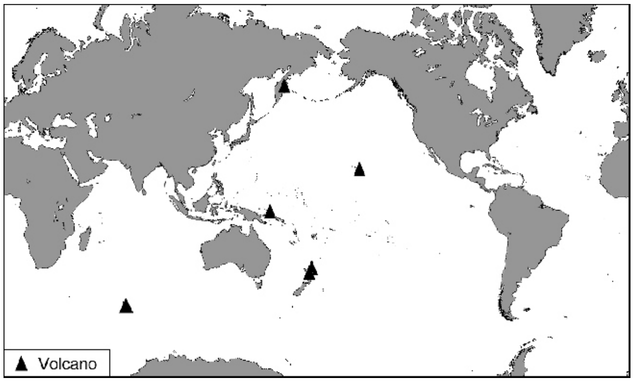
Bulletin of the Global Volcanism Network



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

Kliuchevskoi

Kamchatka Peninsula, Russia
56.057°N, 160.638°E; summit elev. 4,835 m

Increased seismicity and volcanic activity began in January 2005 and continued through at least March 2005 (*BGVN* 30:03), with Strombolian eruptions, lava flows, ashfall, lahars, and tall steam plumes. Activity was intermittent during April 2005 through January 2007, primarily consisting of variable seismicity. Significant volcanic activity began again in mid-February 2007, after which large ash plumes became frequent and lava flows were observed. From that time through early August 2007 there have been Strombolian eruptions, lava flows, mudflows, and some large (though not particularly high) eruptive plumes extending up to ~ 2,000 km from the volcano, though cloudy weather often blocked views of the summit.

The seismic network maintained by the Kamchatka Experimental and Methodical Seismological Department (KEMSD) lacks a calibration linking ash-plume height with associated seismic signal. Instead, visual and video data were typically used by ground-based observers. Some height estimates cited here were based on satellite observations and comparisons with ancillary observations such as atmospheric wind profiles.

Activity during April 2005-January 2007. According to the Kamchatka Volcanic Eruptions Response Team (KVERT), ash-and-gas plumes rose to 1 km above the crater the first week of April. Eruptive and seismic activity decreased significantly on 7 April 2005, but remained above background levels until 8-9 May. During 8-15 July, seismicity again increased. This heightened activity continued through 15-22 July, with spasmodic volcanic tremor, shallow earthquakes, and gas-and-steam plumes rising to ~ 5.5 km above the crater. Ashfall was noted in Kozyrevsk on 22 June. On 22 July a weak ash-and-gas plume rose to ~ 100 m above the crater. This activity decreased in late July and returned to background levels by 3-9 August 2005. Weak fumarolic activity continued.

During 9-16 September, seismicity again increased. During this week, the amplitude of volcanic tremor increased, and weak gas-and-steam emissions and a thermal anomaly were visible on satellite imagery. By the middle of October 2005, activity had again returned to background levels where it apparently remained until December 2006. During the middle of December 2006, KVERT noticed a slight increase in seismicity, with moderate fumarolic activity. A thermal anomaly in the crater was detected on satellite imagery on 14, 15, and 18 December.

Activity during February-July 2007. Eruptive activity began again on 15 February 2007. Strombolian activity was observed during 15-18 February that ejected bombs 300 m above the crater. Video data and observations between 16 and 22 February indicated gas-and-steam plumes with small amounts of ash rising to altitudes of 5.3 km and drifting SW and then E. A thermal anomaly at the summit was detected during 16-19 and 21 February. Based on information from KEMSD and satellite imagery, the Tokyo Volcanic Ash Advisory Center (VAAC) reported that eruption plumes during 22-23 February may have reached altitudes of 6.1 km and drifted E. A news article in RIA Novosti cited local scientists who mentioned that on 26 February ash particles up to 2 mm in diameter fell on the village of Klyuchi, about 30 km NNE.

Clouds inhibited visual observations during most of February and March, but satellite data disclosed a daily thermal anomaly of 1-11 pixels in the crater area. Strombolian activity was seen again during 21-22 March, with lava bombs being ejected typically about 50-100 m above the crater; bomb heights of 100-200 m were noted on 31 March. On 29 March lava flowed down the NW flank.

A 23 March news report from RIA Novosti paraphrased Alexei Ozerov of the Russian Academy of Sciences in the department of Volcanology and Seismology, saying that activity had increased sharply since 15 February 2007. The article went on to quote Ozerov, stating that "The size of the lava globs reaches several meters in diameter." Geophysicists also reported through RIA Novosti that lava flows interacting with snow and ice were producing powerful explosions and vapor plumes.

KVERT reported that seismicity continued at heightened levels during April and May 2007. Volcanism over this period included Strombolian activity, lava flows down the NW flank, fumarolic activity, mudflows, and frequent gas-and-steam plumes with a small amount of ash that rose to altitudes of 5.3-6.3 km. Intensified fumarolic activity during 15-18 April resulted in higher gas-and-steam plumes, to altitudes of 6.3-7.2 km, possibly containing ash.

An ash plume drifting E on 22 April reached 8.8 km altitude. KVERT reported continuing mudflows and phreatic activity at lava flow fronts on the NW flank where lava interacted with ice (figure 1). Mudflows and lava flows advanced on the NW flank the following week, and plumes containing ash rose to altitudes of 5.2-7.2 km. Thermal anomalies were seen at the summit throughout April. Similar activity continued during the first half of May. Residents in Kliuchi heard explosions during 3-6 May, and reported ashfall on 4 May. Ash plumes that rose to 9.7 km on 11 and 16 May drifted E and NE, respectively, and again caused ashfall in Kliuchi. On 18 May KVERT reported that deposits from a mudflow filled the Krivaya river.

Ash plumes during 18-22 May rose to 8.5 km altitude, and Vulcanian summit activity and phreatic bursts on the NW flank were observed from 22 to 24 May. Strombolian activity at the summit built a new scoria cone that was visible on the night of 22 May, along with incandescent lava flows down the NW flank (figure 2). Strong eruptions oc-

Figure 1. Lava flows and mudflows on the NW flank of Kliuchevskoi, 22 April 2007. Courtesy of KVERT; photo by Yu. Demyanchuk.

Figure 2. Strombolian activity and a new scoria cone in the crater of Kliuchevskoi, 22 May 2007. Lava flows continued to move down the flanks. Courtesy of KVERT; photo by Yu. Demyanchuk.

Figure 4. Photograph of Kliuchevskoi on 31 May 2007 showing an ash plume from the summit and a large steam plume rising from the E flank where lava flows were interacting with ice. Note snow line in the foreground. Courtesy of KVERT; photo by Yu. Demyanchuk.

curred on 26 and 27 May, sending plumes to 10.1 km altitude on the latter day (figure 3). Ash plumes continued to be generated over the next few days, but only rose to 5-7 km altitude. A new lava flow moved down the E flank on 31 May, causing strong phreatic bursts (figure 4).

Heightened seismic and volcanic activity continued throughout most of June, with Strombolian and Vulcanian summit eruptions. Frequent ash plumes were often visible on satellite imagery, with estimated altitudes of 4.5-10 km. Plumes extended ~ 300 km S and E the entire week ending 8 June, and ~ 400 km N, W, and S the week ending 22 June. Increased seismicity on 19 June was followed by plumes and ashfall in Kozyrevsk village. A large ash cloud, ~ 300 km in diameter, was observed on 20-21 June near Yelizovo airport, 340 km S. On 29 June, ash plumes drifted E more than 2,000 km, while on 30 June, they drifted at least 900 km SW, based on satellite imagery. A thermal anomaly continued to be detected in the crater. Seismic activity decreased during 29 June-6 July, but remained above background levels through 13 July. Ash plumes visible on satellite imagery during 2-11 July rose to estimated altitudes of 5-7 km and drifted in various directions.

During 13-20 July, KVERT reported that seismic activity had returned to background levels, although a thermal anomaly in the crater and some ash plumes and gas-and-steam plumes were still noted. The hazard status had been either Orange or Red since mid-February, but toward the end of July the Level of Concern Color Code was lowered from Orange to Yellow due to a decrease in seismicity and an absence of ash plumes during 17-20 July. In a 9 August update, KVERT indicated that seismic activity had remained a background levels during the previous week, although some volcanic tremor and a few shallow earthquakes were registered. According to satellite data, a thermal anomaly was noted on 4 August (the volcano was obscured by clouds on other days).

Geologic Summary. Kliuchevskoi is Kamchatka's highest and most active volcano. Since its origin about 6000 years ago, the beautifully symmetrical, 4835-m-high basaltic stratovolcano has produced frequent moderate-volume explosive and effusive eruptions without major periods of inactivity. Kliuchevskoi rises above a saddle NE of sharp-peaked Kamen volcano and lies SE of the broad Ushkovsky massif. More than 100 flank eruptions have occurred at Kliuchevskoi during the past roughly 3000 years, with most lateral craters and cones occurring along radial fissures between the unconfined NE-to-SE flanks of the conical volcano between 500 m and 3600 m elevation. The morphology of its 700-m-wide summit crater has been frequently modified by historical eruptions, which have been recorded since the late-17th century. Historical eruptions have originated primarily from the summit crater, but have also included numerous major explosive and effusive eruptions from flank craters.

Figure 3. Photograph of an eruption from Kliuchevskoi, 27 May 2007. The view is from Klyuchi, 30 km NNE. Three eruptions occurred on 27 May, with plumes rising to 6.7, 8.8, and 10.1 km altitude. Courtesy of KVERT; photo by Yu. Demyanchuk.

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Petropavlovsk-Kamchatskii 683006, Russia (Email: girina@kcs.iks.ru, URL: http://www.kscnet.ru/ivs/eng/index.html), the Kamchatka Experimental and Methodical Seismological Department (KEMSD), GS RAS (Russia), and the Alaska Volcano Observatory (USA); *Alaska Volcano Observatory (AVO)*, 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); *Tokyo Volcanic Ash Advisory Center*, Tokyo, Japan (URL http://ds.data.jma.go.jp/svd/vaac/data/); *RIA Novosti*, Russian News and Information Agency, 4 Zubovsky Bulvar, 119021, Moscow, Russia (URL: http://en.rian.ru/).

Kilauea

Hawaiian Islands, USA
19.421°N, 155.287°W; summit elev. 1,222 m
All times are local (= UTC - 10 hours)

According to the Hawaiian Volcano Observatory (HVO) of the U.S. Geological Survey (USGS), Kilauea's eruption that began in 1983 had by January 2007 emitted 3.1 km^3 of lava, covering 117 km^2 of land surface, and adding 201 hectares (201 x 10^4 m^2) to Kilauea's southern shore. HVO has divided the multi-decade eruptive interval into a series of episodes, and on 19 June 2007 they announced the start of episode 56. This background section provides context on the later report consisting of subsections discussing 1 April-19 June 2007 (episode 55) activity and some large earthquakes during 2006 and 2007.

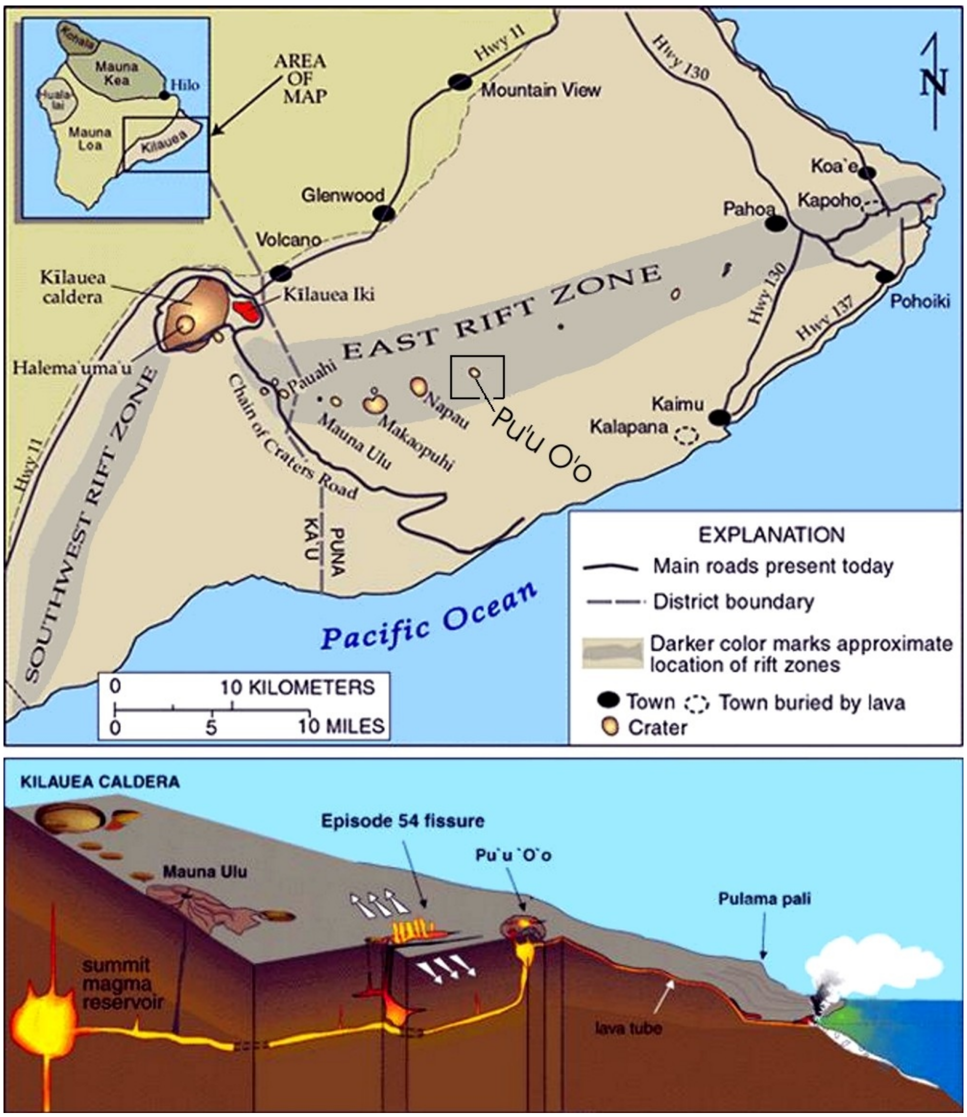

Figure 5. Plan-view and cross-sectional diagrams illustrating the island of Hawaii (the largest and southernmost in the Hawaiian chain) showing selected volcanological features. The inset shows the five volcanoes that comprise the island (old to young): Kohala, Hualalai, Mauna Kea, Mauna Loa, and Kilauea. Kilauea is cut by the SW and E rift zones, and the summit caldera lies near their intersection. From the summit caldera the E rift zone extends 55 km to the eastern tip of the island. Along that path lies a string of craters, including Mauna Ulu and Pu`u `O`o. The cross-section displays a simplified model of Kilauea's inferred internal structure. Note the location of vents, at Pu`u `O`o and elsewhere along a fissure, along the E rift zone. The diagram also shows a lava tube running from Pu`u `O`o to the sea. Courtesy of HVO-USGS.

Figure 5 provides an overview of the E and SW rift zones. The lower diagram shows relationships between major features on the surface and those inferred at depth. The ongoing eruption has often emitted lavas from it's upslope vent, Pu`u `O`o, leaving an upper flow-field laden with a complex series of lava flows, lava tubes, and related features.

Figure 6 consists of a map of the Pu`u `O`o region of Kilauea and the names applied to many of the features there as of June 2006. For comparison, maps current through parts of 2004 appeared previously (*BGVN* 29:02 and 29:09). A newer map created during late 2006 extends coverage slightly farther to the S (figure 7). The Campout flow discharged from the Prince Kuhio Kalaniana`ole (PKK) lava tube at a spot ~ 1 km S of Pu`u `O`o.

The Campout flow emerged during May 2006. It advanced over the surface and ultimately reached the ocean (figure 8). The Campout flow later evolved a lava tube system that extended 8-10 km S, bringing lava to an ocean entry at E Ka`ili`ili. A third entry, fed by an offshoot of the Campout flow, became active on 26 December 2006. The PKK lavas met the sea at E Lae`apuki.

Activity during 1 April-19 June 2007. Our previous report noted lava flows reaching the ocean between December 2006 and March 2007 (*BGVN* 32:05). Earthquake swarms that began in mid-May along the upper rift are discussed in a separate subsection below.

During 1 April to 19 June 2007, several key pathways remained active down Kilauea's flanks (figures 7 and 8). First, lava emerged from the PKK tube at the top of Pulama pali and then continued as surface flows down the pali. The Campout lava tube continued to provide lava to the coast at the Kamokuna ocean entry. The Campout lava tube also fed an eastward branch that emerged at the low-elevation end of the Royal Gardens, a long-abandoned housing subdivision (figure 8) where lava ignited fires on 11 April. The Campout lava tube also fed a westward branch to the coastal plain inland of the E Lae`apuki sea cliff, although the ocean entry was not visible. During the reporting interval, Kamokuna was the only consistently active ocean entry point.

During 4-24 April, incandescence was intermittently visible from several breakouts on the Pulama pali and from several vents in Pu'u 'O'o's crater. On 11 April, lava from the E arm of the Campout flow ignited fires at the base of the long-abandoned housing sub-division called Royal Gardens.

Throughout May, lava from Kilauea continued to flow SE across a lava delta into the ocean at the Kamokuna entry. Incandescence was visible from several vents in the Pu'u 'O'o crater and from breakouts on, above, and at the base of the Pulama pali fault scarp. During 3-4 May, the Campout flow sent large channelized a'a' flows descending down the pali. On 4 May, a sheet flow ponded lava at the base of the Royal Gardens.

On 8 May, HVO scientists reported that for the past several months, Kilauea caldera widened at a rate of 1.5 cm/month. Multiple updates around this time noted that Pu'u 'O'o crater was slowly collapsing. This was indicated by both new cracks on the S flank and subsidence of the N flank at a rate of 1 cm/month.

On 10 May, ~ 6.5 hectares of the E Lae`apuki bench collapsed, starting from the E-side and moving progressively westward. Observers saw the collapse during the time interval 1625-1900. The event generated the strongest seismic signals during 1711-1855. Each section of collapse generated steam-plume emissions occasionally blackened by rock fragments. The plumes resulted from the explosive interaction between seawater and incandescent rock exposed immediately after each section collapsed. On 11 May, HVO scientists surveyed the collapse and mapped cracks inland of the sea cliff. They found recently fallen fragments covering 1.2 hectares.

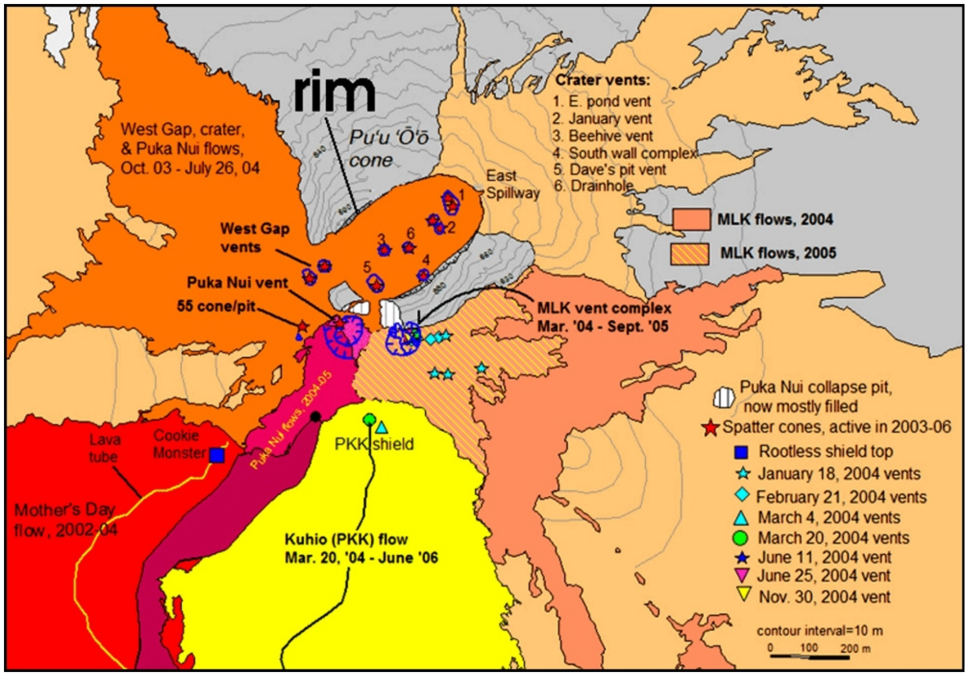

Figure 6. Map of Kilauea's upper SE flank made in June 2006. The map shows the Pu`u `O`o cone and crater ("rim" points to the crater's NW rim), along with nearby vents, lava flows, and numerous other features. Approximate area is outlined in figure 5. Features active in 2005-06 included the numbered vents in the crater, the MLK vent complex and associated lava flows, and the Puka Nui vent. The upper PKK (Kuhio) lava flow, with an associated tube (solid line) feeds lava flows that reach the ocean. Courtesy of USGS-HVO.

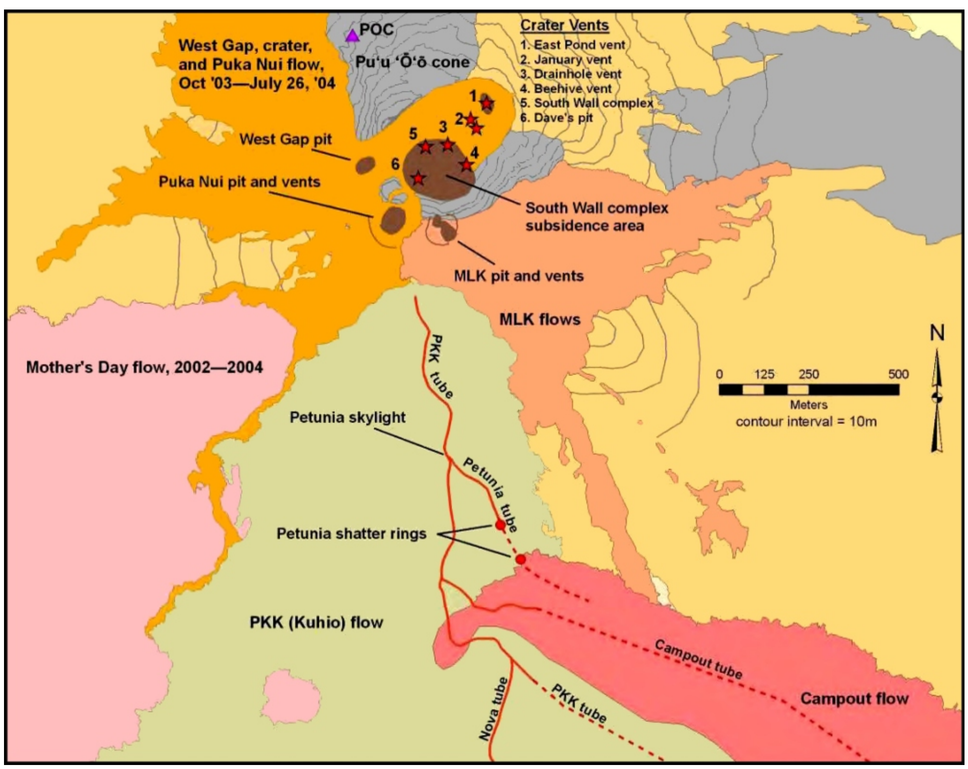

Figure 7. Map of Kilauea showing events at Pu`u `O`O and vicinity through December 2006. The map shows the upper flow field, including the location of crater and flank vents, collapse and subsidence areas, lava tubes and new shatter rings, and the upper Campout flow. Courtesy of HVO (HVO, 2006).

On 16 May, lava from the E-arm of the Campout flow advanced along the coastal plain from the base of the Royal Gardens to reach the ocean at Poupou, a spot ~ 1.6 km E of the Kamokuna entry. On 18 May, HVO field crews reported a delta there reaching 20 m wide. At Poupou, during 23 May-19 June, lava continued to flow SE across this growing lava delta into the ocean. By 24 May, lava had ceased entering the ocean at Kamokuna.

On 18 May, a large lava flow broke out of the PKK lava tube at the site of an old skylight named Petunia. The skylight connected to the PKK lava tube ~ 400 m SE from the tube's head. The Petunia skylight (figure 7) is located in the midst of the upper PKK flows. Color photos of the lava venting on 18 May (figure 9) indicate that the new lava flows have large tongues with prominent zones of incandescence.

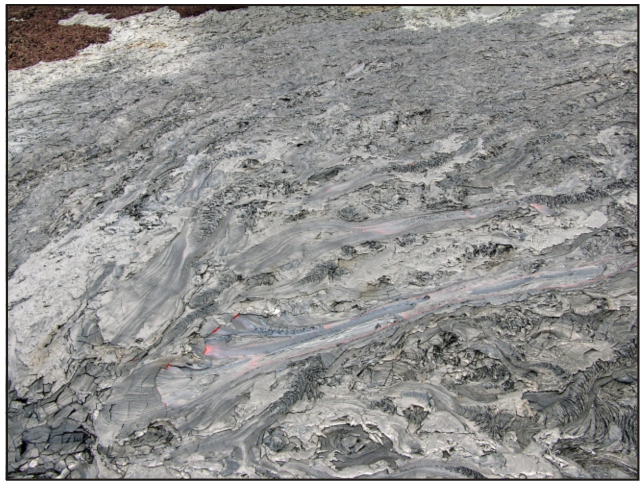

Figure 9. An oblique aerial photo showing a new vent in Kilauea's upper flow field, 18 May 2007. On this date the former Petunia skylight served as the vent for a fairly large lava flow. The point of emission is at the lower left, with lava flowing towards the right (moving S or SE). The new lavas extruded amid the much broader PKK (Kuhio) flow. Courtesy of HVO.

The 18 May HVO update noted that on the coastal plain, 1-2 km^2 of hot, inflating flows were oozing between Royal Gardens subdivision and the Poupou entry. The advance toward the coast had become three-pronged, two on either edge of the now inactive Ka`ili`ili branch of the Campout flow and one farther E. The middle prong fed the growing Poupou entry. The western prong, advancing along the the western edge of the same branch, is still more than 800 m from the ocean. A narrow eastern prong advanced along the far eastern boundary of the National Park, and still remained ~ 500 m from the ocean. This pattern of behavior continued through the rest of May.

The 2 June HVO report stated that the PKK lava tube, still the primary tube from Pu`u `O`o, fed the Campout and the Petunia lava tubes. The Petunia flow had advanced ~ 2 km but was not yet visible below the pali. The Kamokuna and E Lae`apuki ocean entries were not active.

During the week 6-12 June 2007, aerial and satellite observations confirmed that the Petunia flow remained active but was still about the same length. Surface flows were also documented inland of the Poupou entry on the E side of the flow field. On 14 June, the Petunia flow went over the top of the Pulama pali. On 16 June, the front of the Petunia flow advanced down the Pulama pali and was ~ 90-180 m wide.

An E rift intrusion was inferred from increased activity at Kilauea's summit on 17 June. By the morning of 19 June, a small pad of lava was erupted on the NE flank of Kane Nui o Hamo shield. When crews conducted ground-based mapping of the new lava flow about a week later, HVO reported that the eruption occurred from two places along the fissure, separated by ~ 40 m.

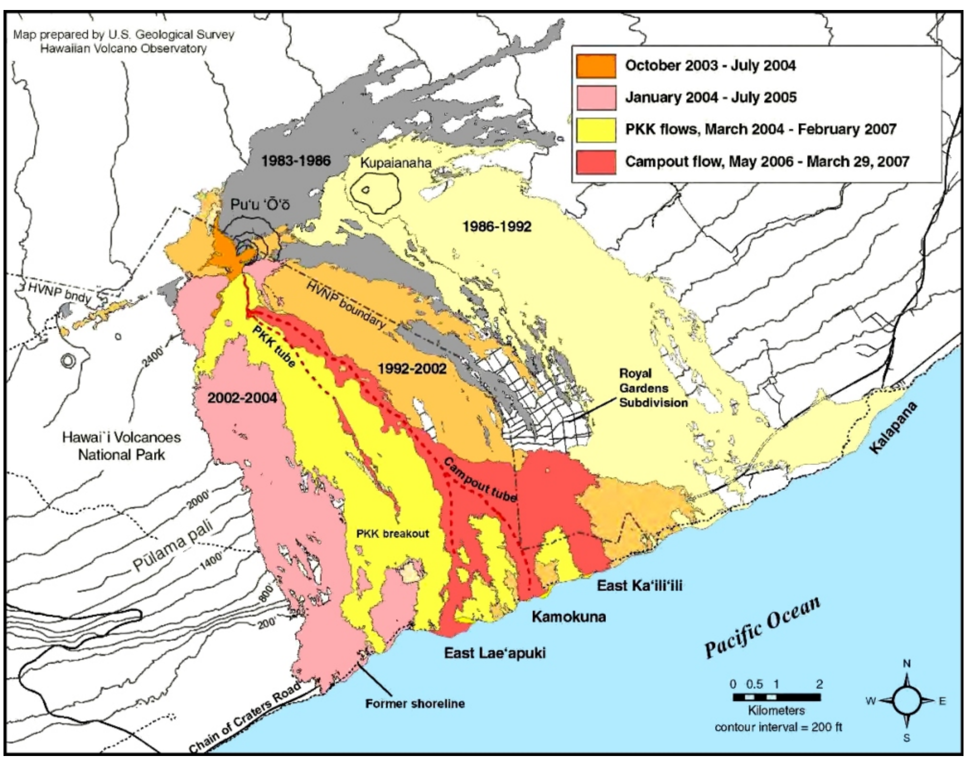

Figure 8. Map of Kilauea's eruption site showing the location of lava flows, tubes, and ocean entries active during January-March 2007. Courtesy of HVO-USGS.

Kiholo Bay earthquake, October 2006. On 15 October 2006 an Mw 6.7 earthquake struck off the NNW shore of the island of Hawaii (~ 11 km NNW of the town of Kalaoa). The focal depth was 29 km. Seven minutes later an Mw 6.0 event followed, part of over 50 aftershocks that occurred.

The intensity was strongest slightly NE of the bay, where it yielded a maximum Modified Mercali value of VII-VIII (very strong to severe). It was felt throughout the region; on Maui some areas may have reached intensity VI. Earthquakes of this type are generally inferred to result from bending stresses within the Pacific plate caused by the weight of overlying islands.

Twelve instruments on Hawaii recorded the shaking. Despite its moderate depth, the earthquake generated high accelerations to the epicenter's NE. An instrument at the Waimea fire station measured large peak ground accelerations nearly equivalent to gravity in both the vertical (0.

88g) and horizontal (1.05g) components. These peak values, which indicate the high-frequency content of the ground motion, primarily affected acceleration-sensitive bodies, such as liquid in containers and nonstructural elements. The ground motions at longer periods (eg., over 1 second), however, were sufficiently small to avert full-scale building destruction. There were no reported deaths.

The earthquake triggered numerous landslides, closed roads, and damaged at least 1,173 buildings. Power outages occurred throughout the Hawaiian Islands. The damage estimates in a later report were high, over 100 million dollars, roughly twenty-fold larger than others in area, although several had larger magnitudes and intensities.

2007 earthquake swarm on the rift zone. A swarm of moderate magnitude earthquakes took place along Kilauea's rift zone beginning 12 May 2007. Since 1998, a few earthquakes with magnitudes greater than 4.0 have occurred at shallow depths beneath the upper E rift zone.

For example, HVO recorded an M 4.7 earthquake at 0913 on 24 May, located beneath the upper E rift zone, near Kilauea's summit at Puhimau crater (at the upper end of Chain of Craters road, figure 5) at a depth of 2 km. On 24 May an M 4.1 aftershock occurred 20 minutes after the main shock, located 1.5 km farther down-rift, beneath Koko`olau crater. An M 3.9 aftershock occurred at 1051 and was located 4 km farther down-rift than the M 4.7 at a depth of 1 km. An M 3.9 aftershock occurred at 1051 and was located another 2.5 km down-rift at a depth of 1 km.

On 17 June, a swarm of earthquakes and rapid deflation began at 0215 in the upper E rift zone. The earthquakes were centered ~ 1 km SW of Mauna Ulu and about 1.5-3 km deep. About 70 earthquakes were recorded in the first 2 hours; at least 10 of those earthquakes were M 3 or greater. National Park Service crews evacuated visitors and closed the Chain of Craters road and the Crater Rim Drive between Jaggar museum and the Thurston lava tube parking lot. Fresh cracks ~ 2 cm wide opened in the Chain of Craters road near the Mauna Ulu turnoff. GPS receivers in the area of most intense seismic activity near Makaopuhi crater documented ~ 10 cm of widening across the rift zone,. HVO observers noted rockfalls from the S wall of Pu`u `O`o cone and collapse of the crater floor around the vents.

Although these were clearly smaller and less damaging than the Kiholo bay earthquake, they occurred along the active vent and fissure system. Substantial earthquakes in this important region continued through at least mid-August (including an M 5.4 earthquake on 13 August).

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Klein, F.W., Frankel, A.D., Mueller, C.S., Wesson, R. L., and Okubo, P.G., 2001, Seismic hazard in Hawaii: high rate of large earthquakes and probabilistic ground motion maps: Bulletin of the Seismological Society of America, v. 91, p. 479-498.

Robertson, I.N., Nicholson, P.G., and Brandes, H.G., 2006, Reconnaissance Following the October 15th, 2006 Earthquakes on the Island of Hawai'i: University of Hawaii, Department of Civil and Environmental Engineering Research Report, UHM/CEE/06-07 (URL: http://www.cee.hawaii.edu/).

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U.S. Geological Survey ShakeMaps, 2006, (URL: http://earthquake.usgs.gov/eqcenter/shakemap/global/shake/twbh_06/).

Geologic Summary. Kilauea volcano, which overlaps the E flank of the massive Mauna Loa shield volcano, has been Hawaii's most active volcano during historical time. Eruptions of Kilauea are prominent in Polynesian legends; written documentation extending back to only 1820 records frequent summit and flank lava flow eruptions that were interspersed with periods of long-term lava lake activity that lasted until 1924 at Halemaumau crater, within the summit caldera. The 3 x 5 km caldera was formed in several stages about 1,500 years ago and during the 18th century; eruptions have also originated from the lengthy E and SW rift zones, which extend to the sea on both sides of the volcano. About 90% of the surface of the basaltic shield volcano is formed of lava flows less than about 1,100 years old; 70% of the volcano's surface is younger than 600 years. A long-term eruption from the E rift zone that began in 1983 has produced lava flows covering more than 100 sq km, destroying nearly 200 houses and adding new coastline to the island.

Information Contacts: *Hawaiian Volcano Observatory (HVO)*, U.S. Geological Survey, PO Box 51, Hawai'i National Park, HI 96718, USA (URL: http://hvo.wr.usgs.gov/; Email:hvo-info@hvomail.wr.usgs.gov); and *Associated Press*.

White Island

New Zealand
37.52°S, 177.18°E; summit elev. 321 m

According to Tony Hurst, reporting in the *GNS Science Alert Bulletin* of 6 March 2007, GeoNet conducted a visit to White Island on 23 February 2007 and found that the water level in the crater lake had fallen by 1.2 m in 10 days. The lake was 9 m below the overflow level, the result of rapid evaporation, with the lake temperature measured at 74ºC. The falling level has reduced the area of the lake by about 10%, and volume by 20%, but there have been no indications of volcanic activity. However, the falling water level could reduce the pressure in the geothermal system, resulting in local boiling events at depth in the lake, and producing transient steam plumes.

Another *Alert Bulletin* prepared by Brad Scott on 3 May 2007 noted that the Alert Level for White Island remained at 1. The rapid decrease in the level of the crater lake seen over the last few months has continued. Recent observations confirmed that the lake was more than 28 m below overflow level, and the depth of water in the lake was likely to be about 10 m. The lake level fell very rapidly during April, significantly decreasing both the area and volume of the lake. The temperature of the lake declined from 74 to 64ºC, probably due to less input from high-temperature steam vents, which are now above the lake. As the water level fell, many steam vents and fumaroles were exposed, producing transient steam plumes as high as 3 km sometimes mistaken as eruptions. However, no eruptions have occurred, and no changes in any of the monitoring data indicate potential increases in volcanic activity in the near future.

Geologic Summary. Uninhabited 2 x 2.4 km White Island, one of New Zealand's most active volcanoes, is the emergent summit of a 16 x 18 km submarine volcano in the Bay of Plenty about 50 km offshore of North Island. The 321-m-high island consists of two overlapping andesitic-to-dacitic stratovolcanoes; the summit crater appears to be breached to the SE because the shoreline corresponds to the level of several notches in the SE crater wall. Volckner Rocks, four sea stacks that are remnants of a lava dome, lie 5 km NNE of White Island. Intermittent moderate phreatomagmatic and strombolian eruptions have occurred at White Island throughout the short historical period beginning in 1826, but its activity also forms a prominent part of Maori legends. Formation of many new vents during the 19th and 20th centuries has produced rapid changes in crater floor topography. Collapse of the crater wall in 1914 produced a debris avalanche that buried buildings and workers at a sulfur-mining project.

Information Contacts: *GeoNet*, a collaboration between the Earthquake Commission and GNS Science (URL: http://www.geonet.org.nz/); *GNS Science*, Wairakei Research Center, Private Bag 2000, Taupo 3352, New Zealand (URL: http://www.gns.cri.nz/); *Earthquake Commission (EQC)*, PO Box 790, Wellington, New Zealand (URL: http://www.eqc.govt.nz/).

Ruapehu

New Zealand
39.28°S, 175.57°E; summit elev. 2,797 m

This material supplements our most recent *Bulletin* report on Ruapehu (*BGVN* 32:03). There we indicated that the tephra dam at Crater lake burst on 18 March 2007, initiating a lahar. Only a portion of the lake drained, a body that contains ~ 9×10^6 m^3 of hot acidic water at 2,530 m elevation (Manville and others, 2007). Recent pictures taken before and after the event show a portion of the lahar channel (figures 10 and 11). This lahar was among the best studied and carefully instrumented to date and may shed light on how volcano dams fail. Vernon Manville coordinated the science response to the lahar and noted that the large boulder that serves as a scale in figures 10 and 11 is "a large chunk of older (probably pre-glacial) lahar deposits. Its long axis is about 10 m, which would give 10-15 m of aggradation in the channel as a result of the 2007 lahar."

An article in *Science* (Bohannon, 2007) described the technology used by the New Zealand Department of Conservation to warn of an impending lahar and to predict its path. Prior to the failure, direct current (dc) resistivity surveys were made across the tephra dam in 2005, 2006, and 2007 (Turner and others, 2007). Investigators found the dam's electrical conductivity, which is sensitive to the degree of water saturation, dropped as the lake water level rose and water infiltrated into the tephra dam. The January 2007 measurement found a large increase in conductivity, suggesting that the dam had become close to saturated.

The early warning system included geophones at the lake's rim and on the slopes, a buried wire set to trip when the dam burst, and a meter in the lake to record sudden drops in the lake level. On 18 March, the instruments recorded a breach in the tephra dam and the resulting lahar, which generated an alarm message transmitted automatically to scientists, police, and highway authorities. No one was injured and damage was minor, even though the lahar traveled 155 km to the ocean. According to the article, data indicated that the surging lahar may have produced a soliton, a standing wave that is able to propagate over great distances without losing energy or changing shape.

The *Science* article also indicated that researchers are developing "before" and "after" landscape images to gain insight into possible future lahar routes. To accomplish this, researchers have collected samples and used Global Positioning System measurements and light detection and ranging (LIDAR) technology to map the composition and distribution of material on the slopes and to develop three-dimensional models of land features.

According to a US National Science Foundation press release (NSF, 2007), a University of Hawaii volcanologist, Sarah Fagents, is using the data from Ruapehu to develop a computer model to simulate the route a future lahar would

Figure 10. Ruapehu's lahar channel just before the collapse of Crater Lake's walls on 18 March 2007. Point of triangle indicates a large boulder to the right of the river channel; it's long axis is ~ 10 m in length. Courtesy of Vern Manville and Rebecca Carey, and the U.S. National Science Foundation.

Figure 11. Ruapehu's lahar channel just after the collapse of Crater Lake's walls on 18 March 2007. Point of triangle indicates the same boulder as in the previous figure. Courtesy of Vern Manville, Sarah Fagents, and the U. S. National Science Foundation.

take and to predict the associated hazards. The model would eventually consider different lahar triggering mechanisms, and incorporate allowances for different locations, to make it widely applicable.

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National Science Foundation, 2007, Geologists Witness Unique Volcanic Mudflow in Action in New Zealand, 13 July 2007: NSF press release 07-077.

Turner, G., Ingham, M., and Bibby, H., 2007, Electrical resistivity monitoring of seepage and stability of the tephra barrier at Crater Lake, Mt Ruapehu, New Zealand: Geophysical Research Abstracts, v. 9, p. 11630.

Geologic Summary. Ruapehu, one of New Zealand's most active volcanoes, is a complex stratovolcano constructed during at least 4 cone-building episodes dating back to about 200,000 years ago. The 110 cu km dominantly andesitic volcanic massif is elongated in a NNE-SSW direction and is surrounded by another 100 cu km ring plain of volcaniclastic debris, including the Murimoto debris-avalanche deposit on the NW flank. A series of subplinian eruptions took place at Ruapehu between about 22,600 and 10,000 years ago, but pyroclastic flows have been infrequent at Ruapehu. A single historically active vent, Crater Lake, is located in the broad summit region, but at least five other vents on the summit and flank have been active during the Holocene. Frequent mild-to-moderate explosive eruptions have occurred in historical time from the Crater Lake vent, and tephra characteristics suggest that the crater lake may have formed as early as 3000 years ago. Lahars produced by phreatic eruptions from the summit crater lake are a hazard to a ski area on the upper flanks and to lower river valleys.

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Rabaul

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

During April and May 2007 (*BGVN* 32:05) and through mid-June 2007, the Rabaul Volcanological Observatory (RVO) reported that low-level activity continued at Tavurvur. Between the afternoon of 19 June and the morning of 20 June, four explosions occurred (at 1745 and 1928 hours on 19 June, and at 0319 and 0933 on 20 June) producing shockwaves that rattled windows of houses in Rabaul Town and surrounding areas. The explosions also showered the flanks with lava fragments.

Ash clouds from the 19 and 20 June explosions rose about 2 km before being blown to the NW, resulting in moderate ashfall in Rabaul and downwind areas such as Ratavul, Volavolo, and Nonga villages (each on the SE shore of Talili Bay about 10 km NW from the Tavurvur summit). Weak-to-moderate glow was visible at night, and occasional weak-to-loud roaring noises, probably due to steam production, continued to be heard during the above 1-day period. RVO attributed the June-July 2007 eruptions to result from residual unquenched magma remaining from the eruption of October 2006 (figure 12).

Summaries of geophysical activity at Rabaul for June-July 2007 are shown in tables 1 and 2. After the four big explosions on 19 and 20 June, Tavurvur emitted variable volumes of white vapor containing very little ash content for the next two days. These emissions were accompanied by blue vapor clouds that rose less than 1 km before drifting N-NW. Very fine ashfall occurred downwind, in-

Date (2007)	High-frequency earthquakes: date (number)	Low-frequency earthquakes: date (number)	Explosion earthquakes: date (number)	Comments on level of seismicity
04-15 June	None			Low
16-20 June	8 June (1), 18 June (3), 19 June (1) (all originated NE of Rabaul caldera)	19 June (26)	19 June (2), 20 June (2)	Low to moderate
20-21 June	21 June (1) (originated NE of Rabaul)	43 total.	21 June (1) (weak)	Low to moderate
22-25 June	Eight total.	[102 total—five originated NE of caldera, two from S (2.5 km S of Raluana), one from NW (2 km S of Watom Island)]		Low to moderate
26-29 June		(range of 27-44 per day—slightly higher than normal background)		Low to moderate
02-14 July	None	3-6 July (range of 9-11 per day, 7-10 July (range of 2-6 per day, 10-14 July (1-7 of per day)	5 July (1)	Low
14-17 July	None	Five on 14 July, 0 on 15 July, 55 on 16 July	17 July (1)	Slight increase to moderate
18-21 July		Eleven total		Decrease to low

Table 1. Summary of seismic activity at Rabaul during June-July 2007. Courtesy of RVO.

Figure 12. Eruption of the Tavurvur cone, seen from across the harbor formed by Rabaul caldera. The photo was taken at 0900 on 7 October 2006. Courtesy of Reinhard Lorenz.

cluding in Rabaul Town where mild smell of hydrogen sulphide (H_2S)gas was evident. Occasional weak roaring noises were heard accompanying the vapor emissions, and weak-to-moderate glow was visible at night. Thick white vapor was emitted from the crater on the morning following rain on the night of 21 June 2007.

By 22 June activity had returned to a low level, with emissions consisting of moderate to dense white and blue vapor rising to about 1 km. An odor of H_2S gas was evident in Rabaul Town on 22 and 25 June (along with rain that stung the eyes on 25 June). Occasional weak roaring noises continued to be heard accompanying the vapor emissions, and weak to moderate red glow was visible at night.

Tavurvur remained quiet during 26-28 June 2007. Variable amounts of white fume were produced, the quantity of steam present reflecting atmospheric conditions (such as temperature and humidity). Moderately strong night-time glow was still present, but Tavurvur made no sound. A slight smell of H_2S lingered downwind. An M 6.7 earthquake that occurred at 1252 on 28 June was located beneath the Solomon Sea, but it was not related to volcanic activity.

Tavurvur remained quiet during 2-4 July 2007, releasing variable amounts of white vapor.

A big explosion occurred at 0511 on 5 July, producing a shock wave that rattled houses in Rabaul Town and surrounding villages. A thick gray ash cloud rose ~ 2 km above the summit before being blown N to NW. Fine ashfall occurred in Rabaul and areas downwind. A weak glow was visible at night and occasional weak to loud roaring noises were occasionally heard. A slight smell of sulphur lingered downwind. A thermal image taken from RVO indicated that the volcano was relatively cool. A weak glow was visible around the crater rim on 7 July.

Tavurvur released pale gray ash clouds from about 1400 on 10 July to 11 July 2007. The ash clouds rose less than 500 m above the summit and were blown to the N and NW of the volcano. Fine ashfall occurred at Rabaul and villages downwind between 10 and 11 July. From 12 until 14 July, the emission returned to white, thin-to-thick vapor accompanied by blue vapor that continued to drift to the N and NW. Downwind there was still a weak smell of sulphur in the emission. Occasional low roaring noise was heard and a weak to moderate glow was visible above the crater rim.

During 14-16 July, Tavurvur was only releasing variable amounts of white vapor accompanied by blue vapor. Occasional low roaring noise was heard during the above period and a weak to moderate red glow was visible above the crater rim.

A large single explosion occurred at Tavurvur at 0648 on 17 July 2007. The explosion was accompanied by a loud booming noise and a thick brown ash cloud that showered the flanks with lava fragments. The ash cloud rose about 1. 5 km above the summit before curving NW of the volcano over Rabaul and Malaguna village. Fine-to-moderate ashfall occurred in Rabaul and Malaguna and areas downwind.

Low activity at Tavurvur continued during 18-22 July 2007. After the explosion on 17 July, Tavurvur continued to release variable amounts of white vapor accompanied by blue vapor that was blown N to NW of the volcano. Some of the white vapor emissions contained a small amount of ash. Smell of sulphur occurred on the downwind side of the vapor plume on 19 July. Occasional low roaring noise continued to be heard during the above period and a weak to moderate red glow was visible above the crater rim.

Date (2007)	Global positioning system (GPS)	Water tube tilt monitoring	Comments
04 Jun-08 Jun	slight uplift	slight uplift	insignificant!
08 Jun-18 Jun	slight inflation	slight inflation	pressure build-up
20 Jun-22 Jun	no apparent deformation	no apparent deformation	
22 Jun-26 Jun	slight uplift	slight uplift	
26 Jun-28 Jun	stable	stable	
28 Jun-29 Jun	slight subsidence	slight subsidence	
03 Jul-06 Jul	low-level deformation	low-level deformation	
06 Jul	minor inflation	minor inflation	
07 Jul-08 Jul	stable	stable	
09 Jul-10 Jul	further inflation	further inflation	precursor to ash release on 10-11 July
11 Jul	subsidence	subsidence	
14 Jul-16 Jul	minor inflation	minor inflation	horizontal movement twice that of vertical movement
18 Jul-22 Jul	inflation trend	inflation trend	northward movement

Table 2. Summary of Rabaul ground deformation, June-July 2007. Courtesy of RVO.

MODIS/MODVOLC data. MODIS satellite thermal anomalies measured between 16 November 2006 and 23 July 2007 are shown in table 3; no thermal anomalies were measured between 17 November 2006 and 12 February 2007.

Geologic Summary. The low-lying Rabaul caldera on the tip of the Gazelle Peninsula at the NE end of New Britain forms a broad sheltered harbor utilized by what was the island's largest city prior to a major eruption in 1994. The outer flanks of the 688-m-high asymmetrical

Date (UTC)	Time (UTC)	Number of Pixels	Satellite
13 Feb 2007	1225	2	Terra
08 Mar 2007	1230	1	Aqua
08 Mar 2007	1530	2	Terra
15 Mar 2007	1235	1	Terra
22 Mar 2007	1240	1	Terra
24 Mar 2007	1525	2	Aqua
05 Jun 2007	1220	1	Terra
05 Jun 2007	1520	1	Aqua
12 Jun 2007	1230	1	Terra
14 Jun 2007	1515	1	Aqua
23 Jun 2007	1510	1	Aqua
16 Jul 2007	1515	1	Aqua
23 Jul 2007	1225	1	Terra

Table 3. MODIS thermal anomaly data for 2007 for Rabaul. Courtesy of Hawai'i Institute of Geophysics and Planetology (HIGP) Thermal Alerts System.

pyroclastic shield volcano are formed by thick pyroclastic-flow deposits. The 8 x 14 km caldera is widely breached on the E, where its floor is flooded by Blanche Bay and was formed about 1400 years ago. An earlier caldera-forming eruption about 7,100 years ago is now considered to have originated from Tavui caldera, offshore to the N. Three small stratovolcanoes lie outside the N and NE caldera rims of Rabaul. Post-caldera eruptions built basaltic-to-dacitic pyroclastic cones on the caldera floor near the NE and western caldera walls. Several of these, including Vulcan cone, which was formed during a large eruption in 1878, have produced major explosive activity during historical time. A powerful explosive eruption in 1994 occurred simultaneously from Vulcan and Tavurvur volcanoes and forced the temporary abandonment of Rabaul Town.

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Heard

Southern Indian Ocean
53.106°S, 73.513°E; summit elev. 2,745 m

Based on Hawai'i Institute of Geophysics and Planetology (HIGP) Thermal Alerts System MODVOLC analysis of MODIS (Moderate Resolution Imaging Spectroradiometer) satellite thermal anomaly data, Matt Patrick reported in June 2007 that the eruption at Heard that started about a year ago (*BGVN* 31:05, 31:11, and 32:03) seemed to have ceased. Due to its isolated location, Heard Island is rarely visited, and satellite imagery provides the only regular information on eruptive activity. There have been three eruptive periods of 11 months or longer during which thermal anomalies were frequent since MODIS data came online in early 2000 up to 21 July 2007 (table 4).

A graph prepared by Patrick and the HIGP Thermal Alert System Team (figure 13) showing radiant heat output and distance of alert pixels from the volcano vent (1 pixel=1 km) also shows the three separate eruptions since 2000. Pixel distances determined from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data and the MODVOLC alert show that activity during all three eruptions was centered around the summit crater, with sporadic lava flows during the 2000-2001 and 2006-2007 episodes. Only the 2000-2001 eruption clearly featured long (i.e. several kilometer long) lava flows, as shown by the > 3 km distance in July 2000 (figure 13). Patrick noted that a 2-km-long lava flow seen in Landsat imagery early in the 2000 eruption, on 7 July 2000 (figure 14), was detected by MODVOLC on 10 July 2000. However, since the location of the MODVOLC alerts from that time period were not far from the source vent, the alerts were not effective for showing the length of the lava flow.

The 2003-2004 and 2006-2007 activity appeared to be largely limited to the summit crater, as indicated by the small MODVOLC distances (i.e. 1 km or less, with 1 km being the size of the pixels and inherent uncertainty) and ASTER data examined. ASTER data did show a possible 900-m-long flow to the SW of the vent in May 2006 (*BGVN* 31:05 and 31:11) and a clear 700-m-long flow of lava extending NE of the summit crater in December 2006, indicating that small effusive events have occurred in addition to central vent activity in the 2006-2007 phase. Patrick has not observed to this time any obvious ash plumes in the ASTER images, but all of the images examined appeared to be partly cloudy.

Eruption	First Anomaly	Last Anomaly	Duration	Comments
2000-2001	07 Mar 2000	02 Feb 2001	332 days	857 days until next eruption. An earlier report (*BGVN* 28:01) indicated that this eruption began in May 2000, while Patrick's data indicated that MODIS thermal alerts began in March 2000.
2003-2004	09 Jun 2003	14 Jun 2004	371 days	635 days until next eruption
2006-2007	11 Mar 2006	06 Apr 2007	391 days	A single anomaly on 11-12 March 2006 was followed by lack on anomalies until 6 May, when they became frequent. (Note: since 6 April 2007, only one, single-pixel anomaly has been measured—24 July 2007. Patrick concluded that the 2006-2007 eruptive phase of nearly daily alerts ended on 6 April 2006.)

Table 4. Summary of eruptive episodes at Heard based on MODVOLC analyses of MODIS thermal satellite data. Courtesy of Matt Patrick.

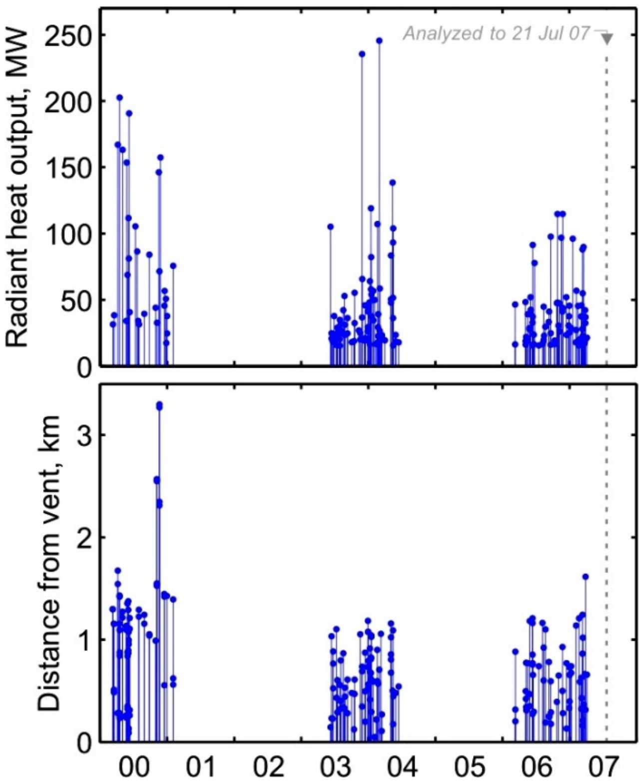

Figure 13. MODVOLC data for Heard showing radiant heat output (top) and distance of alert pixels from the vent (bottom), January 2000-21 July 2007. Courtesy of Matt Patrick.

Patrick noted that it is difficult to determine exactly how often thermal anomalies for Heard Island may be completely obscured by clouds. The benefit of MODIS is the 1-2 observations per day, so that if activity is indeed present, it should not elude detection for very long. In the MODVOLC plot (figure 13), there were fairly regular alerts over the course of a year or so at a time, during which there must have been some cloud cover.

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.

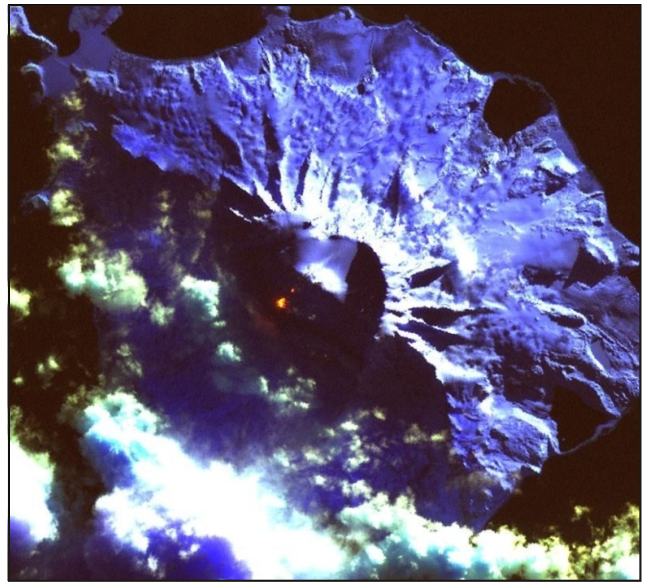

Figure 14. Landsat image showing active flow at Heard Island, 7 July 2000. Courtesy of Matt Patrick.

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