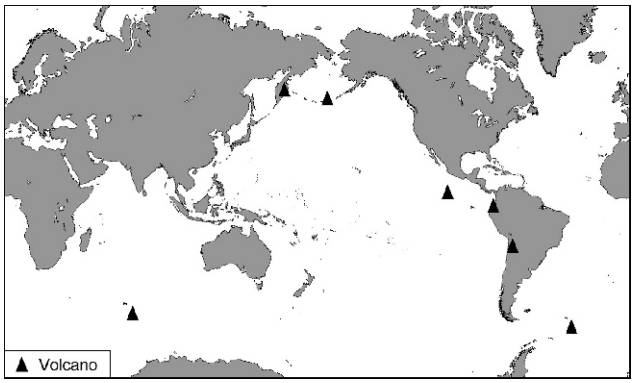
Bulletin of the Global Volcanism Network



Volume 31, Number 11, November 2006

Smithsonian
National Museum of Natural History

James F. Luhr

With deep regret we announce that Jim Luhr passed away unexpectedly and peacefully in his sleep on 1 January 2007 at the age of 53. He directed the Smithsonian's Global Volcanism Program during 1995 through 2006, and in that role helped elevate both this *Bulletin* and its younger sister publication, the *SI / USGS Weekly Volcanic Activity Report*. Jim was well-known for well-crafted, multifaceted analytical studies of his beloved Mexican volcanoes. More details will appear in next month's *Bulletin*.

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

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

Unnamed

East Pacific Rise at 9°50' N
9.42-9.92°N, 104.00-104.32°W; summit elev. -2,500? m

According to the RIDGE 2000 Program website, a new eruption on the East Pacific rise (EPR) was first suspected during a visit to the site by the research vessel (RV) *Knorr* in April 2006. Since October 2003 an array of up to 12 ocean-bottom seismometers (OBSs) had been deployed in an area ~ 4 x 4 km located between 9°49' N and 9°51' N (the EPR Integrated Study Site, ISS) as part of a continuing microseismicity monitoring project being led by Maya Tolstoy and Felix Waldhauser.

Investigators attempted to recover 12 OBSs on 25 April 2006, but only four were recovered. Tolstoy and others (2006), Chadwick (2006), and the Ridge 2000 Program (2006) reported that eight OBS were stuck in the new lava on the sea floor (see figure 1) from an eruption that had occurred since the last OBS servicing in May 2005. Water column measurements were also made by the *Knorr*, yielding light-scattering measurements indicative of extensive particulates in the water column, and corroborating the evidence for a recent eruption (*BGVN* 31:06).

The TowCam images suggested that the new lavas erupted from fissures within the axial summit trough (AST), which reestablished quickly after the event by drain-back and collapse. Comparison of TowCam bathymetry with pre-eruption Alvin mapping suggested that after the eruption the axial summit trough became 10-15 m narrower and a few meters shallower at 9°50.4' N. Lava flow morphologies indicate that the highest effusion rates were near 9°50' N.

Radiometric dating of 10 rocks collected from the young terrain is under way, using ^{210}Po. Preliminary ^{210}Po results in Tolstoy and others (2006) indicate that nine of the rocks were erupted within a year before their collection, with dates ranging from late summer 2005 to January 2006.

According to Tolstoy and others (2006), based on the sea-floor images, the extent of water column anomalies, the preliminary lava ages, and the distribution of OBSs that failed to return, they estimated that the flow extended intermittently for at least 18 km along the ridge axis. This zone extends from 9°46' N to 9°55.7' N, with off-axis extent ranging from 0 to 1 km. The eruption occurred on the same segment (segment B) as the 1991-1992 eruption, with a similar length scale.

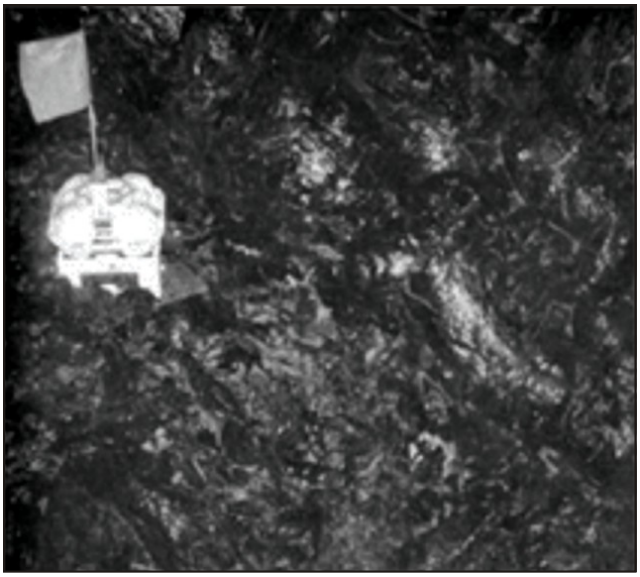


Figure 1. Sea floor photo from the TowCam taken on the EPR during the June 2006 RV *Atlantis* cruise showing an ocean-bottom seismometer caught in a new lava flow. Taken from Chadwick (2006).

The loss of some seismometers did not preclude the capture of important data associated with the eruption, including precursory activity. Tolstoy and others (2006) found a gradual ramp-up in seismicity since monitoring began at this site in October 2003. The pattern of seismicity culminated in an intense but brief (6-hour) inferred diking event on 22 January 2006, followed by rapid tapering to markedly decreased levels of seismicity.

Two follow-up cruises proceeded to the eruption site, the RV *New Horizon* in April-May 2006, and the RV *Atlantis* in June 2006. They assessed the extent of the new eruption and its effect on the biological communities, ecosystems, and chemistry at the EPR ISS. More work on the event was recently reported at the Fall 2006 meeting of the American Geophysical Union (Eg., session V13 C).

Background. The East Pacific Rise (EPR) near 9°50' N spreads at a full rate of ~ 110 mm per year and is one of the better-studied mid-ocean ridge (MOR) segments in the world. Ever since an eruption was documented in 1991, scientists have regularly returned to document ecosystem progression, to study changes in vent-fluid chemistry and temperature, and to conduct detailed geological mapping. Anomalies in water-column measurements of temperature and light scattering indicated vigorous discharge of high-temperature hydrothermal fluids. Radiometric dating of rocks collected from the young terrain, using ^{210}Po, indicated that many of the rocks were erupted within a year before their collection. Sea-floor images give further evidence of the recency of surface lava flows.

Geologic Summary. Evidence for a very recent, possibly ongoing eruption was detected during a series of dives in the submersible vessel Alvin in 1991 on the East Pacific Rise at about 9 degrees 50 minutes N. Hot-vent animal communities that had been documented during November to December 1989 imaging were observed to have been buried by fresh basaltic lava flows, and the scorched soft tissues of partially buried biota had not yet attracted bottom scavengers. Fresh black smoker chimneys were draped by new lava flows. This position was at a depth of about 2500 m south of the Clipperton fracture zone, about 1,000 km SW of Acapulco, México. It coincided with a location where fresh lava flows previously estimated as less than roughly 50 years in age had been found (Haymon et al., 1991). Later dating of very short half-life radionuclides from dredged samples confirmed the young age of the eruption and indicated that another eruptive event had taken place in late 1991 and early 1992.

References. Tolstoy, M., Cowen, J.P., Baker, E.T., Fornari, D.J., Rubin, K.H., Shank, T.M., Waldhauser, F., Bohnenstiehl, D.R., Forsyth, D.W., Holmes, R.C., Love, B. , Perfit, M.R., Weekly, R.T., Soule, S.A., and Glazer, B., 2006, A sea-floor spreading event captured by seismometers, Science, v. 314, no. 5807, p. 1920-1922.

Hinds, J.S., Perfit, M.R., Soule, S.A., Fornari, D.J., and Ridley, W.I., 2005, Discriminating lava flows from the EPR ISS (9°25'-9°55' N) using lava morphology, petrography, and geochemistry: American Geophysical Union, Fall

Meeting 2005, abstract #T31A-0496 (2005AGUFM. T31A0496H).

Chadwick, W.W., Jr., 2006, A submarine volcano is caught in the act: Science, v. 314, no. 5807, p. 1887-1888.

Ridge 2000 Program, 2006, News: Ridge 2000 research discover/document seafloor eruption: Ridge 2000 Program web site, URL: http://www.ridge2000.org/science/tcs/epr_2006_science_supp_material.php.

Information Contact: *Ridge 2000 Program*, Ridge 2000 Program Office, Institute of Geophysics and Planetology (IGPP), University of California San Diego, Scripps Institution of Oceanography, La Jolla, CA 92093-0225, USA (URL: http://www.ridge2000.org/).

Láscar

northern Chile
23.37°S, 67.73°W; summit elevation 5,592 m
All times are local (= UTC - 4 hours)

This report covers the time interval September-October 2006 and was contributed by scientists from the Universidad Católica del Norte (Chile), University of Florence (Italy), Universidad Nacional de Salta (Argentina), and Universidad Nacional Autónoma de México (México). Changes seen in Láscar's central active crater after the May 2005 and April 2006 eruptions and after the gas fumaroles investigation carried out during September 2006. Our previous report covered activity into early May 2006 (*BGVN* 31:04).

Eruptive activity. Substantial ash emissions were noted on 18-21 and 28 April 2006. Several small phreatic explosions occurred starting 18April, continuing through May, July, and August 2006; the last in that time frame occurring on 14 August. After that, three minor explosions occurred between September and October 2006.

An explosion occurred at 0812 on 21 September. The eruptive plume reached 800 m above summit crater. A dark gray-colored plume, with moderate ash content dispersed NNE. The event failed to produce detectable ashfall, seismic activity, or eruption noises.

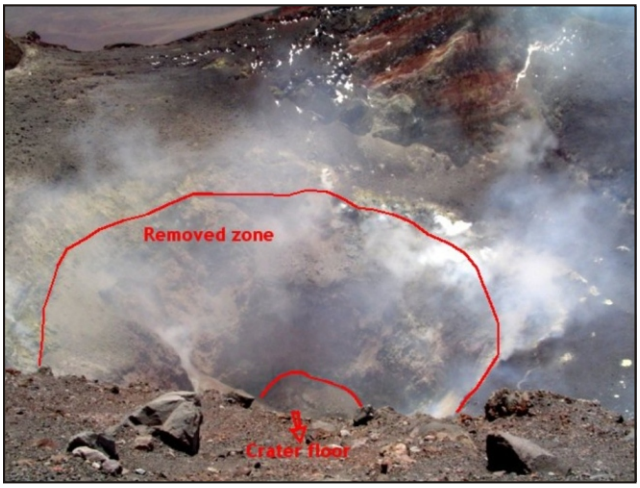


Figure 2. A March 2005 photo of the central active crater of Lascar seen from the S side. The May 2005 Vulcanian eruption removed portions of the crater floor and internal crater wall, leaving a circular crater with a "new rock wall" exposed. Photograph taken by Felipe Aguilera.

A minor explosion at 0830 on 20 October 2006 sent an eruptive plume up to 200 m above the summit crater. A dark gray-colored plume with moderate ash content dispersed E. At 1900 a larger eruption lasted 25 minutes. A dark gray-colored plume with moderate ash content reached 800 m above the summit crater and dispersed E. The October events also did not produce detected ashfall, seismic activity, or eruption noises.

Morphological changes in central active crater. Significant morphological changes, principally to the crater floor, occurred after the May 2005 Vulcanian eruption (Aguilera and others, 2006a; *BGVN* 30:04 and 30:05). Field and aerial observations between October 2002 and March 2005 showed a typical funnel shaped crater, with a depth of 450 m (Aguilera and others, 2003). This phenomena has been recognized as always occurring during the collapse-period of the lava dome growth-collapse cycle described by Matthews and others (1997). The observations during October 2002 and March 2005 show that the crater floor can be recognized from the S border of the central active crater (figure 2). However, observations during December 2005 (after the May 2005 Vulcanian eruption) and September 2006 (after the April 2006 eruptive cycle) show that the crater floor cannot be recognized from S border of central active crater (figure 3), probably indicating subsidence of the crater floor (Aguilera and others, 2006b; *BGVN* 31:04; and Clavero and others, 2006). Observations made in the central active crater indicate subsidence of crater floor.

The photograph from October 2002 (figure 4) shows the position of the crater floor inferred just before the May 2005 eruption, while the photograph from September 2006 (figure 5) shows the crater floor after the May 2005 and April 2006 eruptions. The position of the crater floor before the May 2005 eruption corresponded to a level associated with talus deposits, and the latest crater floor lay at the bottom of a new circular crater. A notable change in the morphology of the internal walls of the central active crater between the March and December 2005 photographs was the absence of a part of the crater wall (probably corresponding to parts of ancient lava domes, ballistic and ashfall deposits), exposing a new N wall of the crater.

Gas fumarole investigations. During 9-15 September 2006, gas sampling from fumaroles inside the central active

Figure 3. Central active crater of Lascar viewed from S side. Shown is the new rock wall of the inner crater after May 2005 Vulcanian eruption. Photograph taken by Felipe Aguilera, December 2005.

Figure 4. Central active crater of Lascar seen from the N internal wall, October 2002. Photograph taken by Franco Tassi.

crater was carried out by personnel of Universidad Católica del Norte (Chile). They noted a lowering of the temperature of fumaroles from 385°C to 250°C in October 2002 (Tassi and others, 2004). Scientists from Università degli studi di Firenze (Italy) and Universidad Católica del Norte (Chile) are conducting a systematic and permanent gas sampling campaign at Láscar and other active volcanoes of the Central Volcanic Zone (e.g. Putana, Lastarria, Isluga and others). Scientists from the Universidad Católica del Norte, the Universidad Nacional de Salta and SEGEMAR (Argentina) are processing data from Landsat TM and ETM+ and from ASTER images, with the objective of understanding the behavior of Lascar volcano during the 1998-2004 period.

Geologic Summary. Láscar is the most active volcano of the northern Chilean Andes. The andesitic-to-dacitic stratovolcano contains six overlapping summit craters. Prominent lava flows descend its NW flanks. An older, higher stratovolcano 5 km to the east, Volcán Aguas Calientes, displays a well-developed summit crater and a probable Holocene lava flow near its summit (de Silva and Francis, 1991). Láscar consists of two major edifices; activity began at the eastern volcano and then shifted to the western cone. The largest eruption of Lascar took place about 26,500 years ago, and following the eruption of the Tumbres scoria flow about 9000 years ago, activity shifted back to the eastern edifice, where three overlapping craters were formed. Frequent small-to-moderate explosive eruptions have been recorded from Láscar in historical time since the mid-19th century, along with periodic larger eruptions that produced ashfall hundreds of kilometers away from the volcano. The largest historical eruption of Láscar took place in 1993, producing pyroclastic flows to 8.5 km NW of the summit and ashfall in Buenos Aires.

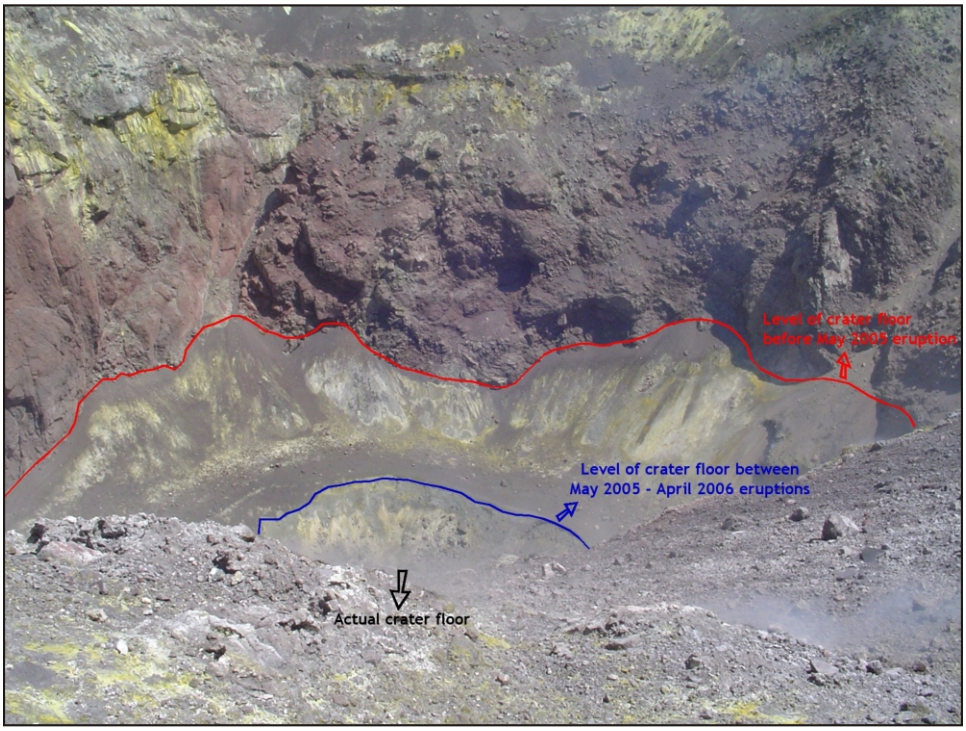


Figure 5. A September 2006 photo of the central active crater of Lascar seen from the NE. Shown are the level of the crater floor before the May 2005 Vulcanian eruption, the level of crater floor between May 2005 and April 206 eruptions, and the current crater floor. Photograph taken by Felipe Aguilera.

References. Aguilera, F., Viramonte, J., Medina, E., Guzmán, K., Becchio, R., Delgado, H., and Arnosio, M., 2006a, Eruptive activity from Lascar volcano (2003-2005): XI Congreso Geológico Chileno, Antofagasta, 2006, p. 397-400.

Aguilera, F., Viramonte, J., Medina, E., Guzmán, K., Becchio, R., Delgado, H., and Arnosio, M., 2006b, Recent eruptive activity from Lascar volcano (2006): XI Congreso Geológico Chileno, Antofagasta, 2006, p. 393-396.

Clavero, J., Naranjo, J., and Cayupi, J., 2006, El ciclo eruptivo del 18 al 25 de Abril de 2006 del Volcán Lascar, Andes Centrales: XI Congreso Geológico Chileno, Antofagasta, 2006, p. 435-438.

Giggenbach, W., 1975, A simple method for the collection and analysis of volcanic gas samples: Bulletin of Volcanology, v. 39, p. 132-145.

Giggenbach, W., and Goguel, R., 1989, Collection and analysis of geothermal and volcanic water and gas discharges: DSIR Chemistry, Rept. No. 2401.

Matthews, S., Gardeweg, M., and Sparks, R., 1997, The 1984 to 1996 cyclic activity of Lascar volcano, northern Chile: cycles of dome growth, dome subsidence, degassing and explosive eruptions: Bulletin of Volcanology, v. 59, p. 72 - 82

Tassi, F., Viramonte, J., Vaselli, O., Poodts, M., Aguilera, F., Martínez, C., Rodríguez, L., and Watson, I., 2004, First geochemical data from fumarolic gases at Lascar volcano, Chile: 32nd International Geological Congress, Florence, August 20-28, 2004.

Viramonte, J., Aguilera, F., Delgado, H., Rodríguez, L., Guzman, K., Jiménez, J., and Becchio, R., 2006, A new eruptive cycle of Lascar volcano (Chile). The risk for the aeronavigation in northern Argentina: Garavolcan 2006, Tenerife, Spain.

Information Contacts: *Felipe Aguilera*, *Eduardo Medina*, *Karen Guzmán*, and *Valeria Ortega*, Programa de Doctorado en Ciencias mención Geología and Depto de Ciencias Geológicas, Univ Católica del Norte, Avenida Angamos 0610, Antofagasta, Chile (Email: faguilera@ucn.cl, emedina@ucn.cl, kgm001@ucn.cl, vop002@ucn.cl); *Franco Tassi* and *Orlando Vaselli*, Dept of Earth Science, Univ of Florence, Via La Pira 4, 50110, Florence, Italy (Email: francot@steno.geo.unifi.it, vaselli@steno.geo.unifi.it; URL: http://www.geo.unifi.it/); *José G. Viramonte*, Instituto GEONORTE and CONICET, Univ Nacional de Salta, Buenos Aires 177, Salta 4400, Argentina (Email: viramont@unsa.edu.ar; URL: http://www.unsa.edu.ar/natura/); *Hugo Delgado G.*, Instituto de Geofísica, Univ Nacional Autónoma de México, Ciudad Universitaria, Del Coyoacán, México D.F., C.P. 04510, México (Email: hugo@tonatiuh.igeofcu.unam.mx; URL: http://www.igeofcu.unam.mx/).

Montagu Island

Antarctica
58.42°S, 26.33°W; summit elev. 1,370 m
All times are local (= UTC - 2 hours)

Matt Patrick provided three new ASTER images showing Montagu on 28 October 2006. The ASTER VNIR image (Bands 3-2-1, RGB) (figure 6) depicts Montagu in a state similar to that observed in other ASTER images of the eruption. The persistent ash plume has covered the NE quadrant of the island in dark tephra, while the lava field extending from the summit vent to the coast is clearly visible. The lava delta, extending to a distance of ~ 3.5 km from the vent, first formed during the September-October 2005 eruptive phase and remains intact (*BGVN* 30:11). It is unclear if any new lava flows erupted since that time have extended as far.

ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is an imaging radiometer that consists of three distinct telescope subsystems: near infrared (VNIR), shortwave infrared (SWIR), and thermal infrared (TIR). These have the following spectral ranges, number of bands, and spatial resolutions: VNIR (spectral range, 0.5-0.9 µm in three bands; spatial resolution, 15 m); SWIR (spectral range 1.6-2.5 µm in six bands, spatial resolution 30 m); TIR (8-12 µm in five bands; spatial resolution, 90 m).

Patrick noted that the ASTER TIR (Band 14; thermal infrared wavelength 10.95-11.65 µm) and SWIR (Band 9; short-wave infrared wavelength 2.360-2.430 µm) images (figure 7) may show a new lava flow reaching ~ 1.5 km NE from the summit. An elongated section of warm pixels in the TIR corresponds to a feature which appears to have a faint outline of anomalous pixels in the SWIR, possibly reflecting a new flow.

Geologic Summary. The largest of the South Sandwich Islands, Montagu consists of a massive shield volcano cut by a 6-km-wide ice-filled summit caldera. The summit of the 10 x 12 km wide island rises about 3000 m from the sea floor between Bristol and Saunders Islands. Around 90% of the island is ice-covered; glaciers extending to the sea typically form vertical ice cliffs. The name Mount Belinda has been applied both to the high point at the southern end of the summit caldera and to the young central cone. Mount Oceanite, an isolated 900-m-high peak with a 270-m-wide summit crater, lies at the SE tip of the island and was the source of lava flows exposed at Mathias Point and Allen Point. There was no record of Holocene or historical eruptive activity at Montagu until MODIS satellite data, beginning in late 2001, revealed thermal anomalies consistent with lava lake activity that has been persistent since then. Apparent plumes and single anomalous pixels were observed intermittently on AVHRR images during the period

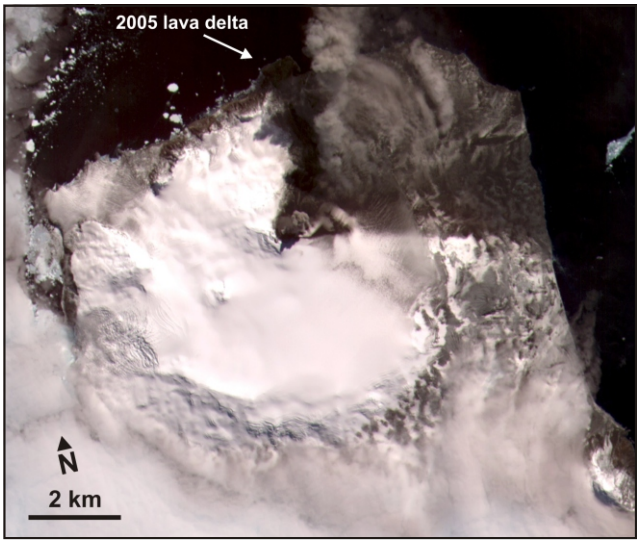


Figure 6. An image of Montagu Island captured on 28 October 2006 by ASTER VNIR. Courtesy of NASA with interpretation in text by Matt Patrick, Michigan Technological University.

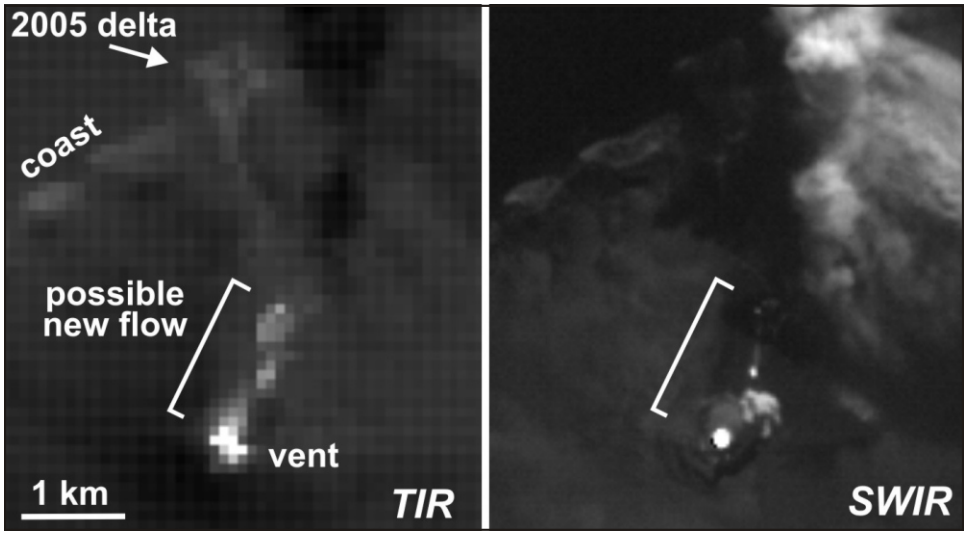


Figure 7. Two image of Montagu Island captured on 28 October 2006 by ASTER TIR and SWIR, which show slightly different features than seen on the previous (ASTER VNIR) image, and may disclose a new lava flow. Courtesy of NASA with interpretation by Matt Patrick.

March 1995 to February 1998, possibly indicating earlier unconfirmed and more sporadic volcanic activity.

Information Contacts: *Matthew Patrick*, Dept. of Geological and Mining Engineering and Sciences, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931, USA (Email: mpatrick@mtu.edu; URL: http://www.geo.mtu.edu/~mpatrick); *Hawai'i Institute of Geophysics and Planetology (HIGP) Thermal Alerts Team*, School of Ocean and Earth Science and Technology (SOEST), Univ. of Hawai'i, 2525 Correa Road, Honolulu, HI 96822, USA (URL: http://hotspot.higp.hawaii.edu/).

Heard

Southern Indian Ocean
53.106°S, 73.513°E; summit elev. 2,745 m
All times are local (= UTC + 5 hours)

Matt Patrick reported that Heard Island continued to display evidence of activity in its summit crater (continuing the phase which began in May 2006, *BGVN* 31:05). Figure 8 presents an ASTER image (Bands 9-3-2) from 8 December 2006 showing a hotspot at the summit, presumably a lava lake, with a recently emplaced lava flow extending 700 m E.

Table 1 lists the thermal anomalies recorded by the Hawai'i Institute of Geophysics and Planetology (HIGP) during 25 June 2006 (as last reported in the *BGVN* 31:05) to mid December 2006. The table lists 27 thermal anomalies during 25 June to 15 December 2006. There is no MODVOLC thermal anomaly on 8 December, the date of the ASTER image in the previous figure.

Matt Patrick noted that it is not surprising that the ASTER image showed a thermal anomaly but MODVOLC did not. First, because ASTER has infrared bands at 30-90 m, it is inherently more sensitive to thermal anomalies than the 1-km MODIS bands (MODVOLC uses MODIS data). Second, the MODVOLC algorithm has a threshold which sometimes disregards low-level eruptive activity in order to avoid false alarms. The anomaly in the ASTER image was not particularly large or intense, so it is not surprising it did not show up in MODVOLC.

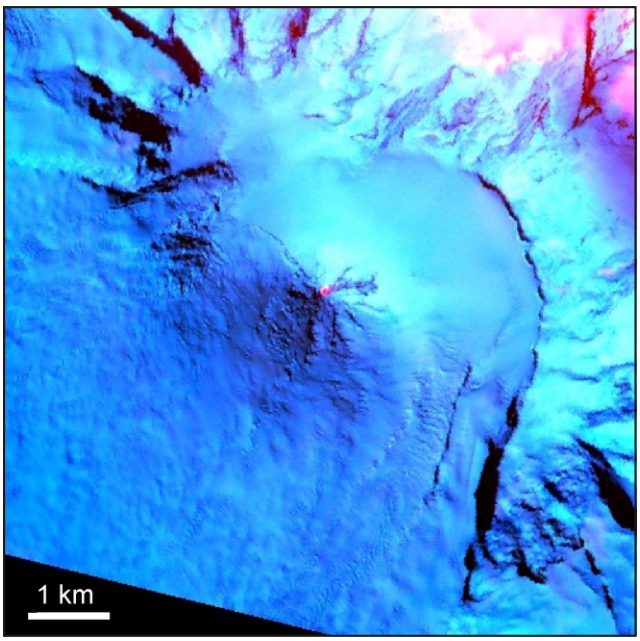


Figure 8. ASTER image (Bands 9-3-2) from 8 December 2006 showing a hotspot at the summit of Heard Island. This is one of the rare daytime ASTER images that shows the summit clearly. Courtesy of Matt Patrick.

Date (2006)	Time (UTC)	Pixels	Satellite
25 Jun	1850	1	Terra
17 Jul	2000	1	Aqua
06 Aug	1935	1	Aqua
13 Aug	0425	1	Terra
13 Aug	1755	1	Terra
13 Aug	1940	1	Aqua
15 Aug	1930	1	Aqua
22 Aug	1935	2	Aqua
10 Sep	1820	2	Terra
12 Sep	1805	1	Terra
20 Sep	0930	1	Aqua
21 Sep	1800	1	Terra
21 Sep	1950	1	Aqua
11 Oct	1735	1	Terra
11 Oct	1925	2	Aqua
24 Oct	0920	1	Aqua
27 Oct	1735	2	Terra
27 Oct	1925	1	Aqua
02 Nov	1835	1	Terra
07 Nov	1715	2	Terra
07 Nov	1905	4	Aqua
17 Nov	0830	1	Aqua
24 Nov	0430	2	Terra
25 Nov	0920	1	Aqua
26 Nov	1750	2	Terra
15 Dec	1820	1	Terra
15 Dec	2005	1	Aqua

Table 1. Thermal anomalies from mid-June to mid-December 2006 from MODIS satellites. Courtesy of HIGP Thermal Alerts Team.

Geologic Summary. Heard Island on the Kerguelen Plateau in the southern Indian Ocean consists primarily of the emergent portion of two volcanic structures. The large glacier-covered composite basaltic-to-trachytic cone of Big Ben comprises most of the island, and the smaller Mt. Dixon volcano lies at the NW tip of the island across a narrow isthmus. Little is known about the structure of Big Ben volcano because of its extensive ice cover. The historically active Mawson Peak forms the island's 2,745-m high point and lies within a 5-6 km wide caldera breached to the SW side of Big Ben. Small satellitic scoria cones are mostly located on the northern coast. Several subglacial eruptions have been reported in historical time at this isolated volcano, but observations are infrequent and additional activity may have occurred.

Information Contacts: *Matthew Patrick*, Dept. of Geological and Mining Engineering and Sciences, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931, USA (Email: mpatrick@mtu.edu; URL: http://www.geo.mtu.edu/~mpatrick); *Hawai'i Institute of Geophysics and Planetology (HIGP) Thermal Alerts Team*, School of Ocean and Earth Science and Technology (SOEST), Univ. of Hawai'i, 2525 Correa Road, Honolulu, HI 96822, USA (URL: http://hotspot.higp.hawaii.edu/).

Cayambe

Ecuador
0.029°N, 77.986°W; summit elev. 5,790 m
All times are local (= UTC - 5 hours)

During 2004, Cayambe's seismicity increased three times, on 25-31 January, on 25 February-5 March, and on 4-12 October. Our previous report on Cayambe discussed events through November 2003 (*BGVN* 28:11).

The first seismic swarm began on 25 January 2004 when the number of volcano-tectonic (VT) earthquakes increased, with seismic activity occurring in bands lasting 2-3 hours. The events were small in magnitude and were located ~ 1-4 km below the SW flank. At 1934 on 27 January, a magnitude 3.4 earthquake was recorded. On 29 January, the activity peaked with 148 earthquakes reported. Seismicity thereafter decreased to normal base-line levels.

The second earthquake swarm began on 25 February with an increased number of VT earthquakes. Like the January events, these earthquakes were of low magnitude. The largest event occurred on 29 February at 1059 measuring M 3.1. The events were localized primarily below the E flank with peak activity on 2 March, when 271 earthquakes were registered. The energy released by this cluster was far larger than the one in January and was almost comparable to activity in March 2003 (figure 9).

On 12 March, a small increase in activity was recorded, and on the morning of 15 March, a M 3.6 earthquake was recorded on the S flank. Residents reported no felt earthquakes.

On 4 October, there was a slight increase in the number of events registered with a total of 18 events, 17 of which were hybrid events. At 2333 on 6 October a M 3.4 event was recorded. These earthquakes were located in the S zone of the volcano edifice. Two seismic swarms on 8 October consisted of 177 VT earthquakes. The first swarm registered at 0500 and lasted an hour. The second swarm began at 1130 and lasted approximately 9 hours. Some of these events were located in the SW flank. After the seismic anomalies on 4 and 6- 8 October, activity returned to normal base-line levels.

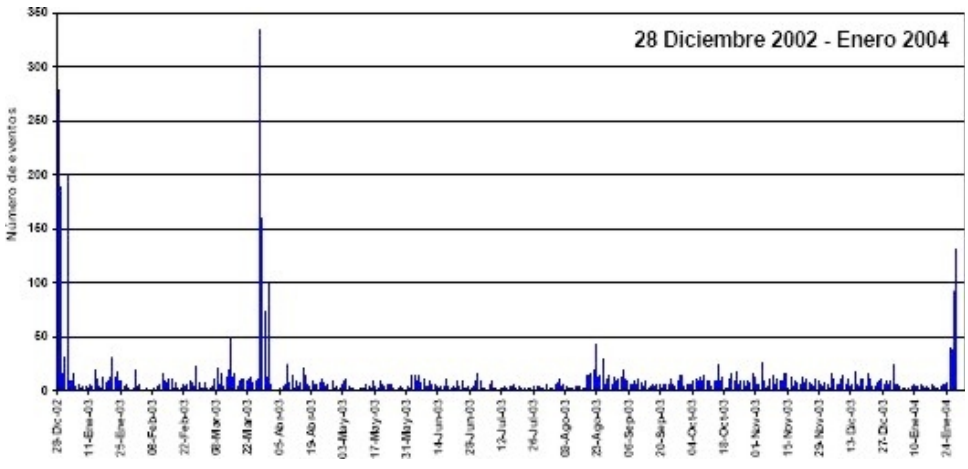


Figure 9. The total number of earthquakes each day at Cayambe during 28 December 2002 through early January 2004. The spike in daily earthquakes seen during late March 2003 (up to 330 per day) was discussed in *BGVN* 28:11. A spike about half that size occurred in late January 2004. Courtesy of the Instituto Geofisico.

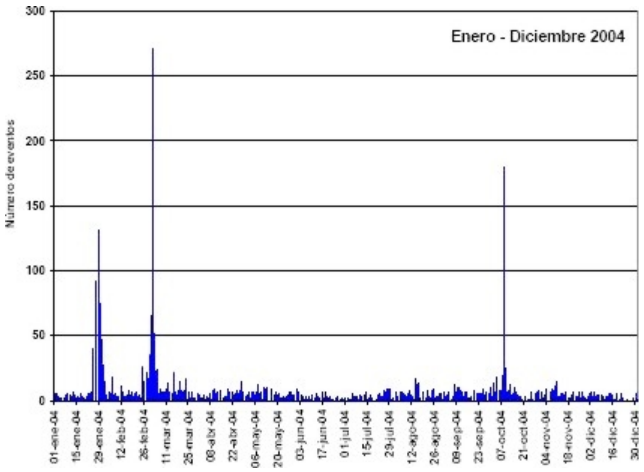


Figure 10. The total number of earthquakes each day at Cayambe during 2004 (tick marks along x-axis are every 14 days). The record was punctuated by three strong increases in seismicity, during late January, during February-March, and during October. The spike in daily earthquakes seen during February 2004 neared 300 earthquakes per day. Courtesy of the Instituto Geofisico.

Apart from the swarms between September and October, the seismicity appears to have changed, with the number of VT events diminishing by one-half in relation to those previously recorded, whereas the number of hybrid events tripled. Later, long-period LP events were again observed, which is characteristic of this volcano returning to normal levels.

The internal seismic activity at Cayambe is characterized by the generation of 10 events per day on average. Nevertheless, this type of activity has alternated with sporadic seismic swarms consisting of hundreds of events lasting several days, after which activity returns to the base-line level. These types of seismic swarms were recorded in December 2002, March 2003, and in January, March, and October of 2004 (figure 10), with similar characteristics and averaging 2 days in duration. Scientists inferred the cause of the observed seismicity as related to motion of fluids in the interior of the edifice. Thermal images obtained during 2004 did not contain anomalies.

During 16-18 September 2005 a short seismic episode occurred with earthquakes on the SW flank, ranging from 135 to 330 events per day. The earthquakes reached a maximum magnitude of 3.6.

Geologic Summary. The massive compound andesitic-dacitic Cayambe stratovolcano is located on the isolated western edge of the Cordillera Real, east of the Inter-Andean Valley. The 5,790-m-high volcano, whose southern flank lies astride the equator, is capped by extensive glaciers, which descend down to 4,200 m on the eastern Amazonian side. The modern Nevado Cayambe volcano, constructed to the E of older Pleistocene volcanic complexes, contains two summit lava domes located about 1.5 km apart, the western of which is

the highest. Several other lava domes on the upper flanks have been the source of pyroclastic flows that reached the lower flanks of the volcano. A prominent Holocene pyroclastic cone on the lower eastern flank, La Virgen, fed thick andesitic lava flows that traveled about 10 km to the E. Nevado Cayambe was recently discovered to have produced frequent explosive eruptions during the Holocene beginning about 4,000 years ago, and to have had a single historical eruption, during 1785-86.

Information Contact: *Instituto Geofisico (IG),* Escuela Politécnica Nacional, Apartado 17-01-2759, Quito, Ecuador (URL: http://www.igepn.edu.ec/).

Atka

Aleutian Islands
52.381°N, 174.154°W; summit elev. 1,533 m
All times are local (= UTC -10 hours)

Korovin, the most frequently active cone in the Atka volcanic center, has been relatively quiet since 23 February 2006, when it emitted minor though abruptly discharged steam and ash (BGVN 31:02). At that time, an initial ash burst rose to an altitude of ~ 2.4 km and was followed by several smaller ash-and-steam bursts, but no ashfall was reported in Atka village (figure 11). There were no reports of accompanying volcanic odors, earthquakes, or larger volcanic explosions. While there was minor steaming during the period 25 February-4 March 2005, seismicity at Korovin remained only slightly above background levels. During that time frame, the Alaska Volcano Observatory (AVO) raised the concern color code at Korovin from green to yellow but reduced it to green on 8 March.

An increase in seismicity during July 2006 represented a transition from prior low activity, meanwhile volcanic activity remained mild during that time (figure 12).

This report also covers further minor events during September through December. During September and October, episodes of volcanic tremor increased in number, strength, and duration. On 28 October, residents of Atka village observed and photographed steam emissions to several hundred meters above the volcano.

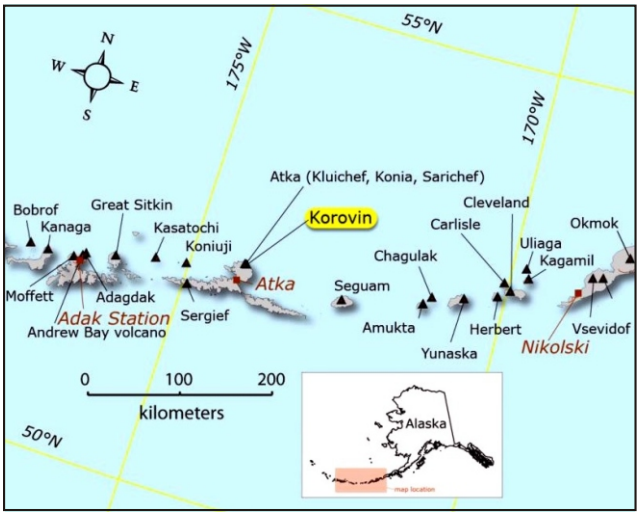


Figure 11. Sketch map of the central Aleutian Islands including Atka Island and the city of Atka (population 27, according to 1999 US Census estimate). Courtesy of USGS/AVO.

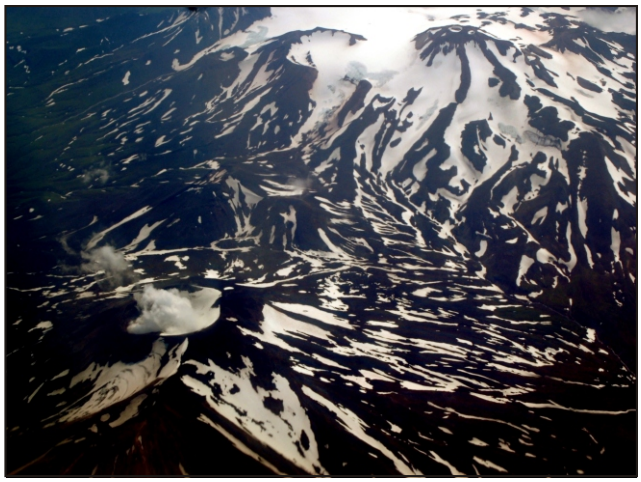


Figure 12. The Korovin cone (lower left) in the Atka volcanic center was puffing steam to ~ 300 m above the summit on 30 July 2006 when seen from an Alaska Airlines jet. The Kliuchef cone (upper right, with two snow-clad craters) is one of multiple satellite cones. Photo credit to Cyrus Read; image courtesy of AVO/USGS.

For the duration of November and December, seismic levels remained above background levels. In late November satellite information showed a light dusting of ash on the E flank of the main crater along with several plumes and/or their shadows visible along the N side of the crater. Satellite radar images indicated uplift of the volcano; the area of uplift was consistent with locations of earthquake activity and the effects were interpreted as the result of magma injection. Cloud cover permitted only erratic satellite observation during November and December. On 11 and 21 December 2006. Atka residents again witnessed steam plumes, on the latter date possibly containing ash.

Geologic Summary. The largest volcanic center in the central Aleutians, Atka consists of a central shield and Pleistocene caldera ringed by 7 or 8 satellitic volcanoes. The most prominent of these are the post-caldera cones of Korovin, Konia, Kliuchef, and Sarichef, some of which have been active in historical time. Korovin, the most frequently active volcano of the Atka volcanic center, contains a 1,533-m high double summit with two craters located along a NW-SE line. The NW summit has a small crater, but the 1-km-wide crater of the SE cone has an unusual, open cylindrical vent of widely variable depth that sometimes contains a crater lake or a high magma column (Marsh; in Wood and Kienle, 1990). A fresh-looking cinder cone lies on the flank of partially dissected Konia volcano. Sarichef has a symmetrical profile, and Korovin and Kliuchef are relatively uneroded and the source of most if not all historical eruptions. Hot springs and fumaroles are located on the flanks of Mount Kliuchef and in a glacial valley SW of Kliuchef.

Information Contacts: *Alaska Volcano Observatory* (AVO), a cooperative program of the U.S. Geological Survey, 4200 University Drive, Anchorage, AK 99508-4667, USA (URL: http://www.avo.alaska.edu), Geophysical Institute, University of Alaska, P.O. Box 757320, Fairbanks, AK 99775-7320, USA, and Alaska Division of Geological & Geophysical Surveys, 794 University Ave., Suite 200, Fairbanks, AK 99709, USA.

Shiveluch

Kamchatka Peninsula, Russia
56.653°N, 161.360°E; summit elev. 3,283 m
All times are local (= UTC +12 hours)

In December 2006 Shiveluch underwent heightened seismic and volcanic activity of an intensity not seen since 22 September 2005. During the latter episode, plumes reached ~ 7.5 km altitude (*BGVN* 30:08). This report covers from September 2005 to December 2006.

Activity during 2005. Seismic levels declined in the weeks subsequent to the previously described 22 September eruption. The Kamchatka Volcanic Eruptions Response Team (KVERT) had raised the Concern Color Code level to orange due to the 22 September 2005 eruption and then lowered it to yellow at the start of November. During October, KVERT noted that weak shallow earthquakes, hot avalanches, and small fumarolic activity persisted. Incandescence at the dome was reported on 13, 15, 17, 22, and 29 October, and thermal anomalies over the lava dome were frequently registered.

On 22 October a weak ash-gas plume extended to the E. Seismic activity decreased further and did not exceed background levels in October and November, and remained at low levels in December. Weak avalanches were reported at the start of November. Weak seismicity and fumarolic activity was registered in December. Numerous thermal anomalies over the lava dome and incandescence at the dome were widely reported (specifically, on 1, 7, 8-11, 15, 17-18, 25, and 27-29 December).

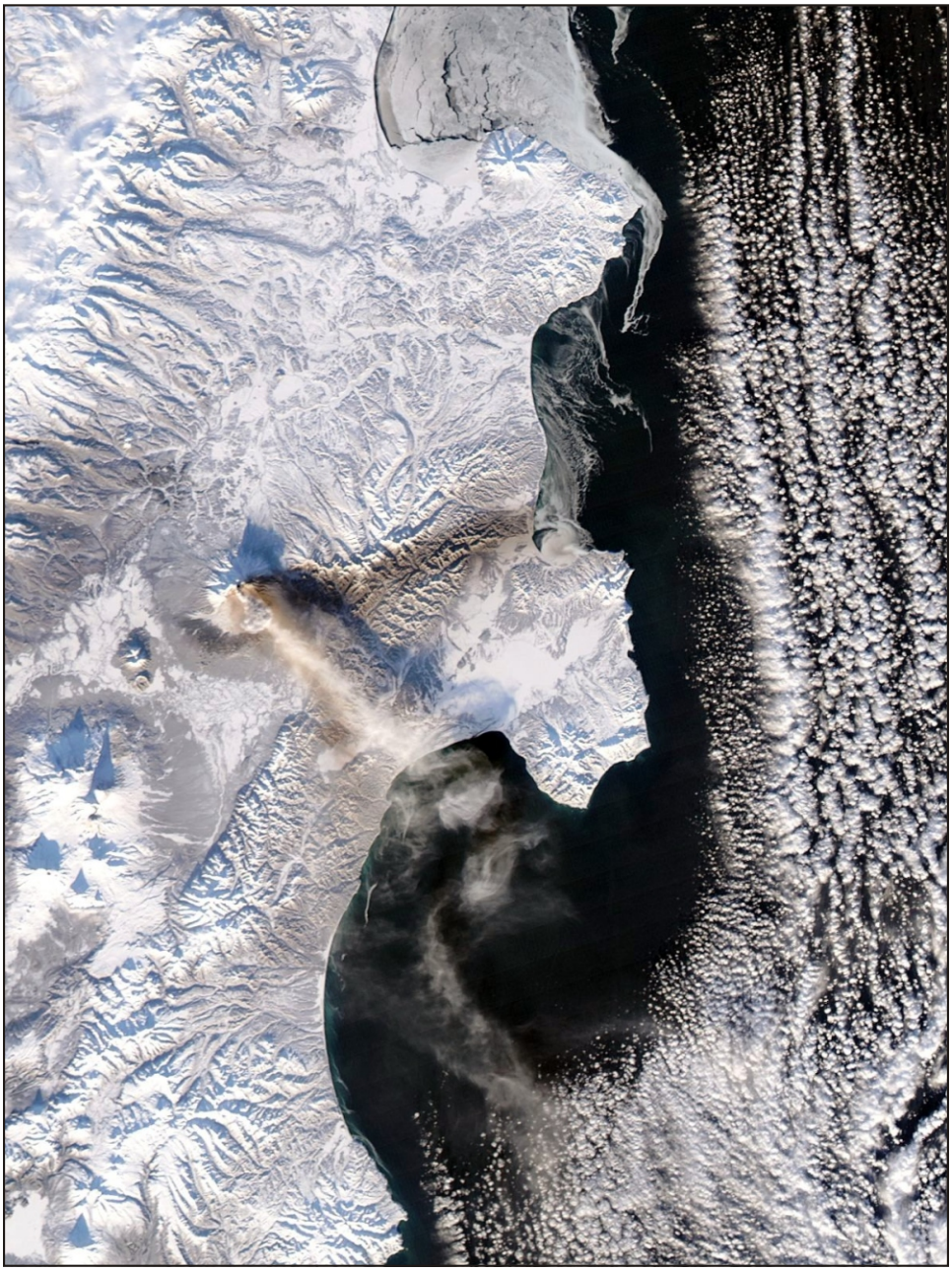


Figure 13. Satellite image of Shiveluch eruption taken on 27 December 2006 using the MODIS instrument on Terra satellite. The image shows a plume blowing SE. In addition, on the white ice surface resides a brownish streak, remnant of an earlier ash fall, which trends from the summit E towards the coast. Courtesy of NASA Earth Observatory.

Activity during 2006. The lava dome continued to grow in 2006; overall volcanism and seismicity remained low during January to May 2006. Visual and satellite observations of weak fumarolic activity and thermal anomalies were noted during periods of visibility early in 2006 (13-14, 16-17, 22, and 30-31 January and 1 February). One shallow earthquake was registered on 30 January. On 23 May a thermal anomaly was reported, and on 21, and 27-31 May moderate gas-and-steam plumes were observed.

Three deep earthquakes were recorded, one each day, on 1-2 and 5 June, and a shallow earthquakes was recorded on both 2 and 4 June. On 5 and 8 June gas-and-steam plumes rose over the volcano. A thermal anomaly from the volcanic crater was noted on 2-5 and 7-8 June. Fumarolic activity of the lava dome was observed on 23 and 29-30 June. On 16 and 19 June, gas-and-steam plumes rose to ~ 3-3.5 km altitude from the lava dome summit. A steam plume extending 9.5 km NE from the volcano was observed on a 24 July satellite image. Observers noted frequent fumarolic emissions from the dome (on 1-2, 8, 10, 17-20, 22, and 24-26 July). Frequent thermal anomalies over the dome also were noted (on 4, 7-8, 17-18, and 23-26 July).

In August and September, activity remained the same with periods of fumarolic activity and reports of thermal anomalies. Seismicity remained low except

for five earthquakes in the middle of August. Several weak earthquakes were registered throughout October and November, as well as fumarolic activity of the lava dome in periods of good visibility. Sporadic thermal anomalies were recorded (on 6, 8, 14-15, 22, and 27-31 October and 1-2, 6-7, 13-15, and 19-22 November). According to visual and video data, gas-and-steam plumes rose to ~ 3.5 km altitude and extended NW on 23 October. A weak continuous spasmodic volcanic tremor was registered on 29-30 October and 2 November.

Heightened volcanic activity during December began with a strong seismic event on 4 December from 1906-1940. According to satellite data, an ash plume raising up ~ 6 km altitude and extending NW was observed at 2100, and during 2130-2400 gas-and-steam plumes containing ash extended NW at ~ 3.0 km altitude. On 4 December ashfall extended ~ 150 km. Several tens of shallow earthquakes were registered in the following days. On 5 December the level of Concern Color Code was raised from yellow to orange. On 8 December another eruption occurred with ash plumes to ~ 4 km altitude that extended NW.

On 12 December, ash explosions to a height ~ 4 km produced a plume that extended E-SE from 25-460 km, according to satellite data from various sources. According to visual and video data, two separate ash plumes rose to ~ 10 km altitude and extended NW on 16, 17, and 20 December. On subsequent days, satellite data showed ash clouds extended primarily ~ 570 km to the E, as well as to the NE.

On 26 December 2006 the Concern Color Code level was raised to red. At 2130 on 27 December, video data recorded a gas-and-steam plume rising to ~ 3.5 km altitude. An ash plume rose to ~ 10 km altitude and extended E on 25-27 December (figure 13) and N on the 28th. The Concern Color Code level lowered to orange on 28 December 2006, where it remained in early January 2007.

Geologic Summary. The high, isolated massif of Shiveluch volcano (also spelled Sheveluch) rises above the lowlands NNE of the Kliuchevskaya volcano group. The 1,300 cu km Shiveluch is one of Kamchatka's largest and most active volcanic structures. The summit of roughly 65,000-year-old Stary Shiveluch is truncated by a broad 9-km-wide late-Pleistocene caldera breached to the south. 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 Stary 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.

Information Contacts: *Olga A. Girina*, Kamchatka Volcanic Eruptions Response Team (KVERT), a cooperative program of the Institute of Volcanic Geology and Geochemistry, Far East Division, Russian Academy of Sciences, Piip Ave. 9, Petropavlovsk-Kamchatskii 683006, Russia (Email: girina@kscnet.ru), GS RAS (Russia), and the Alaska Volcano Observatory (AVO), a cooperative program of the U.S. Geological Survey, 4200 University Drive, Anchorage, AK 99508-4667, USA (URL: http://www.avo.alaska.edu/; Email: tlmurray@usgs.gov), the Geophysical Institute, University of Alaska, P.O. Box 757320, Fairbanks, AK 99775-7320, USA (Email: eisch@dino.gi.alaska.edu), and the Alaska Division of Geological and Geophysical Surveys, 794 University Ave., Suite 200, Fairbanks, AK 99709, USA (Email: cnye@giseis.alaska.edu); *Jeff Schmaltz*, MODIS Land Rapid Response Team, NASA Goddard Space Flight Center (URL: http://modis.gsfc.nasa.gov/gallery/); *National Aeronautics and Space Administration Earth Observatory* (URL: http://earthobservatory.nasa.gov/NaturalHazards).

Bezymianny

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

Except for brief heightened activity at the end of December 2006, moderate volcanic activity and seismicity has prevailed at Bezymianny since the extensive eruption in May 2006, last reported on in *BGVN* 31:04. This report covers activity following the 9 May 2006 explosion to the start of January 2007.

The Kamchatkan Volcano Eruption Response Team (KVERT) raised the Concern Color Code to red, the highest level, in response to the 9 May 2006 eruption (*BGVN* 31:04). They lowered it on 10 May to orange, and again, on 11 May to yellow, where it remained until the end of December. By 11 May, seismicity remained at or below background levels. Two shallow earthquakes were recorded on 15 and 19-20 May; five shallow earthquakes were recorded during 27-30 May. Similar low levels of seismicity were recorded during June to November 2006, with seismic activity exceeding background levels only on 14 August and 25, 27, and 30 November.

Growth of the lava dome continued during June to December 2006. Video data on 28-29 May showed weak gas-and-steam plumes. A thermal anomaly was noted during the latter part of the month (specifically, on 16-18, 23-25, 27, and 29 May). Video data showed gas-and-steam plumes rising to ~ 7.5 km altitude on 5 June and to ~ 4.0 km altitude the week of 16 June. Weak gas-and-steam plumes were observed 16 and 19-20 June. Thermal anomalies were often noted, with particularly large ones on 24 and 29 June. On days of good visibility, video data consistently showed fumarolic activity at the lava dome. An increase in size of two explosive craters at the dome's summit and a new lava flow on the dome's SW flank, thought to have resulted from the 9 May 2006 eruption, were observed on 31 July.

Seismic activity was above background levels during much of December and dramatically increased the week of 24 December. Several shallow earthquakes were registered during the weeks of 8, 15, and 22 December.

On 6 and 10 December, respectively, gas-and-steam plumes rose to ~ 4.5 and 3.5 km altitude. Satellite data recorded a thermal anomaly over the dome during the weeks of 8, 15, 22 December and on 29-31 December. The number of hot avalanches per day grew from 4-6 in previous days to 15 on 23 December.

On 23 December, starting at 2352, an explosive eruption occurred, producing ash and pyroclastic flows; a re-

sulting ash plume rose ~ 4.5-6 km altitude and extended NE. In response to the eruption, on 24 December KVERT raised the level of Concern Color Code from yellow to orange.

Another explosive eruption started between 0917-1020 on 24 December and ended on 25 December 2006. A large eruptive column rose to ~ 13 km altitude and developed into a big umbrella cloud. According to satellite data, ash clouds extended ~ 850 km NE on the 24 and 25 December. Late on 24 December, the Concern Color Code was raised to red. According to the Russian News Agency NOVOSTI, Russian government officials instructed residents of a village 40 km E of the volcano where ash fallout occurred to avoid leaving their houses.

About 30 local seismic events occurred at the volcano during 1020-2000 on 24 December. Volcanic seismicity returned to background levels at 2000 on 24 December. According to seismic data on 25 December, two hot avalanches took place. In addition, a large thermal anomaly occurred at the lava dome. Visual and video data on 26-27 December showed moderate fumarolic activity. Photographs, taken by volcanologists who flew around the volcano in a helicopter, revealed that a portion of the lava dome was destroyed during the 24 December eruption. The Concern Color Code was lowered to orange on 25 December, and subsequently to yellow on 29 December, where it remained in early January 2007. According to satellite data collected on 31 December and 3 January, fresh deposits of pyroclastic flows extended 7-8 km SE from the volcano.

Seismic activity stood slightly above background levels on 2 January, and at background levels on the other days. According to visual and video data, moderate fumarolic activity occurred on 29-31 December, although the volcano was often obscured by clouds. A thermal anomaly was noted on 3 January.

Geologic Summary. 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 between 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: *Olga A. Girina*, Kamchatkan Volcanic Eruptions Response Team (KVERT) (see Shiveluch); *Russian News & Information Agency NOVOSTI*, 4, Zubovsky Bulvar, 119021, Moscow, Russia (URL: http://en.rian.ru/).

Karymsky

Kamchatka Peninsula, Russia
54.05°N, 159.45°E; summit elev. 1,536 m
All times are local (= UTC +12 hours)

During late 2006 and into January 2007, ash explosions occurred from the summit crater at Karymsky, continuation of activity observed since the beginning of January 2006 (*BGVN* 31:04 and 31:07). This report covers activity during August 2006 to early January 2007.

The Kamchatkan Volcanic Eruptions Response Team (KVERT) maintained the level of Concern Color Code at orange during the period of reporting, except for the temporary change to yellow during 8-15 September. Throughout this period the dome was a consistent source of thermal anomalies.

Ash plumes reached to ~ 3.0-3.7 km altitude throughout August 2006. Seismicity rose, with a maximum of 500 local shallow earthquakes per day the week of 18 August, and then lowered to 30-70 earthquakes per day the last week of August. Spasmodic tremor registered on 1-12 and 17 August. On 6 August an ash plume extending ~ 10-73 km E and SE was depicted on satellite data. Volcanic plume information sometimes stems from the Airport Meteorological Center (AMC) in Yelizovo (a town 40 km NE of the S-coast town of Petropavlovsk-Kamchatskii; the latter is

Figure 14. Satellite image showing Karymsky and environs, with its faint E-directed plume easily visible over the ocean. Karymsky's vent lies ~25 km W of the point where the plume intersects the coast. The image was taken by the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite on 29 November 2006. Courtesy of NASA Earth Observatory.

the Peninsula's capital, largest city, and features both a major airport and a marine port). The AMC reported that on 16 August, pilots saw a Karymsky ash plume at ~ 6. 5 km altitude that extended NE.

During September 2006, local shallow earthquakes occurred ~ 30-250 times per day. A satellite image for 12 September showed an ash plume extending ~ 140 km SE. On 10 September volcanologists observed from visual data an ash explosion of ~ 2,300 km altitude. Other possible ash explosions were thought to occur toward the end of September 2006, reaching heights of ~ 2.5-4.5 km altitude.

Local seismicity peaked the last week of October with a maximum of 550 weak shallow earthquakes per day, but levels declined through November 2006. Possible ash explosions rising ~ 2.5-5.0 km altitude prevailed the month of October and during 10-11 and 18-19 November. On 25 October staff of the Institute of Volcanology and Seismology (IVS) observed a series of ash bursts up to ~ 2.0 km above the summit with ash plumes that extended ~ 100 km E. On days of sufficient visibility during October and November 2006, ash plumes often extended ~ 29-200 km NE, ~ 20-220 km SE, and ~ 55-137 km E (figure 14). On 28 October observers noted an ash cloud extending to 70 km NE of Karymsky.

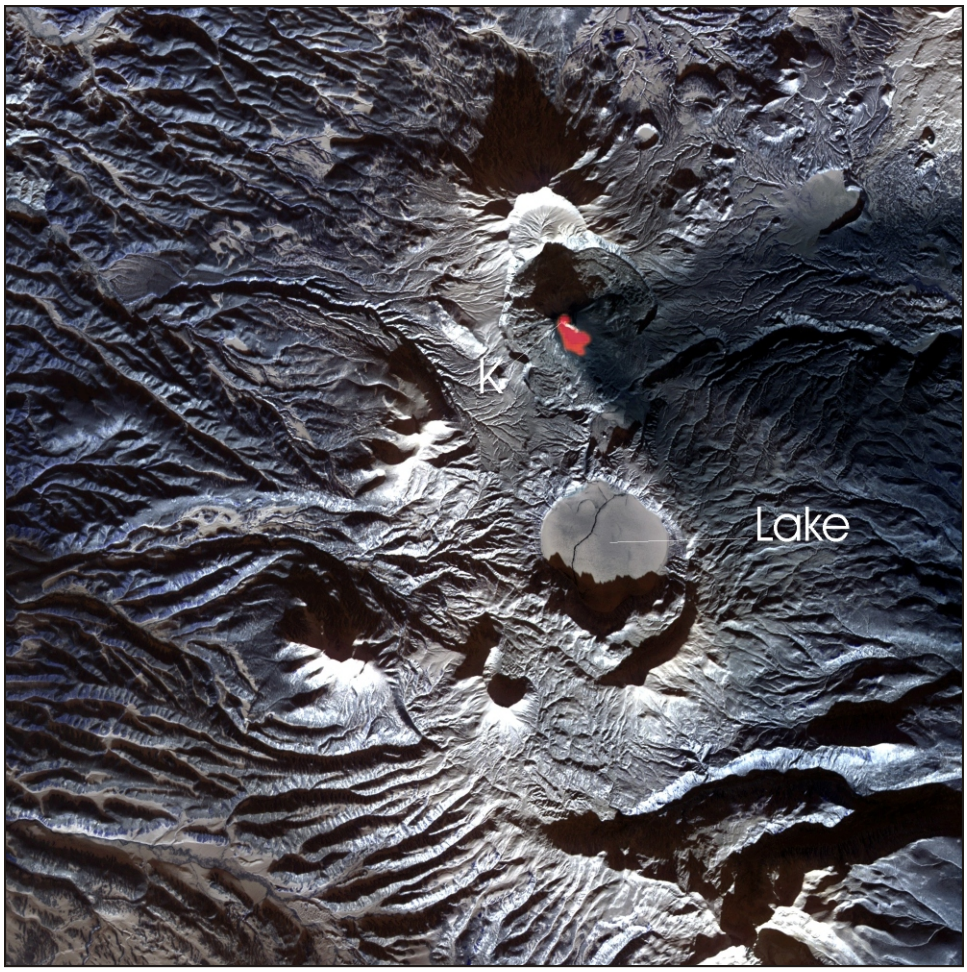


Figure 15. ASTER image of Karymsky ("K" marks the summit) and surroundings taken on 19 December 2006. N is towards the top. The area indicated as hot near the summit (which is false-colored red on color images) indicates a volcanically induced hotspot, and the tiny white streak over the hotspot may be a steam plume. A broad, dark cast spreads E across the right side of the image (the fringes of which are indicated by "F"). This zone narrows to a point near Karymsky's summit; it results from fresh ash deposits draping the landscape. Although myriad ridges and valleys corrugate much of the landscape, a zone without those features resides several kilometers S of the summit. That is Karymsky lake ("Lake"), which lies in a caldera. From Karymsky's summit to the nearest margin of Karymsky Lake, the distance is ~5 km (see maps and scaled images in previous reports, Eg. BGVN 21:05, 31:07). This NASA image created and interpreted by Jesse Allen, NASA Earth Observatory, using data provided courtesy of the NASA/GSFC/MITI/ERSDAC/JAROS, and US/Japan ASTER Science Team.

There were no seismic data the last week of November to the third week December 2006, but satellite data enabled surveillance. Figure 15 shows a 19 December image from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument on the Terra satellite.

During the week of 29 December and the first week in January 2007 there were multiple weak local shallow earthquakes. They occurred at a rate of 100-130 per day during the week of 29 December. On 29 December and 1-3 January tremor was also registered.

According to visual information from pilots of international air flights (reported by AMC, Yelizovo), on 2 December an ash plume rose up ~ 6.9 km altitude and extended E. At 0200 on 22 December an ash plume rose up to ~ 7.0 km altitude and extended E. A number of ash plumes extending 9 to 240 km E were observed during December. At the end of December 2006 and into early January 2007, a possible lava flow was observed on a flank of the volcano.

Geologic Summary. Karymsky, the most active volcano of Kamchatka's eastern volcanic zone, is a symmetrical stratovolcano constructed within a 5-km-wide caldera that formed during the early Holocene. The caldera cuts the south side of the Pleistocene Dvor volcano and is located outside the N 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 S of Karymsky volcano. The caldera enclosing Karymsky volcano formed about 7,600-7,700 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 2,300-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.

Information Contacts: *Olga A. Girina*, Kamchatkan Volcanic Eruptions Response Team (KVERT) (see Shiveluch); *Jesse Allen*, National Aeronautics and Space Administration Earth Observatory (URL: http://earthobservatory.nasa.gov/NaturalHazards).