400 m of the summit was removed by slope failure, leaving a 2 x 3.5 km horseshoe-shaped crater now partially filled by a lava dome. Mount St. Helens was formed during nine eruptive periods beginning about 40-50,000 years ago and has been the most active volcano in the Cascade Range during the Holocene. Prior to 2,200 years ago, tephra, lava domes, and pyroclastic flows were erupted, forming the older St. Helens edifice, but few lava flows extended beyond the base of the volcano. The modern edifice was constructed during the last 2,200 years, when the volcano produced basaltic as well as andesitic and dacitic products from summit and flank vents. Historical eruptions in the 19th century originated from the Goat Rocks area on the N flank, and were witnessed by early settlers.

Information Contacts: *Cascades Volcano Observatory (CVO)*, U.S. Geological Survey, 1300 SE Cardinal Court, Building 10, Suite 100, Vancouver, WA 98683-9589, USA (URL: http://vulcan.wr.usgs.gov/; Email: GS-CVO-WEB@usgs.gov); *Pacific Northwest Seismograph Network (PNSN)*, Seismology Lab, University of Washington, Department of Earth and Space Sciences, Box 351310, Seattle, WA 98195-1310, USA (URL: http://www.pnsn.org/; Email: seis_info@ess.washington.edu).

Kick 'em Jenny

Grenada, West Indies
12.30°N, 61.64°W; summit elev. -185 m

The University of West Indies Seismic Research Unit (SRU) has augmented their instrumental monitoring network and warning system at Kick 'em Jenny submarine volcano. In addition to long-period and broadband seismometers to sense earthquakes, they have also employed tide gauges to measure seawater disturbances, hydrophones to discern submarine explosions, and tilt meters and global positioning system (GPS) stations to detect long-term ground deformation. The instruments may disclose anomalies and critical symptoms before an eruption begins. Various combinations of these instruments were installed at Mt. St. Catherine, Sauteurs, The Sisters Rocks, Isle de Ronde, Isle de Caille, and Carriacou (figure 13).

The NSF Caribbean Tsunami Workshop was held in March 2004 (Mercado-Irizarry and Liu, 2004). The Workshop’s program ended its Introduction section with this statement: “ . . . Kick ‘em Jenny, close to the islands of the southeastern Caribbean (just 10 km N of Grenada), is of much concern to the local governments. Past eruptions during the last century (1939, 1965) resulted in observed deep water tsunamis, with the one in 1939 being measured as 1 m high [Shepherd, 2001]. The concern is such that, for the first time (at least in the region), a banking institution (the Caribbean Development Bank) is funding a monitoring program [at] the volcano.”

A 29 December 2004 article entitled "Tsunami warning system for the Caribbean," posted on the SRU website, also addressed the issue. It noted that, “The devastation caused by the tsunami which ravaged several Asian countries on 26th December 2004 has sparked discussion on the importance of a tsunami early warning system in the Caribbean. While in theory such a system may seem invaluable in light of the Asian disaster, scientists at the Seismic Research Unit currently believe that several factors should be seriously considered before assuming that a tsunami early warning system would be beneficial to the region. Head of the Seismic Research Unit, Dr. Richard Robertson, says that ‘Before the region spends valuable resources on setting up new instruments for a tsunami early warning system, we need to strengthen our existing networks and focus on improving public education and communication activities with regard to geologic hazards in the region.’”

Gas release, T-phase seismicity, and minor eruption clouds. The question of whether or not there is strong fumarolic activity in the crater has been a source of speculation for a number of years. It has been suggested that warmed water rising in convection currents contributed to the reputation of the Kick ‘em Jenny region for rough water. The emission of large quantities of bubbles was observed in 1989 when the submersible *Johnson Sealink* entered the crater a few months after the 1988 eruption (*Bulletin* v. 14, no. 5).

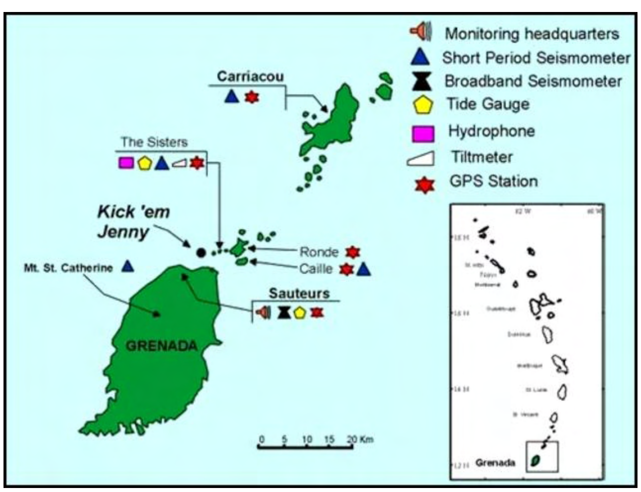

Figure 13. A map indicating positions of monitoring instruments for the current network at Kick ‘em Jenny. Tilt meters and tide gauges were not functioning at the time of this writing (early 2005). (Inset) Grenada and Carriacou islands lie at the S end of the West Indies. Courtesy of SRU.

A water column containing a significant proportion of rising gas bubbles results in a local lowering of the seawater’s density. (The rising bubbles displace some of the sea water, and at or near the sea surface they provide negligible support to the ship, thus resulting in a loss of buoyancy for ships passing over the volcano.) To account for this hazard, and the risk posed by ejecta, an exclusion zone 1.5 km in radius was created over the volcano (Shepherd, 2004).

At least 11 historical episodes of hydro-acoustic (T phase) signals have been detected since 1939 when an eruption cloud rose 275 m above the sea surface (Shepherd and Robson, 1967, Smith and Shepherd, 1995, Lindsay et al., 2005). Material was also ejected during the 1974 eruption, and the 1988 eruption was associated with turbulent discolored water (Lindsay and others, 2005). Some of these were described in Smithsonian reports dating back to 1977.

Regarding T-Phase waves. A short-period wave group from a seismic source that has propagated in part through the ocean is called T-phase or T(ertiary)-wave (Linehan, 1940; Tolstoy and Ewing, 1950; Walker and Hammond, 1998). The wave group propagates with low attenuation as hydro-acoustic (compressional) waves in the ocean, constrained within a low sound-speed wave guide (the sound fixing and ranging-SOFAR-channel) formed by the sound-speed structure in the ocean. The T-phase signal may be picked up by hydrophones in the ocean or by land seismometers. Upon incidence with the continental shelf/slope, the wave group is transformed into ordinary seismic waves that arrive considerably later than seismic wave groups from the same source that propagated entirely through the solid Earth.

2002 and 2003 Surveys. A 2003 oceanographic survey of Kick ‘em Jenny was conducted jointly by the National Oceanic and Atmospheric Agency (NOAA), SRU, and the University of Rhode Island (URI) using the NOAA Research Vessel *Ronald H. Brown*. This survey supplemented data obtained previously from a cruise passing the volcano on 12 March 2002 (*Bulletin* v. 27, no. 6). That effort produced the bathymetric image shown in *Bulletin* v. 27 no. 6 and reproduced here as figure 14. The arcuate scarp on the image suggested that the volcano was once the scene of sector collapse. The inferred submarine debris avalanche has an estimated total volume of ~ 10 km^3, and a maximum runout distance of at least 15 km (Sigurdsson and others, 2004; Shepherd 2004). The collapse clearly occurred prior to the growth of the small central edifice at Kick ‘em Jenny. The ages of these various features remain unknown.

Figures 15 and 16 highlight the discovery of other volcanic features on the sea floor just E of Kick ‘em Jenny. Little is known about them aside from their basic morphology illuminated by the 2003 survey. Discoveries near Kick ‘em Jenny included three craters (C1, C2, and the largest, Kick ‘em Jack) and two domes (D1 and D2). The mutual relations and ages of these newly recognized features remain uncertain.

Background. Kick ‘em Jenny, a historically active submarine volcano 8 km off the N shore of Grenada, rises 1,300 m from the sea floor. The volcano is located on the steep inner western slope of the Lesser Antilles submarine ridge facing the Grenada Basin. Recent bathymetric surveys have shown evidence for a major arcuate collapse structure that was the source of a submarine debris avalanche that traveled more than 15 km to the W. Numerous historical eruptions, mostly documented by acoustic signals, have occurred since 1939, when an eruption cloud rose 275 m above the sea surface. Prior to the 1939 eruption, which was witnessed by a large number of people in northern Grenada, there had been no written mention of Kick 'em Jenny. Eruptions have involved both explosive activity and the quiet extrusion of lava flows and lava domes in the summit crater; deep rumbling noises have sometimes been heard onshore. Historical eruptions have modified the morphology of the summit crater.

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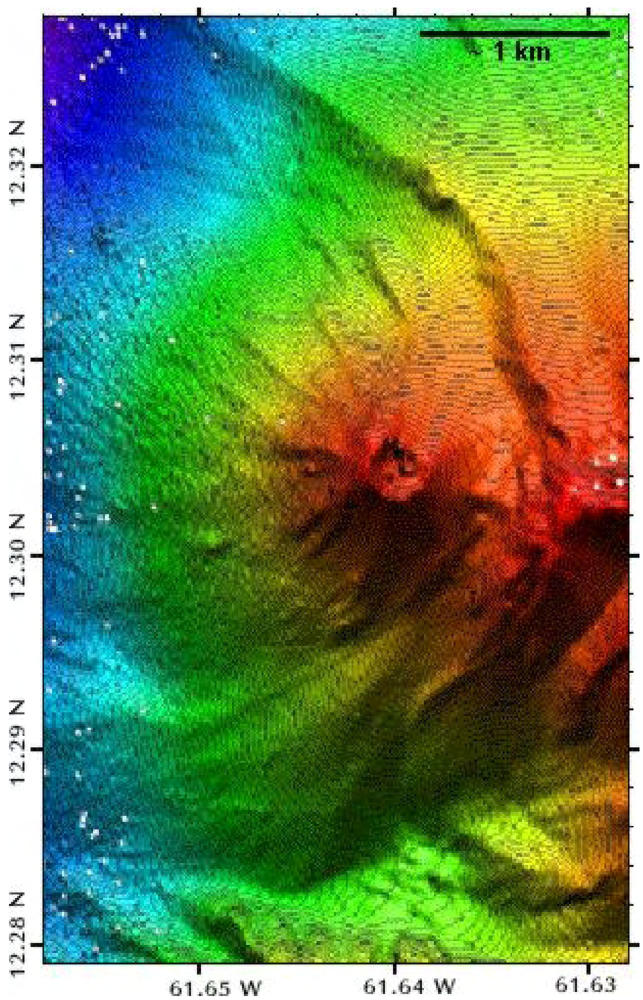

Figure 14. Morphology of Kick 'em Jenny, as revealed by a multi-beam survey by the NOAA Research Vessel Ronald H. Brown in March 2002 (N is toward the top; for approximate scale, the sub-circular summit crater is about ~ 300 m in diameter). The survey showed that the volcano's smaller, modern, active cone sits nested within a larger U-shaped depression that wraps completely around the cone's E side and opens toward the W. This larger depression presumably formed by slope failure and generated a W-directed debris avalanche that appears to lie within a marginal, confining levee. Courtesy of NOAA.

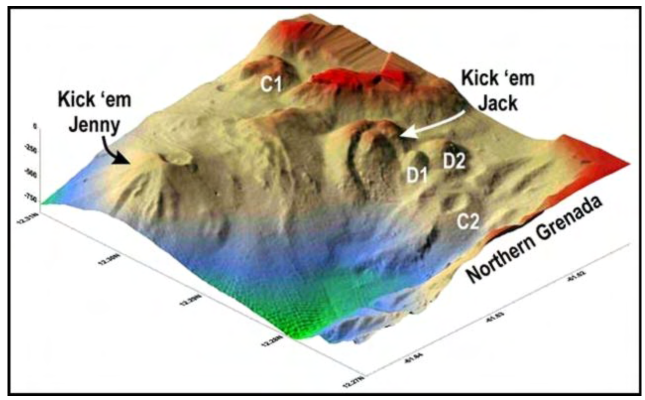

Figure 15. Vertically exaggerated SeaBeam image of Kick 'em Jenny and newly identified craters and domes discovered in March 2003. Kick 'em Jenny's summit occurs adjacent to the crater rim at a depth of ~ 185 m. The deepest point on Kick 'em Jenny's crater floor lies at ~ 264 m depth. The summit sits at 12º18.024' N, 61º38.388' W (12.3004º N, 61.6398º W). The image's left side is drawn N-S (i.e. N towards the upper left). Tick marks along the margins are at 0.01 degree intervals, a spacing equivalent to 1.8-1.9 km. The distance between Kick 'em Jenny and Kick 'em Jack is about 4 km. A vertical scale at the left indicates water depth: 0, -250, -500, and -750 m. Courtesy of NOAA and SRU.

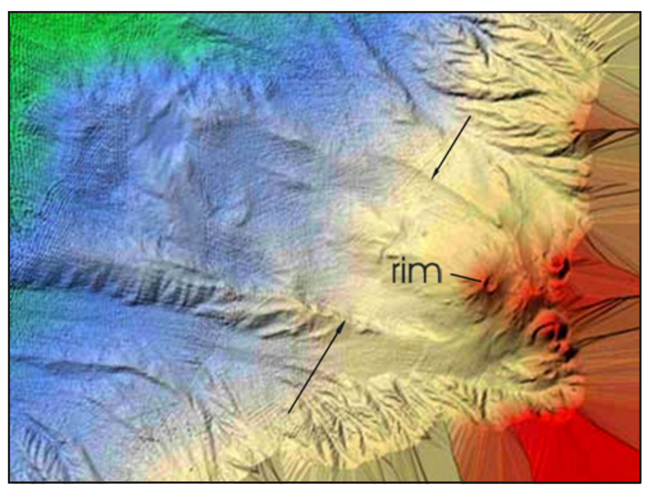

Figure 16. Broad-scale SeaBeam image of Kick 'em Jenny and adjacent features compiled from *Ronald H. Brown* cruise observations, March 2003. North is up. The crater rim of Kick 'em Jenny ("rim"), as well as the rest of the body of that dome, lie within a larger arcuate scarp that wraps around the dome's E side. On the dome's W side the scarp extends outward, crossing a swath of sea floor as two sub-parallel arms (indicated by the arrows). Kick 'em Jack lies well outside this scarp, ~ 4 km SE of Kick 'em Jenny. Courtesy of NOAA and SRU.

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Information Contacts: *Seismic Research Unit (SRU)*, The University of the West Indies, St. Augustine, Trinidad & Tobago, West Indies (URL: http://www.uwiseismic.com); *Research Vessel Ronald H. Brown*, National Oceanic and Atmospheric Agency (NOAA), Marine Operations Center, Atlantic, 439 West York Street, Norfolk, VA 23510-1145, USA (URL: http://oceanexplorer.noaa.gov/explorations/).

Marion Island

Southern Indian Ocean, South Africa
46.90°S, 37.75 E; summit. elev 1,230 m

A small volcanic eruption was observed on 24 June 2004 by a member of the South African National Antarctic Programme’s (SANAP) over-wintering team on Marion Island (figure 17). While conducting fieldwork in a mountainous area on the S part of the island, David Heddings was able to video an eruption that comprised gas and small pieces of scoria (a few centimeters in diameter).

While it has been assumed that small volcanic eruptions often take place on Marion Island, the remoteness and hilly terrain over much of the island has meant that such events have not been witnessed. The last confirmed eruption on Marion took place in 1980 when ornithologists found a fresh basaltic lava flow on the W side of the Island.

Background. Marion Island, South Africa’s only historically active volcano, lies at the SW end of a submarine plateau immediately south of the SW Indian Ocean Ridge, opposite Prince Edward Island. The low profile of 24-km-wide dominantly basaltic and trachybasaltic Marion Island is formed by two young shield volcanoes that rise above a flat-topped submarine platform. The 1,230-m-high island is dotted by about 150 cinder cones, smaller scoria cones, and coastal tuff cones. More than 130 scoria cones and many lava flows formed during the Holocene. Many of these appear younger than the 4,020 BP peat overlying one of the flows (Verwoerd, 1981). Young unvegetated lava flows appear to be only a few hundred years old (Verwoerd, 1967). The first historical eruption, during 1980, produced explosive activity and lava flows from a 5-km-long fissure that extended from the summit to the W coast.

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Figure 17. The SANAP base station, located on the E side of Marion Island. Courtesy of Ian Meiklejohn.

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