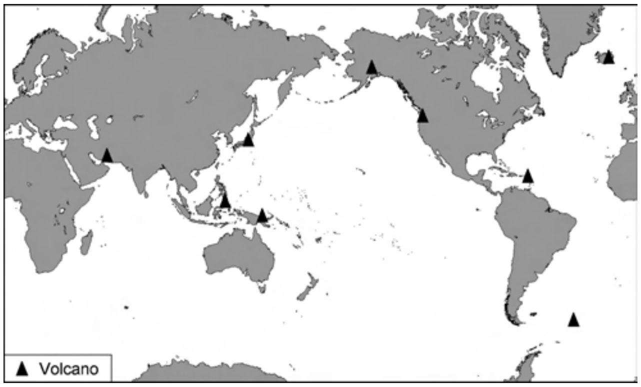
Bulletin of the Global Volcanism Network



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Grímsvötn

SE Iceland
64.42°N, 17.33°W; summit elev. 1,725 m
All times are local (= UTC - 1 hour)

According to scientists from the Institute of Earth Sciences at the University of Iceland and the Icelandic Meteorological Office, an eruption began at the subglacial Grímsvötn volcano in the Vatnajökull ice cap, Iceland, on 1 November 2004 around 2100, and was declining by 5 November. The eruption, preceded by both long- and short-term precursors, was triggered by the release of overburden pressure associated with a glacial-outburst flood (jökulhlaup) originating from the subglacial caldera lake. The jökulhlaup reached a maximum on the afternoon of 2 November. At that time the peak discharge from affected rivers on the coastal plain at Skeidararsandur was 3,000-4,000 m^3/s (based on information from the Icelandic Hydrological Service). Discharge declined quickly after the peak. No damage occurred to roads or bridges. The total volume of the jökulhlaup was ~ 0.5 km^3.

Seismicity increased at the volcano in mid-2003, about the same time that uplift exceeded a maximum reached in 1998. Tthe last eruption at Grímsvötn occurred within the caldera beginning on 18 December 1998 and resulted in a catastrophic flood. Additional uplift and expansion of the volcano since mid-2003 heralded the latest activity. Seismicity further increased in late October 2004, and on 26 October high-frequency tremor indicated increased water flow from the caldera lake and suggested that a glacial outburst flood was about to begin. On 29 October, the amount of discharge increased in the Skeidara River. About 3 hours before the eruption an intense swarm of volcanic earthquakes started, changing to continuous low-frequency tremor at the onset of the eruption.

The release in overburden pressure associated with the outburst flood triggered the eruption. The amount of drop in water level in the caldera at the onset of the eruption was uncertain, but was probably on the order of 10-20 m, corresponding to a pressure change of 0.1-0.2 MPa at the volcano's surface. This modest pressure change triggered the eruption because pressure in the shallow magma chamber was high after continuous inflow of magma since 1998.

Figure 1 shows the epicenters from 18 October to 1 November 2004, along with preliminary locations of the eruption site. In the early morning of 1 November, an earthquake swarm began beneath Grímsvötn. By 1400 there were 12 earthquakes; at 0651 the largest, an event of M 3 occurred. At 2010 on 1 November an eruption warning was sent to the Civil Defence, earthquake magnitudes had increased and around that time the swarm intensified. About 160 earthquakes with magnitudes up to 2.8 were recorded during the next 2 hours.

Initially under ice 150-200 m thick, the eruption melted its way through to the surface in about 1 hour. An eruption plume was detected by radar around midnight on 1 November. Radar estimates of plume altitude stood at 12-13 km numerous times during 2-3 November. A plot of altitude versus time showed two cases where plume heights were almost 13 km; each occurred about 0200 on 2 and 3 November. The weather radar used to make the plot was located at Keflavik-Airport, 260 km from Grímsvötn.

Lightning. Early on 2 November and through most of the morning on 3 November, numerous lightning strikes were detected by instruments, and their computed locations largely centered over Grímsvötn. The ash plume was driven to the N by southerly winds during the whole eruption. Accordingly, both the scatter and SE extension of the lightning were judged likely artifacts of imprecision in estimates of lighning locations (figure 2).

Regarding the lightning data, geophysicist Pordur Arason described the three systems used. First, the Icelandic lightning location system consists of three LLP direction finder stations, each measuring time, direction, polarity, intensity and multiplicity. The stations discriminate lightning and record only cloud-to-ground (CG) lightning. The location system is old (produced pre-1980) and unfortunately only one station (Sydri-Neslond) gave useful mea-

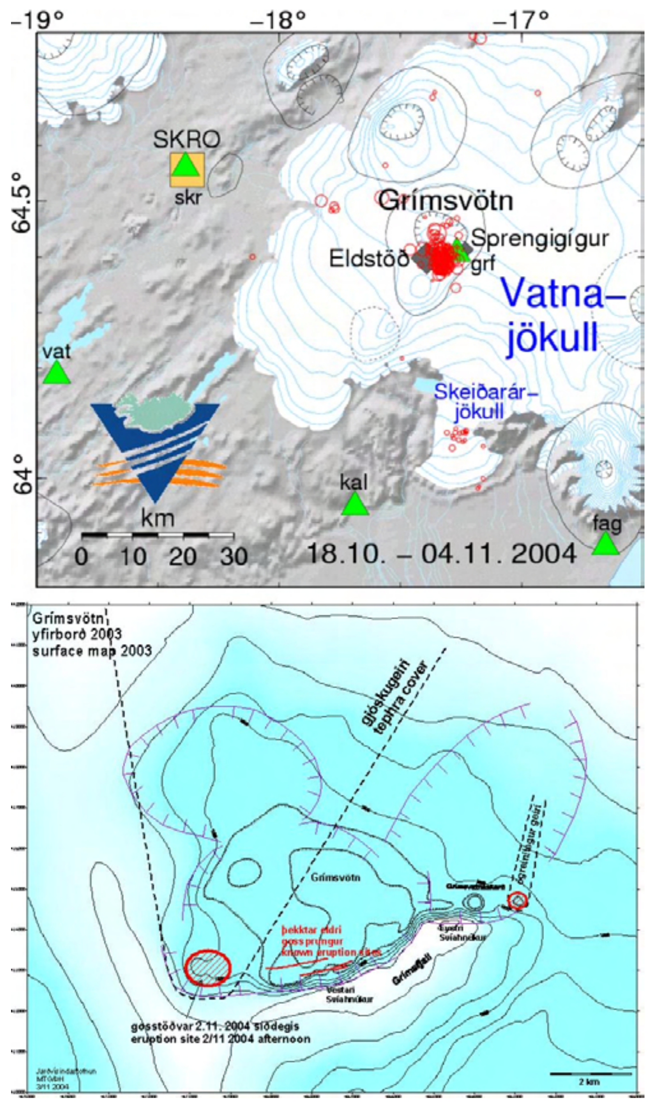

Figure 1. A map of the Grímsvötn area (top) showing epicenters registered from 18 October to 1 November 2004 (circles) and approximate locations of vents through the glacier (two diamonds), which lie just inside the caldera's SE margin. Seismic stations are denoted by triangles, and a continuous GPS (Global Positioning System) station by a square. A larger-scale map (bottom, base map by Magnús Tumi Guðmundsson) provides a closer look at the 2004 eruption site, locating the two ice cauldrons and cracks, as well as the margins of the ash dispersal patterns. Contours reflect 2003 ice-surface contours. A separate set of boldly hachured lines indicates the lobate form of the subglacial caldera's topographic margins. Courtesy of the Icelandic Meteorological Office.

surements. By assuming distance from the station to Grímsvötn, Arason calculated the current in the lightning. He noted that almost all of this CG lightning showed negative polarity (lightning polarity is determined by the charge of the cloud compared to Earth).

A second lightning system results from cooperation with the UK Met Office, and one of their ATD sferics stations in Iceland. Arason had access to their data. The locations on figure 2 are those of the ATD system, which gives times and locations but does not discriminate between cloud-to-ground (CG) lightning and cloud-to-cloud (CC) lightning, although it is biased towards CG, since its antennas only measure vertical electric-field variations.

The third system was a one-station recording system of vertical electric field variations (EFMS) in Reykjavik that records the vertical component of the electric field every 200 ns for a period of a 1 ms. During the eruption it recorded the waveforms of about 150 lightning events. About half of these show characteristics of a negative polarity CG and half CC.

Magma-water interactions lead to explosions, emission of ash and steam, and to charge separation. Erupted ash becomes negatively charged and the steam positively charged. Almost all of the CG lightning had negative polarity, indicating its origin in the ash, and not the steam.

Other observations. The initial inspection of the eruption from an airplane took place around 0800 UTC on 2 November. It confirmed that a phreatomagmatic eruption was in progress from a short (less than 1-km-long) eruptive fissure at 64.40°N, 17.23°W. At that time a continuous plume rose to ~ 9 km altitude. Observations throughout the day revealed periods of high explosive activity, with maximum plume heights of 12-14 km. The strength of the eruption correlated with the seismically recorded volcanic tremor. Some explosive activity had occurred in a second ice cauldron near the SE edge of Grímsvötn, 8 km to the E of the main crater. This ice cauldron issued steam when first detected after noon on 2 November.

The London VAAC reported that the ash plume produced from the eruption reached a height of ~ 12.2 km a.s.l. According to news articles, the eruption occurred in an unpopulated region so no evacuations were needed, but air traffic was diverted away from the region.

Observation flights later on 2 November photographed and videoed the vent that had opened through in the ice (figures 3-5). Plumes were sometimes nearly white and steam dominated, at other times black and ash dominated, and in some cases visible portions of the plumes simultaneously reflected both of these extremes (figure 3, 4, and 5). A 2 November view of the jökulhlaup appears as figure 6.

Figure 3. A view looking NW at the Grímsvötn eruption across an expanse of the Vatnajökull glacier. This photo was taken between 1530 and 1615 on 2 November 2004. Courtesy of the Icelandic Meteorological Office; photo credit, Matthew J. Roberts.

Figure 4. An E-looking aerial photograph showing ash falling from the Grímsvötn eruption plume, which at the time was far from vertical. The shot was taken between 1530 and 1615 on 2 November 2004. Courtesy of the Icelandic Meteorological Office; photo credit, Matthew J. Roberts.

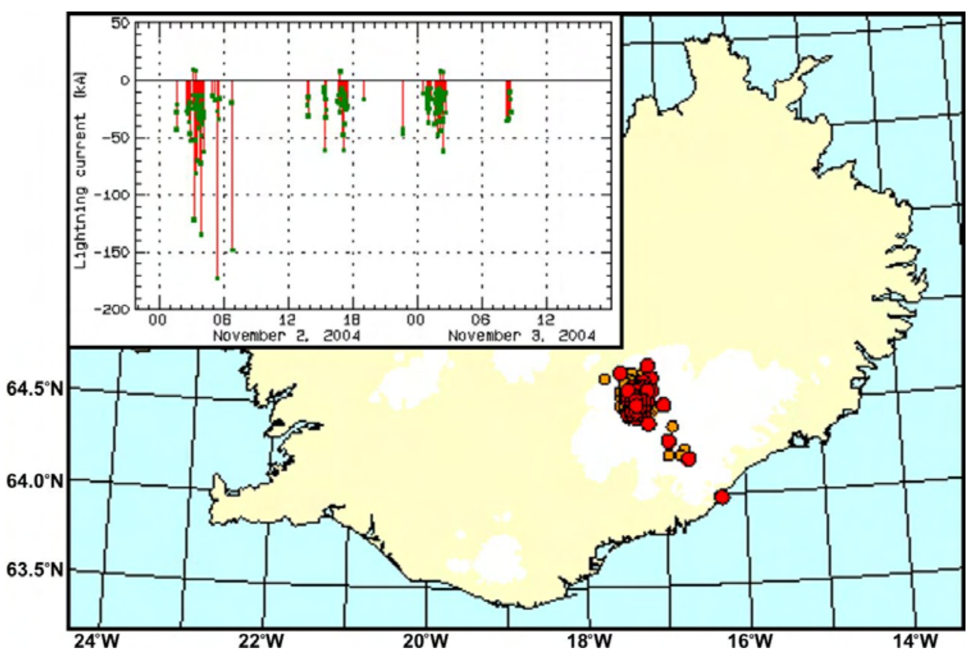

Figure 2. Map view of lightning in Iceland located by the UK Met Office's ATD sferics system during the first 36 hours of the Grímsvötn eruption (posted on the website of the Icelandic Meteorological Office). The inset graph shows a time-series of lightning strikes and their currents in kA (thousands of amps) recorded in conjunction with the Grímsvötn eruption during 2-3 November 2004. The plot was produced with data from the Syðri-Neslönd station, an LLP lightning direction-finder.

Figure 5. Close-up aerial view of the Grímsvötn eruption, taken from the S between 1530 and 1615 on 2 November 2004. Courtesy of the Icelandic Meteorological Office; photo credit, Matthew J. Roberts.

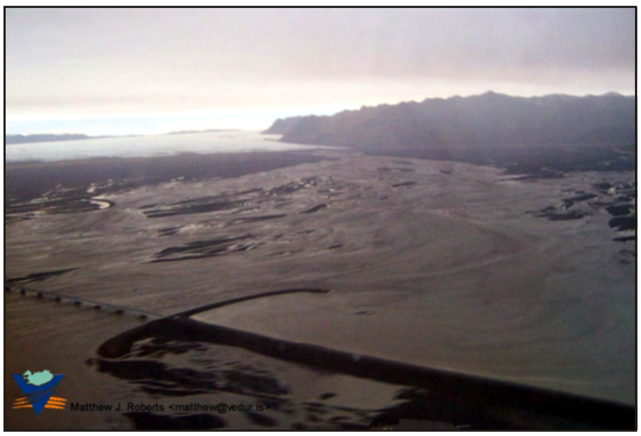

Figure 6. An aerial photo of the jökulhlaup from the Grímsvötn eruption, taken at 1630 on 2 November 2004 (at Skeidarar) looking inland towards the glacier (left, mid-background). The swollen, sediment-charged river system has locally inundated the coastal plains and challenged the roadway system engineered to cope with such occurrences. Courtesy of the Icelandic Meteorological Office; photo credit, Matthew J. Roberts.

On 3 November, eruptive activity occurred in pulses, resulting in changing eruption column heights from 8-9 km to 13-14 km above the volcano. During the course of the eruption, ash plumes and tephra distributions imaged by satellites typically showed trends to the NE; in some cases plumes remained visible at least 150 km from the eruption site. A distal ash plume was observed in Norway, Finland, and Sweden.

On 9 November from 0630 to 1330 a tremor pulse was recorded, and on 11 November, from a little past 0900 and again around 1100, the seismic station at the volcano showed what the Iceland Meteorological Office called "increased jökulhlaup tremor." This tremor decreased after midnight on 12 November, increased from 0500 to 0830, then decreased again. The eruption followed a pattern similar to previous eruptions in 1983 and 1998, with probably less than 0.1 km^3 of magma erupted.

According to scientists at the Iceland Meteorological Office and the Institute of Earth Sciences, University of Iceland, these eruptions, together with the 1996 Gjalp eruption N of Grímsvötn reflect much higher activity at Grímsvötn than during the middle part of last century, and may indicate that Grímsvötn is entering into a new period of high volcanism that may last for decades. Such a high activity period had been predicted on the basis of the observed cyclic volcanism in the area in the preceding millennium.

Background. Grímsvötn, Iceland's most frequently active volcano in historical time, lies largely beneath the vast Vatnajökull icecap. The caldera lake is covered by a 200-m-thick ice shelf, with only the southern rim of the 6 x 8 km caldera exposed. The geothermal area in the caldera causes frequent jökulhlaups (glacier outburst floods) when melting raises the water level high enough to lift its ice dam. Long NE-SW-trending fissure systems extend from the central volcano. The most prominent of these is the noted Laki (Skaftar) fissure, which extends to the SW and produced the world's largest known historical lava flow during an eruption in 1783. The 15 km^3 basaltic Laki lavas were erupted over a 7-month period from a 27-km-long fissure system. Extensive crop damage and livestock losses caused a severe famine that resulted in the loss of one-fifth of the population of Iceland.

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Taftan

Iran

28.60°N, 61.60°E; summit elev. 3,940 m

When visited in October 2003, Taftan's behavior was similar to that reported in July 1999 (*Bulletin* v. 24, no. 10), consisting of a fumarolic zone on the SE cone's W side, ~ 10 m^2 in area, emitting steam and SO_2 gas, and depositing sulfur. Degassing was clearly visible from the refuge at 3,250 m elevation. A mixture of sulfur and clay derived from highly altered lavas gave a snowy appearance to the summit. This snowy appearance was also noted in July 1999 (*Bulletin* v. 24, no. 10). Close to the refuge, a warm acid spring generated deep yellow deposits along the ditch down the valley for more than 1 km. A chemical analysis showed that the deposits were predominantly iron salts.

A surface lava sample, taken on 30 October 2003 from just below the refuge on the volcano's W slopes, was judged to be relatively young. George Morris analyzed the sample by X-ray fluorescence spectroscopy (XRF) and described the sample as andesite. This was the first known chemical analysis for Taftan rocks. In addition to the sampled lava flow, thick deposits of ignimbrite appeared in the walls of a deep gorge followed by the trail ascending to the refuge (at ~ 2,500 m elevation). It looked fresh and was judged to be Holocene in age.

Petrography of the lava sample. The sample is phenocryst rich (by volume, ~ 40-50% phenocrysts) in a microcrystalline to cryptocrystalline groundmass. Plagioclase is the predominant phenocryst phase (30-40%) with hornblende (< 5%), pyroxene (< 1%), opaque Fe-Ti oxide phases (< 1%), and trace amounts of biotite. Microxenoliths (1-3 mm in size) were observed, contributing < 2% volume to the whole rock.

Plagioclase phenocrysts invariably show complex zoning, but can be roughly divided into four groups. Euhedral plagioclase (0.5-1 mm long) show fine oscillatory zoning as well as internal dissolution and overgrowth surfaces. They are invariably euhedral but show no sieve-textured zones or dissolution channeling. Sieve-texture mantled plagioclase (0.5-5 mm long) can either have an un-zoned anhedral or an oscillatory zoned core. This is mantled with a zone of fine sieve-textured plagioclase of variable width, then overgrown by an un-sieved rim that may be oscillatory zoned. Inclusion-rich zones were observed running parallel to the sieve-textured zones within the cores of larger phenocrysts. Sieve-cored plagioclase (0.3-1 mm long) contain a completely sieve-textured core overgrown (normally) with an oscillatory zoned rim. These are generally smaller than the sieve-texture mantled plagioclase; however, the thicker un-sieved rims suggest that they form a distinct group rather than being a smaller version of the above. Small euhedral lath shaped plagioclase (< 0.3 mm) are common in the groundmass.

Hornblende occurs as lozenge-shaped crystals 0.2-1.5 mm long. These are invariably rimmed by thick reaction zones dominated by opaque oxides. These reaction zones can sometimes completely replace the original phenocryst.

Rare euhedral crystals of clinopyroxene were observed as phenocrysts. Similar pyroxenes were observed both in clots (with plagioclase) and in microxenoliths. Opaque oxide phases were observed as euhedral to anhedral phenocrysts 0.2-0.3 mm in diameter but account for less than 1% of the whole rock. Trace amounts of biotite were also observed; similar biotite was seen in microxenoliths.

Most microphenocrysts contained a microcrystalline mass dominated by opaque oxides. Where less altered examples survive, the mineralogy is dominated by subhedral plagioclase and euhedral clinopyroxene, the pyroxene often partially altered to biotite and oxide phases. Crystal faces on feldspar in contact with the groundmass show sieve-textured reaction mantles, which is absent on crystal faces internal to the microxenoliths.

Interpretation. The phenocryst assemblage of the lava sample suggests multiple phenocryst sources and disequilibrium between mineral phases and groundmass, typical of stratovolcanoes. The correspondence of some phenocryst phases with mineral phases in microxenoliths suggest that at least some of the phenocrysts were inherited during the assimilation of country rock, while the oscillatory zoning, sieve-textured cores and mantles, and multiple dissolution surfaces in feldspars indicates that other phenocrysts have undergone long and complex magmatic histories.

Setting and summit elevation. Taftan is in eastern Iran, 100 km SSE of the city of Zahedan and 50 km W of the Pakistan border. Several necks, representing erosional remnants of cinder cones, rise from the plain W from Taftan, as well as a second stratovolcano, Buzman (~ 3,500 m summit elevation), which remains largely unknown.

The summit elevation is listed in the Catalog of Active Volcanoes of the World (Gansser, 1964) as 4,050 m. Jean Sesiano found (presumably more current) Iranian maps with the volcanically active SE summit shown as 3,940 m, and the dissected NW summit, as 3,840 m.

Background. Taftan is a strongly eroded andesitic stratovolcano with two prominent summits. The volcano was constructed along a volcanic zone in Beluchistan, SE Iran, that extends into northern Pakistan. The higher, SE summit cone is well preserved and has been the source of very fresh-looking lava flows. Highly active, sulfur-encrusted fumaroles occur at the summit of the SE cone. The deeply dissected NW cone is of Pleistocene age. The first historical eruption of Taftan took place in 1993, when a lava flow was emitted.

Reference: Gansser, A., 1964, Catalog of the Active Volcanoes and Solfatara Fields of Iran; Rome, IAVCEI, part XVII-Appendix, p. 1-20.

Information Contacts: *Jean Sesiano* and *George Morris*, Earth Sciences Section, Mineralogy Dept, University of Geneva, 13 rue des Maraîchers, 1205 Genève, Switzerland

Awu

Great Sangihe Island, Indonesia
3.67°N, 125.50°E; summit elev. 1,320 m
All times are local (= UTC + 8 hours)

Awu extruded a new dome in its crater by 2 June 2004 (*Bulletin* v. 29, no. 5). Several photos received from the Directorate of Volcanology and Geological Hazard Mitigation (DVGHM) taken from the crater's upper S side illustrate the crater prior to and just after the 2004 dome emplacement (figures 7-9). Elevated seismicity continued into the week ending on 8 August 2004 (table 1). During 12-25 July, observers saw white thin-medium plumes gently rising to 50 m above the summit. A report covering 9-15 August, noted that the Awu observation post documented a weak plume 200 m tall. They also reported nine type-B earthquakes. A brief message from DVGHM on 7 December noted that Awu was then quiet.

Aviation reports. The Volcanic Ash Advisory Centre at Darwin, Australia, issued 15 reports (Volcanic Ash Advisories) regarding Awu during June 2004. These were the first and only Awu reports available in their archive of reports going back to 1998. The first message (on 8 June) was "Major eruption possible, but no eruption yet." Similar terminology accompanied Advisories until 12 June. The 9 June report noted "continuous small eruptions" and "four larger explosions in past two days." A plume also seen on satellite imagery was estimated by pilots to be at ~ 4.5-6 km. Later it became difficult to see the plume with satellite imagery. On 10 June two Advisories noted thin plumes directed NE extending ~ 37 km. The plumes were seen on imagery at 2325 and 0220 UTC (in aerospace shorthand, the imagery came from DVGHM, DMSP, GOES, and NOAA 17 satellites). The final Advisory, on 14 June, noted "Eruption details: Nil obs[erved] ash." That notice also commented that the alert status had dropped and no significant activity had been recorded, but a white plume rose ~ 100 m above the summit in the last 24 hours.

Background. The massive Gunung Awu stratovolcano occupies the northern end of Great Sangihe Island. Deep valleys that form passageways for lahars dissect the flanks of the 1320-m-high volcano, which was constructed within a 4.5-km-wide caldera. Awu is one of Indonesia's deadliest volcanoes; powerful explosive eruptions in 1711, 1812, 1856, 1892, and 1966 produced devastating pyroclastic flows and lahars that caused more than 8,000 fatalities. Awu contained a summit crater lake that was 1 km wide and 172 m deep in 1922, but was largely ejected during the 1966 eruption.

Figure 7. A N-looking photo of the Awu's crater taken in September 1995. Note the large ephemeral pond on the crater floor. Courtesy of DVGHM; photo by Kristianto.

Figure 8. A N-looking photo from 25 May 2003 showing the active crater at Awu. Compared to the photo from 1995 (figure 7, above), the pond on the crater floor had shrunken. A photo from 8 December 2002 (not included in this report) showed that at that time the pond was largely gone. Courtesy of DVGHM; photo by Endi T. Bina.

Figure 9. A N-looking photo of Awu's crater on 14 June 2004 showing the newly emplaced intra-crater dome and associated deposits. Disruption in the crater is also apparent, for example, the burial and heavy damage to vegetation . Thick steam made it difficult to see the distinctive rim on the crater's far side. Courtesy of DVGHM; photo by Agus Solihin.

Date	Type A (volcanic)	Tectonic
22 Jun-28 Jun	5	84
29 Jun-05 Jul	6	74
07 Jul-12 Jul	3	93
13 Jul-18 Jul	2	74
19 Jul-25 Jul	25	110
26 Jul-01 Aug	—	—
02 Aug-08 Aug	7	92
09 Aug-15 Aug	0	75

Table 1. Summary of volcanic type-A earthquakes and tectonic earthquakes at Awu during 22 June through 15 August. Volcanic type-B volcanic earthquakes also occurred occasionally, perhaps once a week, except in the 9-15 August interval, when they occurred nine times. Data for several days and time intervals (eg., 6 and 11 July, and 26 July-1 August) was not available. Courtesy of DVGHM.

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Manam

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

The Rabaul Volcano Observatory (RVO) issued a series of information bulletins on Manam, describing conditions and hazard status recommendations associated with a strong eruption that started on 24 October 2004. That eruption was preceded by a clear buildup in seismicity, leading to a felt earthquake the day prior to the eruption. The eruption generated pyroclastic flows which traveled down the valley SE of the volcano and into the sea. The aviation color code rose to Red, the highest value.

The eruption's plume was imaged from space. Ash and condensed water vapor in the form of ice reached a maximum height of ~ 15 km altitude, intersecting the base of the tropopause but not entering the stratosphere. Low-level eruptive activity persisted after the 24 October eruption.

Lead-up to the 24 October eruption. RVO noticed increased low-frequency earthquakes at Manam beginning 15 October 2004. Its reports suggested the volcanic system had changed to a dynamic mode from its previously stable state. The escalation in low-frequency earthquakes during that interval was described as a "steady rise." But overall, the level was portrayed as low to moderate. In retrospect, RVO reports noted that seismicity increased steadily after 16 October; moreover, it rose further after a felt earthquake at about 1845 on the 23rd.

During 15-21 October RVO noted occasional weak roaring and rumbling noises from the Main Crater. The noises prevailed on 15, 16, and 17 October, becoming more frequent on the 18th, but reduced again on the 19th. The noises continued at a level similar to the 16th and 17th on the 20th and 21st. Noise from Southern Crater began on the 19th, consisting of the sound of a single low explosion. After the 20th, occasional low roaring and rumbling noises continued from both craters. Observers saw night glow from the Main Crater on the 18th and 19th. Occasionally the glow fluctuated at 3-5 minute intervals. Glow remained absent over Southern Crater. Both Craters released weak white-gray vapor.

Occasional ash-laden vapor was seen on the 21st from Southern Crater. In their report for 15-21 October, RVO recommended Alert Level 1. They said "Whilst no official public warning is required under this Alert Level, people living in and near the four main valleys of the Island should be informed to refrain from venturing into them unnecessarily." RVO later stressed the presence of NW winds at altitude, warning residents on that flank of possible ashfall.

Eruption on 24 October 2004. The eruption came from Southern Crater, beginning after 0800 on the 24th; it persisted throughout the morning and the early part of the afternoon, peaking between 1000 and 1100. At 1400 the eruption's intensity decreased slightly. Later that day it continued at a reduced level with moderate explosions and sub-continuous low rumbling and roaring noises.

The eruption produced a pyroclastic flow channeled into the SE valley, that eventually reached the sea. The NW part of the island, including villages between Tabele Mission and Baliau, were affected by ash and scoria falls. Some of the scoriae were fist-size and punched holes through the thatched-roofing of houses. The greatest impact occurred at Kuluguma and the surrounding villages. Casualties remained unreported. Between the hours of 0300 and 0500, residents of Wewak town called RVO, advising that fine ash had reached them.

Seismicity reflected the eruptive activity, with events peaking between the hours of 1000 and 1100, after which event counts reverted to low to moderate levels. Ongoing seismicity suggested that the volcano has not reached a completely quiet state. Still, the eruption level had declined as it continued. It was recommended that the Alert Level be upgraded from 1 to 2 (Stage 2 Alert Level does not call for evacuation from the Island). Authorities called for community information exchange ("toksave") on volcano status; for avoiding the four main valleys; for the population to stay prepared and organized, including village efforts.

The 24 October eruption caused the aviation color code to rise to Red, the highest value. According to RVO, low-level eruptive activity persisted after the 24 October eruption, decreasing further by 26 October. A RVO report issued at 0800 on 27 October noted that activity had subsided significantly since late on the 24th. An aerial inspection confirmed pyroclastic flows had gone down the SE- and upper part of the SW-trending valleys. A lava flow traveled 600 m down the SE valley. Tephra fall most affected the area from Kuluguma to Boda villages, including the Bieng Catholic mission on the island's NW side. Numerous food gardens were destroyed by the tephra deposit, which had an average thickness of 7 cm measured at the Bieng mission. RVO recommended that the Alert Level be downgraded to 1.

On 27-28 October occasional ash emissions still escaped from Southern Crater. Brown ash clouds rose several hundred meters above the summit before drifting to the NW and SW, resulting in fine ashfall. The ash emissions were accompanied by weak roaring and rumbling noises. Weak night-time glows were visible. Although earthquakes were few, tremor persisted. Low seismicity was coupled with a decline in eruptive vigor.

During 28-29 October, comparatively mild eruptions continued. Southern Crater continued to eject occasional emissions of dark, moderately thick, ash-laden clouds. The ash clouds were again blown NW, traversing the area between Yassa and Baliau villages. Low roaring and rumbling noises accompanied some of the activity. It was difficult to observe Main Crater due to cloud cover. Glow was difficult to observe due to cloud cover as well. Few earthquakes occurred, but volcanic tremor continued.

Media reports. News articles reported that authorities advised evacuation of ~ 3,000 people to safer parts of the island. Some of those articles revealed that the island's current population stood at 7,000, and that the government had helped provide food and shelter for those displaced.

According to the online version of the Papua New Guinea (PNG) *Post-Courier*, the Inter-Government Relations Minister, Sir Peter Barter, flew over the eruption. He allegedly saw large volumes of lava discharging into the sea, but judging from RVO observations, the term "lava" was mistakenly used for pyroclastic flows. In the news report Peter Barter had also stated that the entire SE side of the mountain, ~ 1 km wide, blew out, forcing lava (or other hot pyroclastic material) to flow down the SE valley to the sea. He was also reported as saying that at Bien (sometimes spelled Bieng, on the island's NW coast) his helicopter was hit by rocks (or other volcanic particles) that damaged its windscreen. Also, the Bien mission station lay beneath a heavy layer of ash. The damage to his helicopter kept him from flying completely around the island, missing the western segment between Bien, Yassa, Jorai, and the SW-flank settlement of Tabele, areas hit hardest by dust and rocks. He commented that much of the SE side of the island was relatively ash-free and safe, apart from the S-coast area between Dugulava (on the S coast) to Warisi.

A 27 October article by Dominic Krau in PNG's *The National* noted that the 24 October eruption had included a forceful outburst at 0800 on the 24th, and then climaxed during 1100-1400 that day, but had since been emitting only "smoke" and ash. It noted that prime minister Michael Somare had flown to Manam for a first-hand look at the damage. The same article mentioned that Peter Barter had assured that functioning radios were available at the settlements of Bien, Tabele, Warisis, Dugalava, Abereia, Bukure, and Kolang. It reported that volcanic ash fell in Wewak (on the main island's coast, 120 km NW), resulting in the civil aviation authority temporarily closing down the Boram airport for safety reasons.

Andrew Tupper of the Australian Bureau of Meteorology (BOM) posted satellite images of the 24 October eruption's ash cloud, which occurred just before the Terra and Aqua satellites passed over. They also captured AVHRR and GOES data of a very ice-rich volcanic cloud. The coldest temperature measured by BOM from the high-level cloud was about 204 K (a couple of hours after the eruption), which translates to an altitude of ~ 15 km. This altitude was in harmony with the cloud's subsequent dispersion pattern and wind-velocity models. Pilot reports have been generally lower, as is usual for large eruptions. There was no evidence of significant stratospheric penetration (the tropopause height was 15-16 km).

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

Information Contacts: *Andrew Tupper*, Australian Bureau of Meteorology (Email: A.Tupper@bom.gov.au); *Darwin Volcanic Ash Advisory Centre*, Australian Bureau of Meteorology (URL: http://www.bom.gov.au/info/vaac); *Rabaul Volcanological Observatory (RVO)*, P.O. Box 386, Rabaul, Papua New Guinea; *Papua New Guinea Post-Courier Online* (URL: http://www.postcourier.com.pg).

Asama

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

An explosive eruption occurred from the summit crater of Asama at 2002 on 1 September 2004 (*Bulletin* v. 29, no. 8). Most of the initial reporting was in Japanese, although many of those reports had segments in English. Setsuya Nakada and Yukio Hayakawa provided links to initially available reports. In initial assessments of the eruption, investigators identified several distinct suites of ejecta, including darker- and lighter-colored groups. The ERI report also discussed a breadcrust bomb sampled at Kromamegawara 3.5 km NE of Asama's crater, which contained a vitric outer film and vesicular interior. ERI compiled some initial major element compositions on the of products of the 1 September eruption, including those taken on both fresh pumices (bombs) and lithics. Both types of materials were chemically close to lavas erupted in the years 1783, 1973, and 1108.

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

Information Contacts: *Geological Survey of Japan*, National Institute of Advanced Industrial Science and Technology (GSJ AIST) (URL: http://www.gsj.jp/kazan/kazan-bukai/yochiren/asama040909/material.html); *Yukio Hayakawa*, Faculty of Education, Gunma University, Aramaki 4-2, Maebashi Gunma 371-8510, Japan (Email: hayakawa@edu.gunma-u.ac.jp; URLs: http://maechan.net/hayakawa/asama/gankoran/; http://www.edu.gunma-u.ac.jp/~ hayakawa/English.html); *Setsuya Nakada*, Volcano Research Center, Earthquake Research Institute (ERI), University of Tokyo, Yayoi 1-1-1, Bunkyo-ku, Tokyo 113, Japan (Email: nakada@eri.u-tokyo.ac.jp; URL: http://www.eri.u-tokyo.ac.jp/topics/ASAMA2004/index-e.html).

Spurr

Alaska, USA
61.299°N, 152.251°W; summit elev. 3,374 m

Spurr, ~ 125 km W of Anchorage across Cook Inlet, became restless in recent months. This activity consisted of increased seismicity beginning in February 2004, melting of the summit ice cap, and substantial emission rates of carbon dioxide (CO_2) and sulfur dioxide (SO_2). Scientists at the Alaska Volcano Observatory (AVO) recorded hundreds of small earthquakes centered 4.8-6.4 km beneath the summit. Elevated levels of seismicity continued through early November 2004 (table 2). Although the rate of seismicity is greater than typical background levels, AVO has found no indication that an eruption is imminent.

Aerial reconnaissance in mid-July and early August documented recent small flows of mud and rock and a depression in the icecap (an "ice cauldron") just NE of the summit that was ~ 50 x 75 m in size and ~ 25 m deep. The floor of the depression contained an icy pond, with small areas of open water. No steam or volcanic emissions were observed. The ice cauldron is a collapse feature possibly caused by an increase in heat coming from deep beneath the summit. Using sensitive instruments, scientists flying around the volcano on 7 August detected small amounts of the volcanic gases in a plume from the summit.

Observations and photography during the week ending 10 September revealed that the ice cauldron had enlarged substantially (to ~ 150 x 170 m), presumably as the roof of the meltwater basin continued to subside and collapse. AVO scientists measured gases being emitted by the summit vent and Crater Peak, a flank vent, during a fixed-wing flight on 15 September 2004. The combined output of CO_2 from the two vents was ~ 2,300 tons/day, an increase from the ~ 760 tons/day measured 7-8 August 2004. The gray color of the lake at the bottom of the ice cauldron is typical of crater lakes containing dissolved SO_2.

AVO staff took an overflight of the volcano on 18 October and reported that the summit ice cauldron persisted without appreciable change of its geometry or of the surrounding crevasses. The ice cauldron continued to contain standing water, no steam or sulfur scent was observed from the summit, and steam issuing from Crater Peak had not changed from previous observations.

Background. The summit of Mount Spurr is a large lava dome constructed at the center of a roughly 5-km-wide horseshoe-shaped caldera that is open to the south. The volcano lies 130 km west of Anchorage and NE of

Week of (2004)	Average earthquakes per day
24 Jul-30 Jul	10-20
31 Jul-06 Aug	10-20
07 Aug-13 Aug	10-20
14 Aug-20 Aug	15 (70 events on 14 Aug)
21 Aug-27 Aug	12
28 Aug-03 Sep	14
04 Sep10 Sep	13
11 Sep-17 Sep	12
18 Sep-24 Sep	10
25 Sep-01 Oct	13
02 Oct-08 Oct	8
09 Oct-15 Oct	9
16 Oct-22 Oct	2-14
23 Oct-29 Oct	12-24 (3 per hour on 26 Oct)
30 Oct-05 Nov	0-24 (10 per hour on 4 Nov)

Table 2. Weekly seismicity within 30 km of the summit at Spurr, with magnitudes over 1.5 and depths of 1-6 km. Courtesy of AVO.

Chakachamna Lake. The caldera was formed by a late-Pleistocene or early Holocene debris avalanche and associated pyroclastic flows that destroyed an ancestral Spurr volcano. The debris avalanche traveled more than 25 km to the SE, and the resulting deposit contains blocks as large as 100 m in diameter. Several ice-carved post-caldera cones or lava domes lie in the center of the caldera. The youngest vent, 2,309-m-high Crater Peak, formed at the breached southern end of the caldera and has been the source of about 40 identified Holocene tephra layers. Spurr's two historical eruptions, from Crater Peak in 1953 and 1992, deposited ash on the city of Anchorage.

References: Power, J., 2004, Renewed unrest at Mount Spurr Volcano, Alaska: Eos (Transactions, American Geophysical Union), v. 85, no. 43, p. 2.

Waythomas, C.F., and Nye, C.J., 2002, Preliminary volcano-hazard assessment for Mount Spurr Volcano, Alaska: U.S. Geological Survey Open-File Report 01.482, Alaska Volcano Observatory, Anchorage, Alaska, 39 pp.

Information Contacts: *U.S. Geological Survey Alaska Volcano Observatory (AVO)*, a cooperative program of the USGS, University of Alaska Fairbanks Geophysical Institute, and the Alaska Division of Geological and Geophysical Surveys (URL: http://www.avo.alaska.edu; Email: tlmurray@usgs.gov).

St. Helens

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

At St. Helens, rapid dome growth and pronounced uplift continued. Although this report covers 9 October-12 November 2004, there are several photos and comments on prior events. Figure 10, for example, contains a satellite image from 5 October. R. Scott Ireland photographically documented the 4 and 5 October eruptions, starting from the smallest plumes and including later wind-blown ash-bearing plumes. Digital copies of Ireland's set will be preserved in the Smithsonian's archives. Much of this report came from information posted by the Cascades Volcano Observatory (CVO).

Figure 11 presents four aerial views into the crater, taken on 8 August and 7, 10, and 14 October. They portray the southern part of the crater containing a broad area of uplift and deformation associated with a more restricted zone of dome emergence. On 7 October the broad area of uplift on the S side of the 1980-86 lava dome stood ~ 400 m (N-S) by ~ 500 m (E-W), with a maximum uplift of about 100-120 m. For perspective on this growth, CVO's 11 November estimate noted an expanded area of uplift and some parts of the dome rising ~ 250 m above the glacier.

Table 3 summarizes CVO's observations. The terminology of numbered days for this eruption began at Day 1 (23 September), when precursory earthquakes began (*Bulletin* v. 29, no. 9). In contrast to those initial several weeks, during the current reporting interval seismicity generally remained low, an observation consistent with the slow rise of gas-poor magma. The emerging magma drove uplift of the glacier within the crater but did not yield large explosive discharges and tall plumes.

Thermal images of the exposed dome revealed elevated temperatures there. This confirmed that new lava had reached the surface of the uplift.

Other details. The weather enabled clear views on 10 October. A photo of the scene at dawn showed an orange-colored plume. Field observers noted fresh snow over the crater floor contained a thin SE-directed ash deposit stretching to just beyond the crater rim. A steam plume rose to crater rim level or slightly above all day on 10 October and continued to blow SE. USGS field workers described the plume as "lazy," emphasing the absence of gas thrusts or notably vigorous convection. When the field crew visited the volcano, the plume appeared clean, with no noticeable ash nor blue nor orange haze. The odor of H_2S was noted at the crater's breach, but not elsewhere.

On 14 October observers noted an increase in the deforming and uplifting area on the S side of the 1980-1986

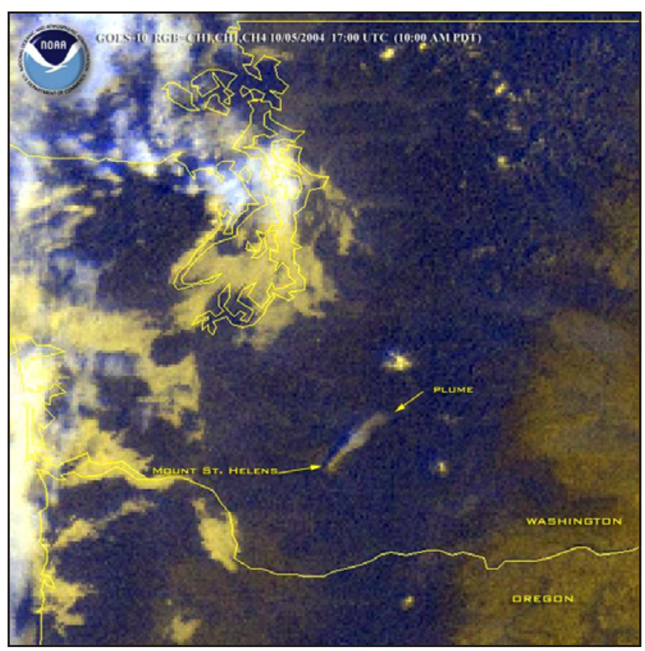

Figure 10. Image of St. Helens on 5 October 2004 from a Geostationery Operational Environmental Satellite (GOES-10) showing a consistent ash-bearing plume extending NE for ~ 40 km. Courtesy of NOAA.

lava dome and the new lobe of lava in the W part of that area. The maximum temperature of 761°C was measured in parts of the new lobe from which ash rich jets rose ten's of meters. Magma extruded onto the surface, forming a new lobe of the lava dome. Instruments detected low levels of H_2S and SO_2, but no CO_2.

Crews collected samples and documented clear dome growth on 20-21 October. The new lava extrusion had horizontal dimensions of ~ 300 x 75 m and a thickness of ~ 70 m. The fin-shaped lava spine had collapsed. The 21 October volume estimate was almost 2 x 10^6 m^3. By 21 October the area of uplift and intense deformation had advanced S, nearing the crater wall. That day, ~ 30 cm of new snow with a light dusting of ash covered much of the uplift, except for the new lava extrusion, which steamed heavily. A vigorous steam plume rose to 3 km. Fluxes of gaseous H_2S, SO_2, and CO_2 were low. Samples of the new dome were scooped up by a container slung on a line beneath a helicopter.

Atmospheric conditions on 27 October and 7 November again gave airborne observers clear views into the crater (figures 12, 13, and 14). The N-looking photo in figure 12 documents how the new dome and area of uplift had achieved substantial size, standing topographically above what was previously the moat to the S of the older dome. In plan view, the margin of the dome complex shifted from a circle to a figure-eight.

In addition to photos documenting crater changes, a CVO report on 29 October discussed rapid movement at a new GPS station on the southern part of the new dome (an area of uplifted glacial ice, rock debris, and new lava). The station showed continued southward motion of ~ 6 m in the previous 36 hours. A station near the summit of the old dome showed continued, slow northward motion.

Analysis of aerial photographs taken on 4 November led to an estimate of the volume of the uplifted area and new lava dome at ~ 20 x 10^6 m^3. This followed other preliminary estimates made for 4 and 13 October of ~ 5 x 10^6 m^3 and ~ 12 x 10^6 m^3, respectively. This most recent volume estimate (20 x 10^6 m^3) amounted to more than 25% of the 1980-86 lava dome volume.

On 5 November the SO_2 emission rates remained low. No H_2S was detected and CO_2 emission rates were not measurable. On that day viewers noted that a new mass of dacite had extruded, forming a spine rising ~ 100 m. Exposed rock faces had temperatures of 400-500°C. The steep new faces on the dome generated small hot rockfalls and avalanches. The finer particulate material rose to about 3 km altitude, a height ~ 900 m above the crater rim.

A sample of the new dome collected on 4 November established that the new dacite lava contained visible crystals of plagioclase, hornblende, and hypersthene. A comparison of the 1986 and 2004 dacites (table 4) shows that the new

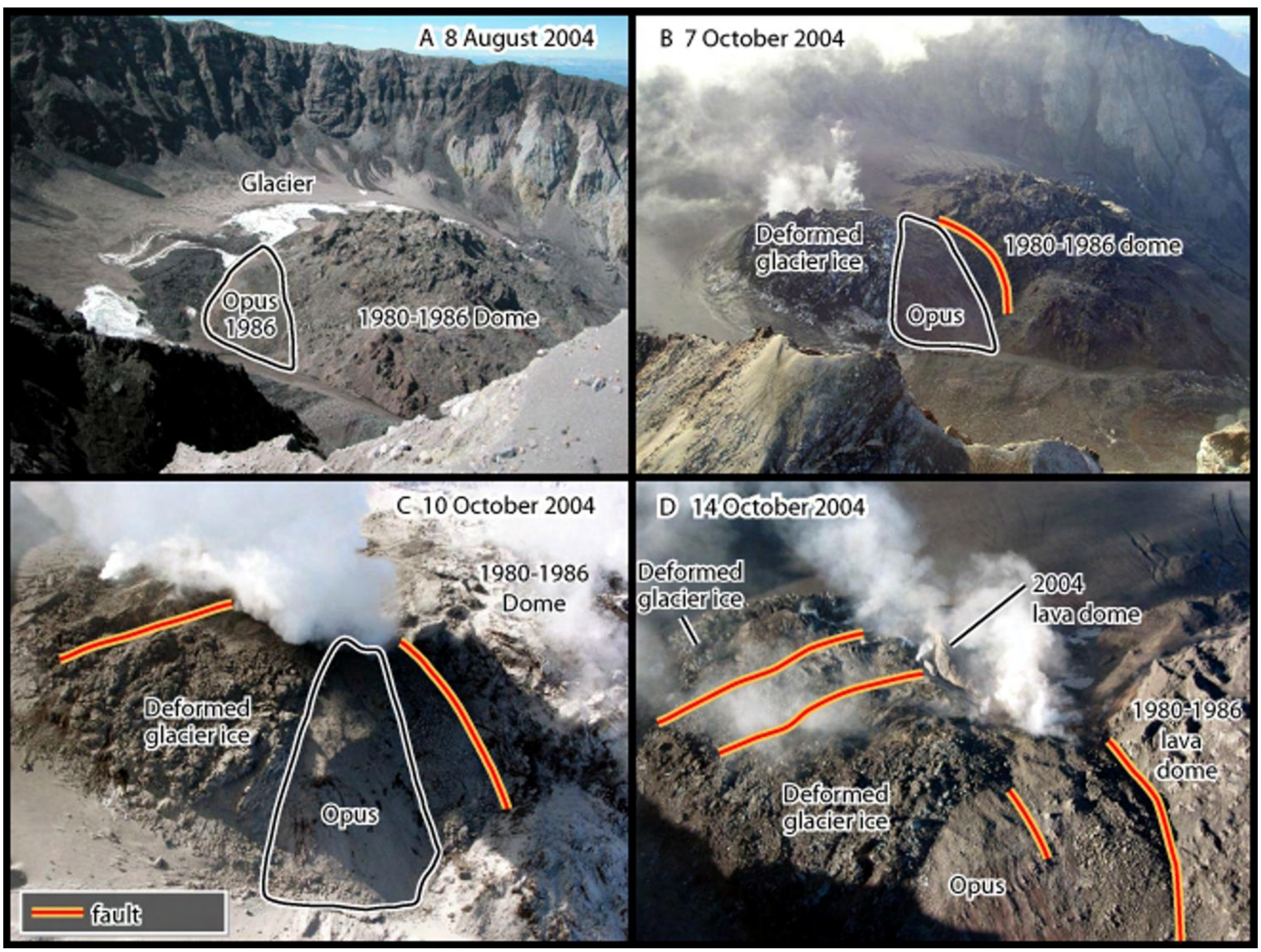

Figure 11. Four aerial photos depicting the southern portion of St. Helens's crater, an area of rapid uplift and dome emergence, from the S on 8 August and 7 October, and from the E on 10 and 14 October. The photos include an older dome lobe that was recently uplifted (Opus), steam releases, faulting (with upwards displacement towards the center), and the emergence of fresh dome lavas. Courtesy of USGS Cascades Volcano Observatory.

lava lacks augite, distinctive reaction rims on hornblende, and large plagioclase with sieve-textured cores.

On 11 November the dome had reached ~ 250 m in height; it lay within a broad area of deformation that was ~ 600 m in diameter. Within this area, the new lava dome continued to occupy the E-central segment (broadly similar to the situation on figures 13 and 14). In plan view, the new dome stood 400 x 180 m. Regarding its height, the 11 November report noted that the highest point on the new lava dome was ~ 250 m "above the former surface of the glacier that occupied that point in mid-September."

Aviation Advisories. The first sentence of this section in *Bulletin* v. 29, no. 9 should be corrected to read, "The Washington VAAC issued advisories beginning on 29 ***September***" (not 29 October).

The Washington Volcanic Ash Advisory Center issued one Ash Advisory each day during 9-18 October, noting elevated seismicity but a lack of explosive eruptions and substantial plumes. On 18 October the VAAC mentioned GOES-10 and -12 infrared and multispectral imagery of the volcano but concluded that ". . . after discussion with authorities at [CVO] we are discontinuing the Watch . . .. There continues to be low level [activity] . . . not posing an [imminent] threat to aviation. A Notice to Aviation within ~ 9 km and below FL 130 should continue [Note: FL130, *Flight Level 130*, is the aviation community's shorthand for 13,000 feet; an altitude equivalent to 3,962 m, but typically rounded in the *Bulletin* to the nearest hundred meters]. If threat conditions rise[,] a Watch will again be issued. The Washington VAAC will continue to monitor the area and if ash is observed or reported a Volcanic Ash Advisory will be issued as soon as possible."

As of 12 November, the last Ash Advisory on St. Helens was issued on 6 November. It was in response to a minor ash emission that day. The emission was too small to detect with available satellite imagery. The local webcamera showed a weak, passively rising plume that barely rose above the crater rim.

Figure 12. An aerial photo looking downward and N-ward into the crater of Mt. St. Helens on 27 October 2004. The old (1980-86) dome is in the background and the new one, steaming, is in the foreground. Note uplifted, fractured ice around the margins of the 2004 intrusion. Some areas of ice and snow have gray color indicative of ashfall. The ridge along the inner crater wall intersects the rim at the approximate point where Ivan Savov stood when taking the photo presented in *Bulletin* v. 29, no. 9. Courtesy of CVO.

Day	Date	Hazard Status	Comment
DAY 17	09 Oct 2004	2 - Advisory (Orange)	Moderate seismic activity-earthquakes up to M 2 at one event every two or three minutes.
DAY 18	10 Oct 2004	2 - Advisory (Orange)	Earthquakes up to M 1 every minute.
DAY 19	11 Oct 2004	2 - Advisory (Orange)	Low seismicity. Thermal imaging of the uplifted area (last seen on the 7th) found it had grown. The W portion of the uplift was steaming over a large diffuse area. Maximum measured surface temperatures were 200-300°C. Uplifting area discharged a brief emission at about 1600. Dusting of ash on new snow disclosed minor ash emissions the previous night.
DAY 20	12 Oct 2004	2 - Advisory (Orange)	Low seismicity (earthquakes up to M 1 every 5-10 minutes). Thermal imaging of the W part of the uplifting area revealed temperatures of 500-600°C on a large pinkish-gray fin of rock and in nearby fumaroles and cracks.
DAY 21	13 Oct 2004	2 - Advisory (Orange)	Hot (600°C) area both confirmed and appeared to have increased in size. Low seismicity; abundant steaming; SO_2 and H_2S detected; CO_2 undetected; temperature and flow rate of water in streams similar to that measured in September.
DAY 22	14 Oct 2004	2 - Advisory (Orange)	A zone approaching 700°C and in places reaching 761°C was measured on the new lobe, which emitted ash-rich jets rising ten's of meters. Abundant steam continued to rise from the area of lava extrusion to the crater rim. Low seismicity.
DAY 23-40	15-31 Oct 2004	2 - Advisory (Orange)	Slight increase noted in area of uplift and new lobe of lava. On the 22nd a new protrusion of lava registered ~ 650°C. Slight increase in seismicity on 17th, but storm noise as well as rainfall triggering a small debris flow had also occurred; otherwise, seismicity was low.
DAY 41-53	1-12 Nov 2004	2 - Advisory (Orange)	On the 5th there was an ash plume to ~ 3 km altitude; on the 9th, a steam plume rose to similar altitude. Also, a new extrusion was noted on the 5th (see text). By the 11th the dome's highest point stood ~ 250 m above the height of the glacier's surface prior to the eruption. On the 11th the hottest lava registered ~ 700°C. Low seismicity generally prevailed.

Table 3. A simplified chronology of the events at St. Helens from 23 September to 12 November 2004. Regarding the Hazard Status column, the colors in parentheses represent an informal aviation hazard status (low to high; green, yellow, orange, and red). Taken from material posted by the USGS.

Background. Prior to 1980, St. Helens formed a conical, youthful volcano. During the 1980 eruption the upper 1,400 m of the summit was removed by slope failure, leaving a 2 x 3.5 km horseshoe-shaped crater now partially filled by a lava dome. St. Helens was formed during nine eruptive periods beginning about 40,000-50,000 years ago, and has been the most active volcano in the Cascade Range during the Holocene. Prior to 2,200 years ago, tephra, lava domes, and pyroclastic flows were erupted, but few lava flows extended beyond the base of the volcano. The modern edifice was constructed during the last 2,200 years, when the volcano produced basaltic as well as andesitic and dacitic products from summit and flank vents. Historical eruptions in the 19th century witnessed by early settlers, originated from the Goat Rocks area on the N flank.

Information Contacts: *Cascades Volcano Observatory* (USGS/CVO), U.S. Geological Survey, 1300 SE Cardinal Court, Building 10, Suite 100, Vancouver, WA 98683-9589, USA (URL: http://vulcan.wr.usgs.gov/; Email: GS-CVO-WEB@usgs.gov); *Pacific Northwest Seismograph Network* (PNSN), Seismology Lab, University of Washington, Department of Earth and Space Sciences, Box 351310, Seattle, WA 98195-1310, USA (URL: http://www.pnsn.org/; Email: seis_info@ess.washington.edu); *Washington Volcanic Ash Advisory Center (VAAC)*, Satellite Analysis Branch (SAB), NOAA/NESDIS E/SP23, NOAA Science Center Room 401, 5200 Auth Rd., Camp Springs, MD 20746, USA (URL: http://www.ssd.noaa.gov/); *R. Scott Ireland*, 1660 NW 101 Way, Plantation, FL 33322, USA (URL: http://www.rsiphotos.com, Email: info@rsiphotos.com); *Stephen and Donna O'Meara*, Volcano Watch International, PO Box 218, Volcano, HI 96785, USA.

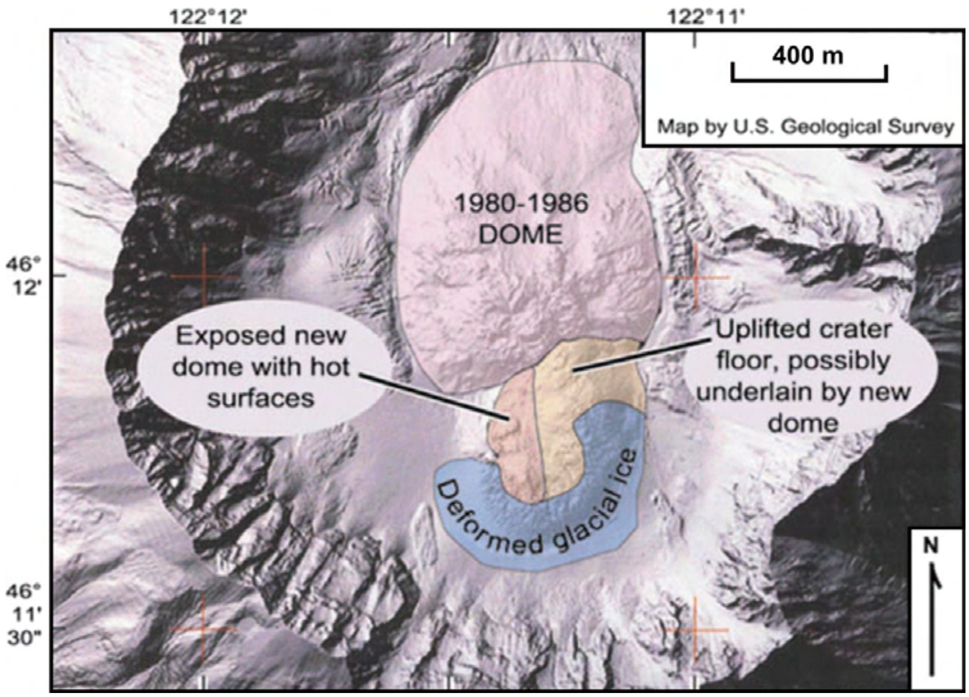

Figure 13. A simplified map of the St. Helens crater, based on the scene on 27 October 2004. More complex maps appeared in early November. Courtesy of CVO.

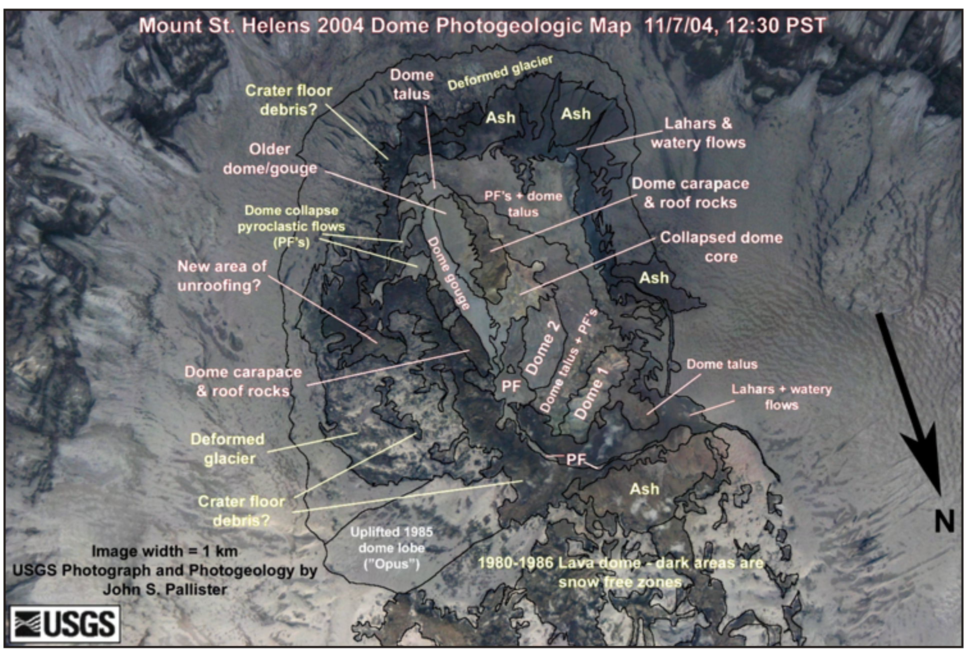

Figure 14. A photogeologic map depicting the southern end of the crater at St. Helens on 7 November 2004 and serving to identify and interpret recent deposits and features there. The map is centered on the new dome (N towards bottom, see arrow; for approximate scale, photo is ~ 1 km wide). The 1980-86 dome lies largely off the bottom of the photo. Courtesy of CVO.

1986 — Augite-hornblende-hypersthene dacite	2004 — Hypersthene-hornblende dacite (collected 4 November)
63.5 weight percent SiO_2	65.3 weight percent SiO_2
Hypersthene is the dominant mafic mineral	Hornblende is the dominant mafic mineral, but it lacks significant reaction rims
Hornblende contains distinctive reaction rims	Hypersthene is smaller and less abundant
Accessory augite	Augite absent
Large plagioclase phenocrysts, commonly with sieve-textured cores	Plagioclase phenocrysts, but absent large ones with sieve-textured cores

Table 4. A comparison of the dome dacites extruded at St. Helens in 1986 and 2004. Courtesy of CVO.

Soufrière Hills

Montserrat, West Indies
16.72°N, 62.18°W; summit elev. 915 m
All times are local (= UTC - 4 hours)

Table 5, taken from reports of the Monserrat Volcano Observatory (MVO), summarizes activity at Soufrière Hills between 1 October and 26 November. The activity level remained elevated during much of this time period due to increases in seismicity, gas emission, rainfall, and mudflows.

Heavy rains during the first six weeks of the reporting period led to steam venting, which triggered an increase in hybrid and volcanic-tectonic earthquakes. A large number of hybrid and volcano-tectonic (VT) earthquakes was recorded during most of October and early November. The most intense seismicity occurred during 2106-2216 on 12 November and 1335-1436 on 14 November.

Following the rains of 5-12 November, several fumaroles developed along the former Tuitt's Bottom and Pea Ghauts, but by 12 November, drier conditions prevailed and fumaroles diminished. Sulfur dioxide emissions remained low throughout most of the reporting period, however two surges in SO_2 flux occurred during the weeks of 1 October and 15 October.

Mudflows occurred since May. As heavy rainfall continued during October and November, more mudflows occurred. Nine separate mudflow events were recorded for this reporting period. The flows of 15, 19, 21, 22-29 October and 1, 3, 9, and 11 November were minor, though one of the flows, which traveled down the NW flank, reached the Belham River. A much heavier flow began around 0620 on 19 November, with a pulse occurring at 1138.

One MVO scientist deemed mudflows the "ongoing legacy of this [the 1995] eruption." Montserrat's rainy season typically continues until December, and more mudflows may occur in coming months. Mudflows have proven to be destructive, whether they have arisen from short, intense downpours or from a buildup over several rains. The example was given of mudflows after two hours of heavy rain on the afternoon of 21 May, which led to burial of the gateway to the Radio Antilles' offices.

MVO personnel made two observation flights during the reporting period (on 28 October and 4 November). Both flights confirmed the presence of the pond seen 30 August in the pit formed by the 3 March dome collapse. Looking into the crater, MVO scientists found no evidence of ongoing dome-building.

Background. The complex andesitic Soufrière Hills volcano occupies the southern half of the island of Montserrat. The summit area consists primarily of a series of lava domes emplaced along an ESE-trending zone. Prior to 1995, the youngest dome was Castle Peak, which was located in English's Crater, a 1-km-wide crater breached widely to the east. Block-and-ash flow and surge deposits associated with dome growth predominate in flank deposits. Non-eruptive seismic swarms occurred at 30-year intervals in the 20th century, but with the exception of a 17th-century eruption, no historical eruptions were recorded on Montserrat until 1995. Long-term small-to-moderate ash eruptions beginning in that year were later accompanied by lava dome growth and pyroclastic flows that forced evacuation of the southern half of the island and ultimately destroyed the capital city of Plymouth.

Information Contacts: *Montserrat Volcano Observatory*, Fleming, Montserrat, West Indies (URL: http://www.mvo.ms/).

Montagu Island

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

Matt Patrick of the Hawaii Institute of Geophysics and Planetology reviewed our previous report on Montagu Island (*Bulletin* v. 29, no. 9) and noted some erroneous interpretations. These had relied on imagery from 1 October 2004. Patrick generated a significantly improved, scaled, higher (4-m) resolution IKONOS image from the same time frame (figure 15), and offered some refinements and important corrections.

First, the previous report noted that "the area of apparently continuous flows seems to have reached the island's N margin (a distance of 3 km)." Over the entire new image there doesn't seem to be any new vents nor lava. The darkened area N of the Belinda summit cone contains clear crevasses indicating a region of ice entirely covered in ash.

A second erroneous statement was, "Another visible feature, the black area to the NNW . . . presumably reveals lava flows emerging from beneath the ice." Patrick points out that on the new image this area is seen to contain some of the island's rocky cliffs contrasting against the ice cover. He attributed the darkness around this area mainly to shadow. The presence of rocky cliffs negates another statement in the previous issue: "The black area to the NNW may thus be a new vent area."

Date (2004)	Activity level	Hybrid Earthquakes	Mixed Earthquakes	Volcanic-tectonic Earthquakes	Long-period Earthquakes	SO_2 emissions (metric tons/day)	Rockfalls
01 Oct-08 Oct	elevated	8	—	—	2	187-1144	1
08 Oct-15 Oct	elevated	9	—	—	—	156-553	1
15 Oct-22 Oct	elevated	49	—	1	—	250-1100	4
22 Oct-29 Oct	elevated	40	—	1	—	320-370	—
29 Oct-05 Nov	elevated	33	—	39	—	140-440	1
05 Nov-12 Nov	—	21	—	14	—	147-225	3
12 Nov-19 Nov	—	12	—	40	5	1111	3
19 Nov-26 Nov	—	25	—	5	1	125-330	3

Table 5. Activity recorded at Soufrière Hills, 1 October to 26 November 2004. One of the gas-monitoring sites only functioned on 18 November. Courtesy of Montserrat Volcano Observatory (MVO).

The previous report commented that, "Another such [dark, presumably lava-covered] area may reside on the NNE flanks, midway from the summit area and the coast." Patrick noted that on the new image this area appears chaotic and can easily be misidentified as recent volcanics. He goes on to say, "We made a similar mistake earlier on, thinking there were concentric fractures related to subglacial melting. But it turned out from pre-eruption images that this area is just covered in topographic crevasses. Looking at the [improved] IKONOS image, one can see this more clearly."

Patrick offered interpretations of some features on the new image, the first high-resolution image since February 2004. It shows continued steaming from Mount Belinda as well as tephra cover on the surrounding ice field, activity very similar to that seen on all the previous imagery. Although the new IKONOS image lacks any evidence of new lava since the 2003 lava flow, that particular lava field lies hidden under the steam plume in the IKONOS image. Thus, there could be newer material in that small region. The IKONOS image appears devoid of new vents, and emissions come solely from the summit area.

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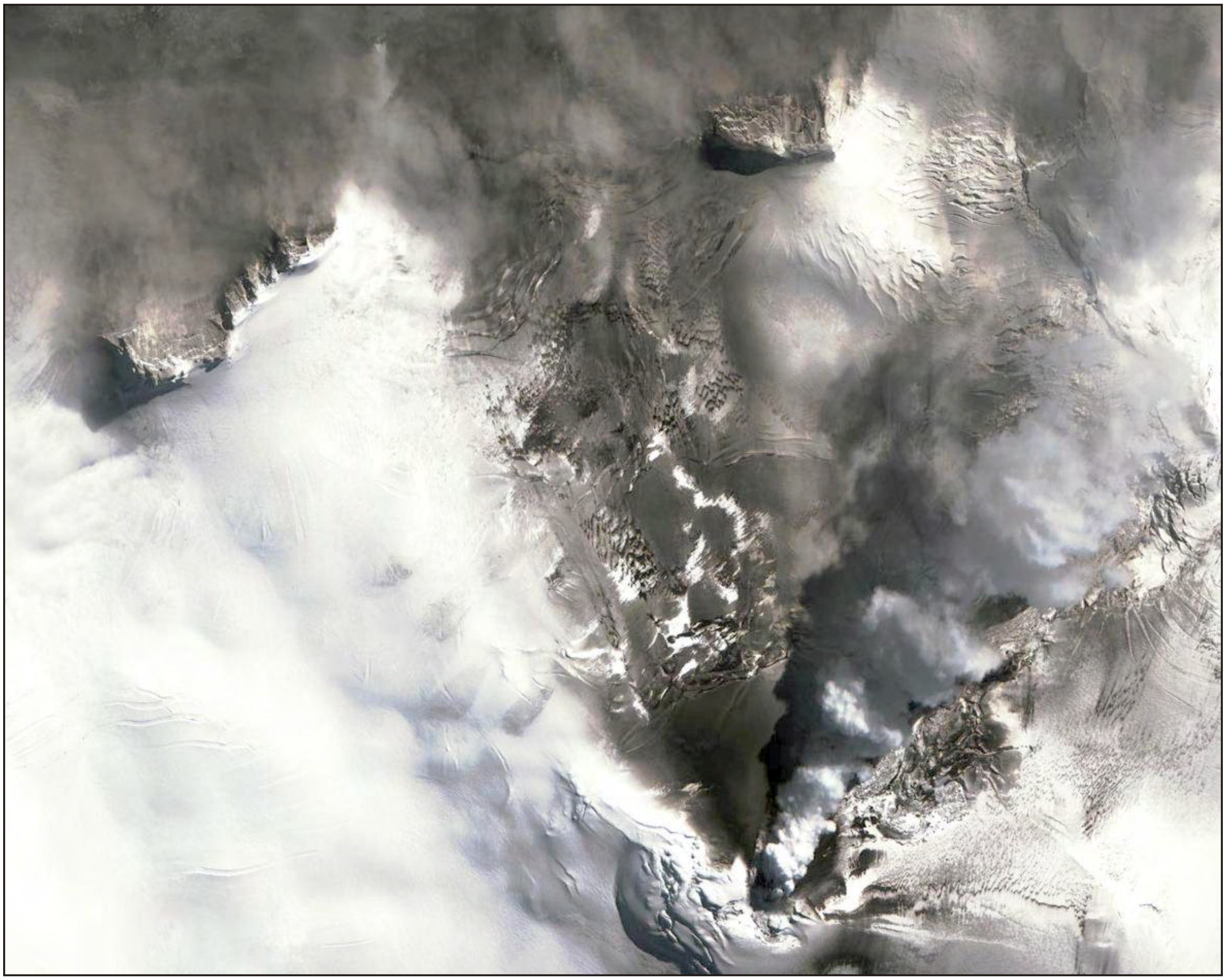

Figure 15. A 1 October 2004 image of Montagu Island taken with the IKONOS satellite (N towards the top; distance from summit vent to N coast is ~3 km). A lower higher resolution image appeared in *Bulletin* v. 29, no. 9. This new image indicates that tephra¾ not lava flows as previously reported¾ covers much of the ice over a sector on the island's N side. Courtesy of Space Imaging, NASA, and Matt Patrick.

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