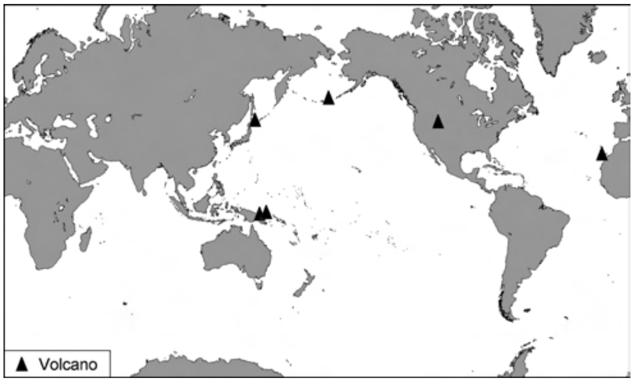
Bulletin of the Global Volcanism Network



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Manam

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

Manam currently represents one of Papua New Guinea's most potent volcanic crises. It erupted several times during October-December 2004 and January 2005 (*BGVN* 29:10, 29:11). According to the Rabaul Volcano Observatory (RVO), the eruption on the evening of 27 January 2005 (*BGVN* 30:02) was the most severe activity during the current eruption period; 14 people were injured and one person killed at Warisi village (see villages in plan views of island, *BGVN* 30:02).

This report discusses the mild outbursts during April-May 2005, and the strong eruption on 27 February 2006. The latter eruption cloud rose into the stratosphere, ascending to a satellite-estimated altitude of 19 km. After a 9 March eruption, the press reported one elderly person missing. An eruption during the reporting interval dropped tephra on a village, forcing 49 residents to flee.

Generally mild behavior during April through mid-February 2005. Throughout April 2005, both summit craters released occasional pale gray to brown ash clouds to a few hundred meters above the summit before being blown SW, W, and NW, resulting in fine ashfall. Occasional low rumbling and roaring noises from Southern Crater were heard on 23 April and 29 April. A weak-to-moderate glow accompanied by projections of incandescent lava fragments was visible on 28 and 30 April. There were no audible noises and no night-time glow from the Main Crater. During the month, seismicity was at low-moderate levels, and tremor was occasional and weak. The daily number of low-frequency earthquakes ranged between 700 and 1,350.

A pilot reported a Manam eruption on 13 June 2005 at 0445 UTC. In addition, Darwin Volcanic Ash Advisory Centre (VAAC) reported ash plumes visible on satellite imagery during 16-17 June, 30 June, 1-2, 19, and 20 July. Imagery indicated that Manam's 19 July ash extended SW. In all instances, the heights of the plumes were not reported.

According to RVO, on 15 August, ash discharged from Southern Crater; otherwise during 15-21 August, comparatively weak volcanism prevailed and the Alert Level was reduced to Level 1. The Darwin VAAC reported a low-level plume on 22 August imagery. Mild eruptive activity continued during 22-28 August, with occasional emissions of weak-to-moderate ash plumes on several days. The ash clouds emitted on 22 and 26 August rose several hundred meters above the volcano's crater and drifted NW, depositing ash in areas between the towns of Jogari and Kuluguma, and beyond to Boisa Island.

During September weak emissions of diffuse white-gray ash clouds continued from Main Crater. On 17 September, the ash clouds increased slightly in volume and were blown to the NW part of the island. No glow was observed at night and technical problems thwarted seismic recording.

On 1 October, a pilot observed ash from Manam below ~ 3 km altitude extending NW. Ash was not visible on satellite imagery. During 3-9 October RVO reported that ash emissions continued from Main Crater. Ash clouds rose to low levels and drifted NW, depositing ash in downwind areas. RVO learned that ash was visible on satellite imagery at ~ 3 km altitude.

During the last 10 days of October, low-level eruptive activity continued at Manam with plumes visible on satellite imagery extending NW. Manam remained at Alert Level 1, indicating low levels of activity from August 2005 through December 2005.

During January 2006, mild eruptive activity occurred with occasional ash emissions during 1-4 January, and dull incandescence was visible on 1 and 2 January. Gas was emitted from Southern Crater during 1-7 January. Seismicity was at low levels during January 2006.

Large eruption of 27-28 February 2006. A large eruption began on 27 February around 1733 from Manam's Southern Crater. According to Andrew Tupper of the Darwin VAAC, satellite imagery showed an umbrella cloud above the volcano and a strong hot spot. The edges of the ash cloud were ice-rich and the eruption-plume height appeared to be about 19 km based on a warm-temperature anomaly in the middle of the cloud indicating stratospheric intrusion (figure 1).

Fred Prata processed Manam ash cloud data using the Atmospheric Infrared Sounder (AIRS, which uses a grating spectrometer on the Aqua satellite). Prata produced the atmospheric SO_2 analyses in the sequential images in figures 2 and 3, which show areas of greatest concentration displaced ~ 70 and ~ 100 km W of Manam, respectively. At the bull's-eye centers, figure 2 portrays a somewhat higher peak for the product of concentration and path length (milli-atmosphere-centimeter values), ~ 60, compared to figure 3, which indicates ~ 50. Figure 3 also contains a much larger low-value area, consistent with post-eruption dispersal. The 27 February eruption clearly emitted considerable SO_2, with the two analyses on figures 2 and 3 yielding respective assessed masses of 0.027 Tg and 0.054 Tg of SO_2.

RVO reported that the strong phase of the eruption declined around 0030 on 28 February. Earlier, during the height of the activity, incandescent lava fragments were thrown 700-800 m high above the volcano, but ejection heights later decreased to 200-300 m. Ash was deposited on

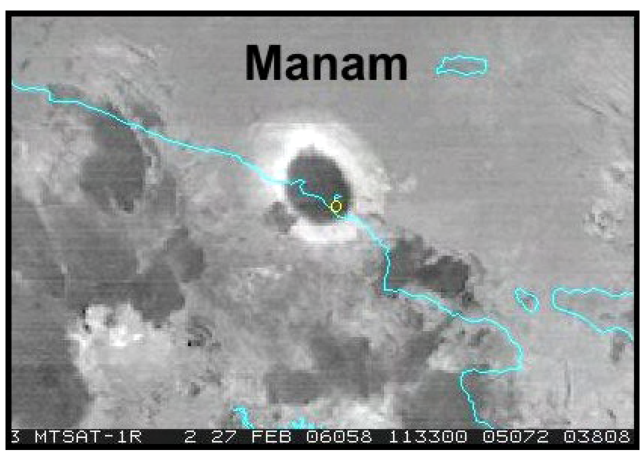

Figure 1. An MTSAT image of the eruption cloud over Manam captured at approximately 2145 (1145 UTC) on 27 February 2006, showing a very strong hot spot. The image contains an 11-12 µm enhancement. In past Manam eruptions where there has been a similar white halo around the thinning umbrella cloud, the cloud has later been verified as having a large ice and SO_2 content (as well as fine ash and other volcanic aerosols). The warm temperature mass persisted for 2-3 hours, suggesting a prolonged, continuing eruption. Courtesy of Andrew Tupper.

the E part of the island and lava flowed down the SW valley. Field inspections on 28 February confirmed that a lava flow traveled down the SW valley to about 600 m elevation, a pyroclastic flow traveled down the same valley to about 500 m elevation, and the maximum ash thickness on the E part of the island was about 7-8 cm. Later, on 7 March, it was determined that pyroclastic flows had also traveled down the SE valley and that scoria and ashfall affected the area between Warisi and Bokure 1.

After mid-February, Manam's seismic station and radio communication with the observer at Bogia had both ceased operating. RVO noted that the island had been inhabited by about 300 former residents who returned to the island after evacuating following the 27 January 2005 eruption. (A March press report, below, indicated over 2,000 people on the island, including people who had previously refused to leave.) The mid-February Alert Level at the volcano was at Level 2. By 1 March, only gas was emitted from Southern Crater, no noises were heard, and weak incandescence was visible around the vent. Occasionally, incandescent lava fragments were thrown 100-150 m above the vent and fell into the crater. Main crater emitted occasional ash clouds, and then gas later in the day.

Based on information from RVO, the Darwin VAAC reported that a minor explosion occurred at Manam on 6 March. The height of the resultant plume was not reported and ash was not visible on satellite imagery. A report faxed from RVO said that during 9-11 March, both summit craters at Manam released gas, and seismicity then stood at moderate levels.

According to RVO, a recent (ambiguously disclosed) eruption had endangered about 49 people (mostly women) pelted by tephra who ran for their lives to take shelter at Dangale village to the N. The RVO team called the evacuation centers on the main island at Mangem and Asaruba where people from villages on the E part of the island were located and advised them not to go to the island unless clearance was given from the authorities. RVO warned of possible mudflows during heavy rainfall, moderate-to-high levels of seismicity, and sporadic explosions.

Press reports. On 15 March 2005 *The National* newspaper (online edition) reported that "[a]uthorities dispatched a vessel, the *Motuan Chief*, to the island [on the afternoon of 14 March] to evacuate over 2,000 islanders who had refused to move earlier or who had returned recently. A sudden explosion last Thursday [9 March] has left an elderly [man] from Wirisi village missing, believed covered by the pyroclastic [material] from the eruption . . .. Authorities . . . reported several houses burnt down from the hot emissions while others collapsed under the weight of ash dust and pyroclastic [material] . . .. [Q]uite a number of resettled people . . . have moved back to the island after an earlier evacuation and now are pleading

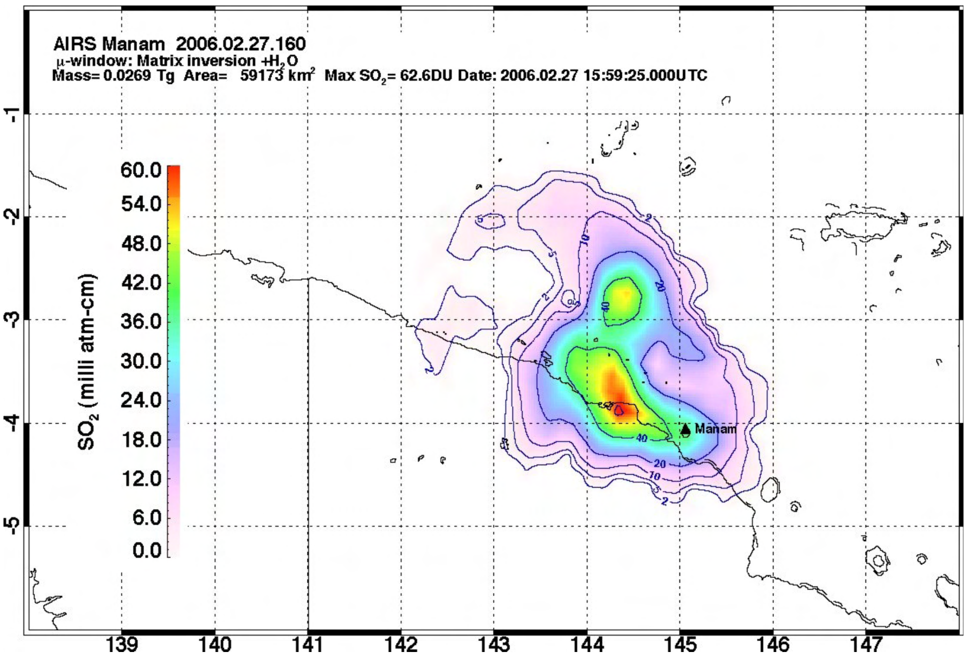

Figure 2. An AIRS image indicating the Manam ash plume's SO_2 content at 1559 UTC on 27 February 2006. The area of detected SO_2 coverage reported for this image was 59,173 km^2. Further details about the image appear in the text on the image. Courtesy of Fred Prata.

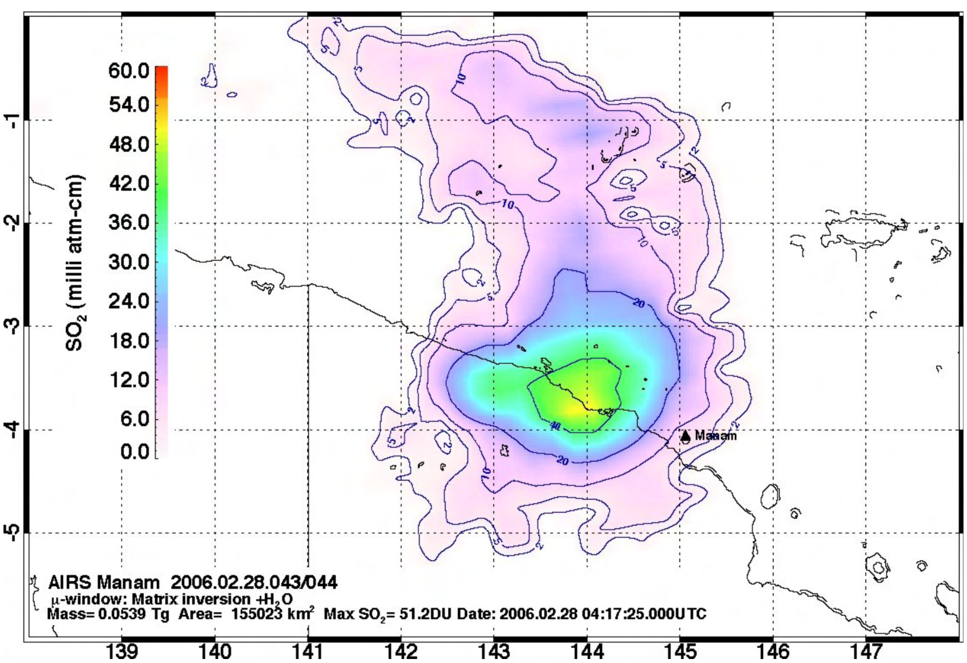

Figure 3. The Manam ash plume's SO_2 content at 0417 UTC on 28 February 2006. The area of detected SO_2 coverage reported for this image was 155,023 km^2. Further details about the image appear in the text on the image. Courtesy of Fred Prata.

to be evacuated back to the mainland following the recent volcanic activities.

"Some people from Warisi village who were at the [evacuation] centres on the mainland travelled back to Manam last Thursday to gather food from their gardens. They were to return to the [evacuation] centre but unfortunately their boat . . . was destroyed by rocks from the eruption."

A January 2006 article in the *PNG Post-Courier* (and online in the *Pacific Islands Report*) noted that the Red Cross and Red Crescent Societies had spent about US $377,000 on emergency aid for resettlement camps on the main island. The article noted that aid societies had helped the government, funding 350 houses constructed of bush-materials at the camps since October 2004. Those camps (also termed care centers) include Mangem, Asuramba (Asaruba?), and Potsdam.

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

Information Contacts: *Ima Itikarai*, Rabaul Volcano Observatory (RVO), P.O. Box 386, Rabaul, Papua New Guinea; *Andrew Tupper*, Darwin Volcanic Ash Advisory Centre (VAAC), Bureau of Meteorology, Northern Territory Regional Office, PO Box 40050, Casuarina, Northern Territory 0811, Australia (URL: http://www.bom.gov.au/info/vaac/); *Bonney Bonsella* and *Thomas Kilala*, The National Online, Lot 13 Section 38, Waigani Drive Hohola, PO Box 6817 Boroko, National Capital District, Papua New Guinea (URL: http://www.thenational.com.pg/); *PNG Post-Courier*; *Pacific Islands Report*.

Langila

New Britain, SW Pacific
5.525°S, 148.42°E; summit elev. 1,330 m

Vulcanian eruptions continued at Langila's Crater 2 during 21-27 November 2005, with a slight increase in the level of activity compared to the previous week. The increase in activity was marked by light to dark gray ash emissions that sometimes rose to heights between 1 and 2 km above the summit crater (7,650-10,900 feet altitude). The ash clouds drifted W, SW, SE, and NW, depositing ash in those areas. Incandescence and projections of volcanic material were visible at the volcano during the nights of 21, 23, and 25-27 November along with weak to loud noises. Crater 3 was quiet during the report period. Seismicity was at low-to-moderate levels, consisting of low-frequency earthquakes associated with the Vulcanian activity and periodic volcanic tremor.

A slight increase in vulcanian activity occurred at Langila's Crater 2 during 1-15 January. The increase was characterized by nearly continuous ash emissions that rose to 1-2 km above the summit (7,650-10,900 feet altitude) and drifted WSW. Occasionally during the report period observers noted loud noises, incandescence, and weak emissions of glowing lava fragments.

Crater 3 continued to be quiet during this period.

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

Information Contacts: *RVO* and *Darwin VAAC* (see Manam).

Garbuna Group

New Britain, SW Pacific
5.45°S, 150.03°E; summit elev. 564 m

Garbuna volcano's first historically witnessed eruption in October 2005 was reported in *BGVN* (30:11) and by 14 November the mountain was climbed. Since that time two reports from the Rabaul Volcano Observatory (RVO), one dated 21-27 November 2005 and the other 1-15 January 2006 both noted weak-to-moderate releases of white vapor from the two vents on the summit. Both reports also indicated that there were no noises or glow accompanying the emissions and that seismic activity was low.

The November 2005 report stated that on some days plumes rose vertically a few hundred meters and drifted variably to the NW, W, SW, and occasionally SE. It also noted that the distinct moderate tremor recorded in the previous weeks at the summit ceased by 15 November although weak tremor was recorded on some days, as were small high-frequency earthquakes numbering one to six per day.

RVO's January report described weak to moderate volumes of white vapor released from the two summit vents. The accompanying seismicity was low and dominated by occasional low-frequency earthquakes, as indicated by the two stations located 5-6 km E and SW of the summit.

Background. The basaltic-to-dacitic Garbuna volcano group consists of three volcanic peaks, Krummel, Garbuna, and Welcker. They are located along a 7-km N-S line above a shield-like foundation at the southern end of the Willaumez Peninsula. The central and lower peaks of the centrally located 564-m-high Garbuna volcano contain a large vegetation-free area that is probably the most extensive thermal field in Papua New Guinea. A prominent lava dome and blocky lava flow in the center of thermal area have resisted destruction by thermal activity, and may be of Holocene age. The 854-m-high Krummel volcano at the S end of the group contains a summit crater, breached to the NW. The highest peak of the Garbuna group is 1005-m-high Welcker volcano, which has fed blocky lava flows that extend to the eastern coast of the peninsula. The last major eruption from both it and Garbuna volcanoes took place about 1800 years ago. The first historical eruption of the complex took place at Garbuna in October 2005.

Information Contacts: *RVO* and *Darwin VAAC* (see Manam).

Pago

New Britain, SW Pacific
5.58°S, 150.52°E; summit elev. 742 m

Since 18 September 2005 (*BGVN* (30:09) through 31 March 2006, Pago has remained quiet. Only small volumes of diffuse white vapor released from all vents have been observed, with no noises or glow. Between 16 February and 31 March low-frequency earthquakes were recorded at a rate of 1-4 per day. The daily number of high-frequency events during that period ranged from 7 to 26.

Background. Pago is a young post-caldera cone that was constructed within the 5.5 x 7.5 km Witori caldera. Extensive pyroclastic-flow deposits are associated with formation of the caldera about 3300 years ago. The gently sloping outer flanks of Witori volcano consist primarily of dacitic pyroclastic-flow and airfall deposits produced during a series of five major explosive eruptions from about 5600 to 1200 years ago. The Buru caldera, which may have formed around the same time, cuts the SW flank of Witori volcano. The post-caldera cone of Witori, Mount Pago, may have formed less than 350 years ago. Pago has grown to a height above that of the Witori caldera rim. A series of ten dacitic lava flows from Pago covers much of the caldera floor. The youngest of these was erupted during 2002-2003 from vents extending from the summit nearly to the NW caldera wall.

Information Contacts: *RVO* and *Darwin VAAC* (see Manam).

Ulawun

New Britain, SW Pacific
5.05°S, 151.33°E; summit elev. 2,334 m
All times are local (= UTC + 10 hours)

Ulawun remained relatively quiet from mid-September 2005, the date of our last report (*BGVN* 30:09), until 1-2 March 2006 when strong, forcefully expelled “gray-blue emissions” were observed from the main crater. There may also have been incandescence at the base of the plumes. There were no emissions from the NW vent. Small, felt earthquakes occurred and the sound of roaring was heard by nearby villagers. According to the Darwin VAAC, RVO reported that ash reached ~ 3 km (10,000 ft) altitude on 1 March. However, ash was not visible on satellite imagery.

Background. The symmetrical basaltic-to-andesitic Ulawun stratovolcano is the highest volcano of the Bismarck arc, and one of Papua New Guinea’s most frequently active. Ulawun, also known as the North Son, rises above the N coast of the island of New Britain across a low saddle NE of Bamus volcano, the South Son. The upper 1,000 m of 2,334-m-high Ulawun is unvegetated. A prominent E-W-trending escarpment on the S may be the result of large-scale slumping. Satellitic cones occupy the NW and eastern flanks. A steep-walled valley cuts the NW side of Ulawun, and a flank lava-flow complex lies to the S of this valley. Historical eruptions date back to the beginning of the 18th century. Twentieth-century eruptions were mildly explosive until 1967, but after 1970 several larger eruptions produced lava flows and basaltic pyroclastic flows, greatly modifying the summit crater.

Information Contacts: *RVO* and *Darwin VAAC* (see Manam).

Rabaul

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

The previous report on the activity of the Tavurur cone at Rabaul (*BGVN* 30:08) covered the period through 12 September 2005. According to the RVO report of 10 October 2005 Tavurur continued to erupt with discrete ejections of light to dark gray ash clouds with high ash content. The ejections occurred at irregular, but sometimes frequent intervals. Discrete, convoluted explosion clouds were also observed. Ash plumes from the eruptive activity rose between 800 to 1,500 m before being blown variably to the E, W, and S during the beginning of the 3-9 October 2005 period and later in that period towards the NW. Ash fell in the downwind areas. Occasionally roaring and rumbling noises were heard. Projections of glowing lava fragments showering the flanks of Tarvurur were visible at night during strong explosions.

Seismic activity was at moderate-to-high levels with most earthquakes associated with ash emissions and explosions. No high frequency explosions were reported and ground deformation measurements showed a general trend towards a slight deflation.

The RVO report dated 28 November 2005 stated that as of 20 November ash emission from the volcano ceased with only very small traces of white vapor being released from the now silent vent and other spots on the summit area. During 21-27 November seismicity was very low and ground-deformation measurements showed some small degree of inflation.

The volcano remained quiet until the middle of January 2006 when activity resumed. Single ash emissions occurred at 0722 on 10 January, 0854 on the 11th, 1638 on the 12th, and 2100 on the 15th of the month (all local dates and times). The emissions consisted of thick gray ash clouds that rose more than 1.5 km above the summit and then drifted E. The ash emissions on the 12th and 15th lasted three minutes. Seismic activity was at a low level with small, low-frequency earthquakes beginning to occur on 7 January 2006. The daily totals fluctuated between zero and seven per day.

RVO reported that during 30 January to 15 February, Rabaul caldera's Tavurvur cone continued to be relatively quiet. Variable amounts of gas were emitted from an active fumarole at the summit area on the upper part of the W flank. An average sulfur-dioxide flux of 200 metric tons per day was recorded and seismicity was at low levels. According to the Darwin VAAC, ash from Rabaul was visible on satellite imagery at a height of ~ 3.7 km (12,100 ft) altitude on 17 February.

Background. 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 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; it formed about 1,400 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 city.

Information Contacts: *RVO* and *Darwin VAAC* (see Manam).

Akan

Hokkaido, Japan
43.384°N, 144.013°E; summit elev. 1,499 m
All times are local (= UTC + 9 hours)

Yukio Hayakawa of Gunma University notified the *Bulletin* staff that a very small eruption occurred on the morning of 21 March 2006 at Me-Akan. Tremor first started at 0628, followed by the eruption 0637. The Japan Meteorological Agency (JMA) issued a second-level alert at 0643. Ash was found on the snow at 10 km SE of the volcano. No towns or villages were threatened as the volcano is in a remote location, although there are some hot-spring hotels in the area. Me-Akan erupted in 1996 and 1998 from within the summit crater, but the March 2006 eruption was from the NE flank.

According to a news report by Reuters, a JMA official stated that "gray ash was discovered on the snow around the summit, but no movement of lava was detected, and we do not think a large eruption is likely."

Background. Akan is a 13 x 24 km, elongated caldera that formed more than 31,500 years ago immediately SW of Kutcharo caldera. Growth of four post-caldera stratovolcanoes, three at the SW end of the caldera, and the other at the NE side, have restricted the size of the caldera lake. The 1-km-wide Nakamachineshiri crater was formed during a major pumice-and-scoria eruption about 13,500 years ago. Of the Holocene volcanoes of the Akan volcanic complex, only the Me-Akan group, east of Lake Akan, has been historically active, producing mild phreatic eruptions since the beginning of the 19th century. Me-Akan is composed of 9 overlapping cones. The main cone of Me-Akan proper has a triple crater at its summit. Historical eruptions at Me-Akan have consisted of minor phreatic explosions, but four major magmatic eruptions including pyroclastic flows have occurred during the Holocene.

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Atka

Aleutian Islands, USA
52.381°N, 174.154°W; summit elev. 1,533 m
All times are local (= UTC - 9 hours)

The Alaska Volcano Observatory (AVO) received a report that a sudden minor steam-and-ash eruption occurred at Korovin around 1900 on 23 February 2006. Korovin is an active volcano of the larger Atka volcanic center (or complex) in the central Aleutian islands, ~ 184 km E of Adak island and ~ 600 km W of Unimak island, and 1,760 km SW of Anchorage. According to residents of Atka village near Korovin, the initial ash burst rose to an altitude of ~ 2.4 km and drifted E. It was followed by several smaller ash-and-steam bursts.

No ashfall was reported in Atka village, nor were there reports of accompanying volcanic odors, earthquakes, or larger volcanic explosions. Satellite images of the volcano did not clearly show the presence of ash or any thermal anomalies. But, on the morning of 24 February 2006 (the morning after the eruption) the volcano was still steaming with some vigor. During the period 25 February-4 March 2006, cloud cover prohibited satellite views of the volcano, and no unusual seismicity registered.

Although Korovin was not monitored by a standard AVO seismic network, Atka village hosts a seismic station operated by the Alaska Earthquake Information Center. That station recorded several increases in seismicity prior to the 23 February eruption. Distinct seismic signals indicating unrest were recorded on 17, 18, 21, and 22 January 2006. The later day brought an unusually sustained, 11-minute-long signal.

After 22 February, seismicity decreased and distinct seismic signals like those recorded earlier were not detected. An 8 March report noted that Korovin's rate of occurrence of micro-earthquakes had stabilized and then declined, and "it has been close to background levels for the past week."

For some days after 22 February, clouds obscured satellite views of the volcano. However, on the 22nd an aviator reported that, although the summit area was obscured by clouds, no signs of ashfall on the flanks or any steam plume was seen. On 23 February, observers in the village of Atka noted the lack of obvious signs of activity. Prior to the ash-and-steam eruption on the 23rd, AVO received no short-term reports of precursory volcanism to indicate an imminent eruption.

Seismicity at Korovin remained slightly above background levels during 24 February to 3 March 2006. Clouds continued to mask satellite views of the volcano, and AVO received no further reports of activity.

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

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

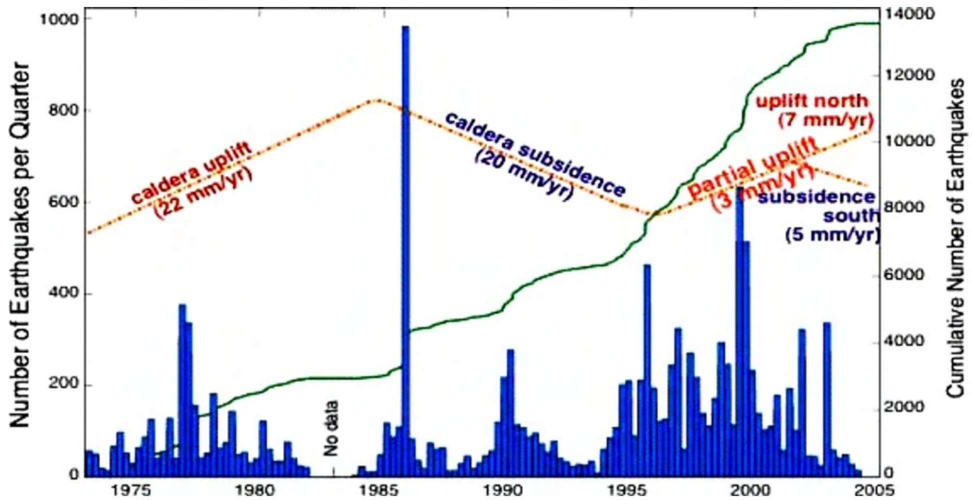

Figure 4. A plot of recorded earthquakes (≥ M 1.5) at Yellowstone from 1974 through 2004 (bars, left-hand scale: each bar represents the sum of the earthquakes of stated size per quarter (~ 90 days)). The curving solid line shows the cumulative number of earthquakes for the thirty-year period (right-hand scale). Estimates of mean caldera uplift and subsidence are shown as a dashed-and-dotted line with no scale. Note that this figure stopped in 2004 and does not depict some of the stronger deformation seen in radar and later GPS data (discussed below). Courtesy of YVO (after a figure by Waite and Smith, 2002).

Yellowstone

Wyoming, USA
44.43°N, 110.67°W; summit elev. 2,805 m
All times are local (= UTC - 7 hours)

According to the Yellowstone Volcano Observatory (YVO), during February 2006 there was relatively low seismicity, with 82 reported earthquakes in the region. The largest of these was on 25 February, M 3.1, located near the N caldera rim (~ 10 km SSW of Canyon Junction). None of these earthquakes were reported as felt. Our previous report discussed elevated temperatures of the ground and increased hydrothermal effects at Norris hot springs in 2003 (*BGVN* 28:07). Norris also represents a frequent epicentral area for earthquakes inside the caldera. In 2002, for example, there were more than 2,350 earthquakes detected at Yellowstone, including over 500 triggered by the November 2002, M 7.9 Denali earthquake. Seismicity during April 2005-April 2006 was comparatively low. Figure 4 plots quarterly earthquakes (≥ M 1.5) during 1974-2004 on a histogram. Figure 5 depicts earthquake swarms during 1985, 1995, and 2004.

Satellite radar created an interferogram of the caldera region (basically, a depiction of the vertical offset determined by satellite radar during 1996-2000). The interferogram portrayed vertical displacement as a large bull's-eye shape (figure 6), and indicated 12.5 cm of uplift centered in the northern portion of the caldera ~ 25 km NW of Yellowstone Lake.

In response to increased heat and steam emissions in parts of Norris geyser basin, a temporary, five-station GPS network was installed in that area in 2003. The network was installed by a UNAVCO engineer, University of Utah students and faculty, and National Park Service scientists as part of a monitoring effort by YVO. Permanent station NRWY currently resides there (figure 7).

Movement near the N end of Yellowstone Lake was measured by GPS at station LKWY during 1997 to late 2005 (figure 8). The N-S movement (top panel) shown in the past year consisted of displacement of 10-15 mm southward. This N-S movement was somewhat stronger and more protracted than in the earlier parts of the GPS data. The E-W movement (middle panel) was comparatively steady and unbroken over the past 6 years or more, directed westward. Over the past 9 years, the overall E-W motion was ~ 15 mm westward. The vertical motion (lower panel) was negative (subsidence) during 1997 to mid-2004. After that, station LKWY moved sharply upward, rising ~ 80 mm in the last year and a half. Caldera systems frequently undergo ground displacements similar to those observed at Yellowstone without progressing to eruptive activity.

Much of the history of older calderas that preceded Yellowstone are buried in the subsurface to the W, and a drilling proposal for that region is under development. "Hotspot," the Snake River Scientific Drilling Project, announced an inter-disciplinary workshop with that goal, to be held 18-21 May 2006 and focused on issues central to a new intermediate-depth drilling program in the Snake River Plain of S Idaho, USA. That region provides a record of inferred mantle plume volcanism in an intra-continental setting. Because it is young and tectonically undisturbed, the complete record of volcanic activity can be sampled only by drilling. The preliminary plan was to drill and core 4-6 holes along the axis of the E and W Snake River Plain.

References: Wicks, C., Thatcher, W., and Dzurisin, D., 1998, Migration of fluids beneath Yellowstone Caldera inferred from satellite radar interferometry: Science, v. 282, p. 458-462.

Wicks, C., Thatcher, W., Dzurisin, D., and Svarc, J., 2006 (in press), Uplift, thermal unrest, and magma intrusion at Yellowstone Caldera, observed with InSAR: Nature.

Waite, G.P., and Smith, R.B., 2002, Seismic evidence for fluid migration accompanying subsidence of the Yellowstone caldera: Journal of Geophysical Research, v. 107, p. 2177-2192.

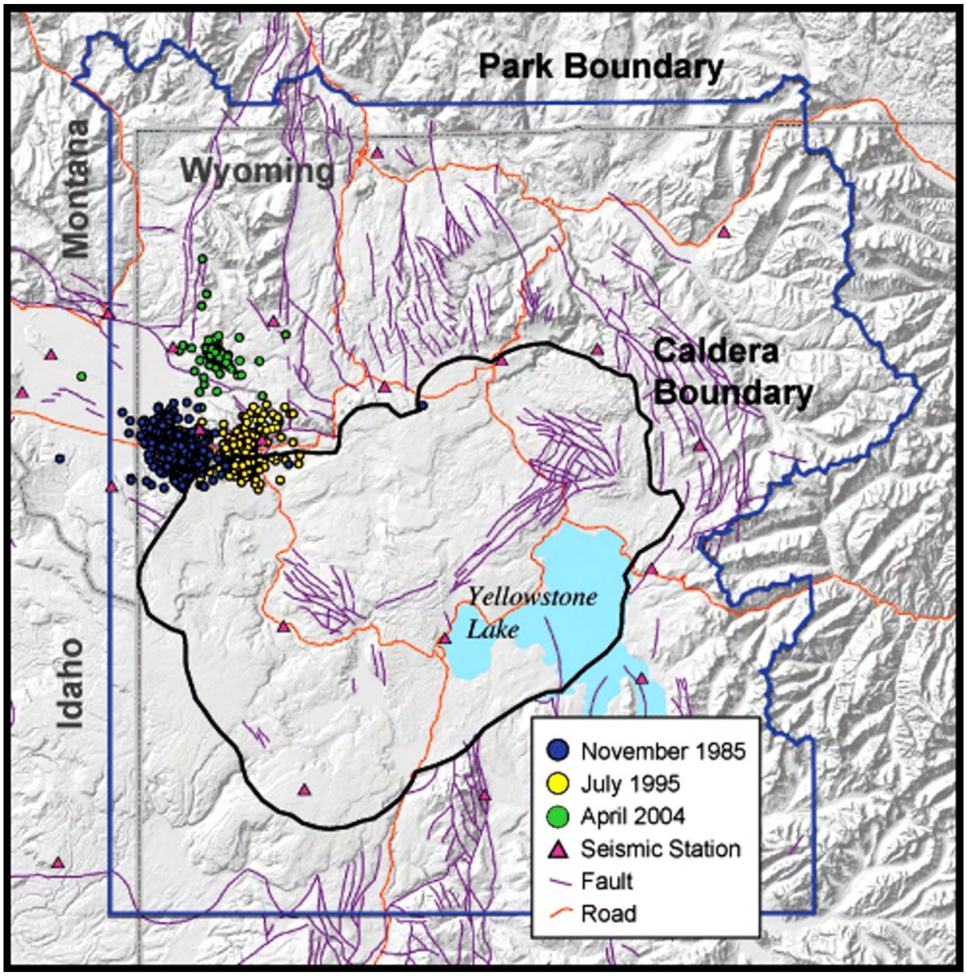

Figure 5. A map of Yellowstone caldera and National Park with circles indicating located earthquakes (≥ M 1.5) from the swarm of 1985 (westerly cluster), 1995 (easterly cluster with substantial events inside the caldera), and 2004 (smaller cluster to the N of the other two). Courtesy of YVO.

Background. The Yellowstone Plateau volcanic field developed through three volcanic cycles spanning two million years that included some of the world's largest known eruptions. Eruption of the more than 2,450 cu km Huckleberry Ridge Tuff about 2.1 million years ago created the more than 75-km-long Island Park caldera. The second cycle concluded with the eruption of the Mesa Falls Tuff around 1.3 million years ago, forming the 16-km-wide Henrys Fork caldera at the western end of the first caldera. Activity subsequently shifted to the present Yellowstone Plateau and culminated 640,000 years ago with the eruption of the more than 1,000 cu km Lava Creek Tuff and the formation of the present 45 x 85 km caldera. Resurgent doming subsequently occurred at both the NE and SW sides of the caldera and voluminous (1,000 cu km) intracaldera rhyolitic lava flows were erupted between 150,000 and 70,000 years ago. No magmatic eruptions have occurred since the late Pleistocene, but phreatic eruptions took place near Yellowstone Lake during the Holocene. Yellowstone is presently the site of one of the world's largest hydrothermal systems including Earth's largest concentration of geysers.

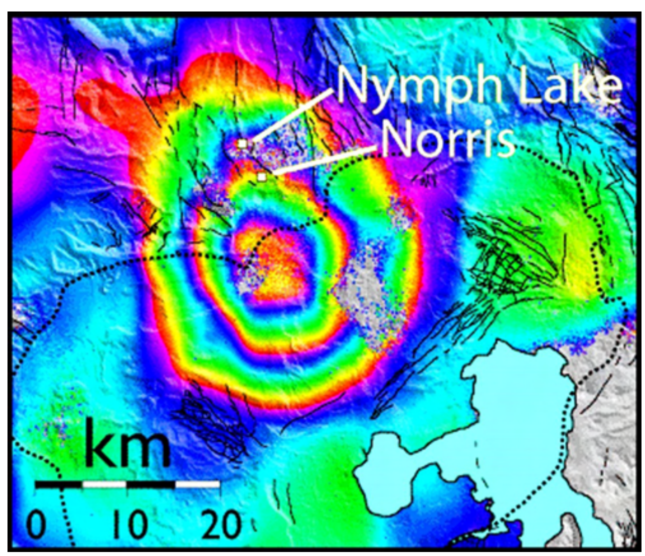

Figure 6. A radar interferogram of the Yellowstone caldera region (after Wicks and others, 1998; 2006). This image of vertical ground deformation was created using data from several satellite passes during 1996 through 2000. The image shows 12.5 cm of uplift centered within the northern end of Yellowstone caldera (black dotted line), about 10 km S of Norris hot springs. Each full spectrum of color (from red to purple) represents ~ 28 mm of uplift. The area of uplift is approximately 35 km x 40 km in size. Courtesy of YVO-USGS.

Information Contacts: *Yellowstone Volcano Observatory*, a cooperative arrangement that includes *Jacob B. Lowenstern*, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025, USA; *Robert B. Smith*, Department of Geology and Geophysics, University of Utah, Salt Lake City, UT 84112, USA; and *Henry Heasler*, National Park Service, P.O. Box 168, Yellowstone National

Park, WY 82190-0168, USA (URL: http://volcanoes.usgs.gov/yvo/).

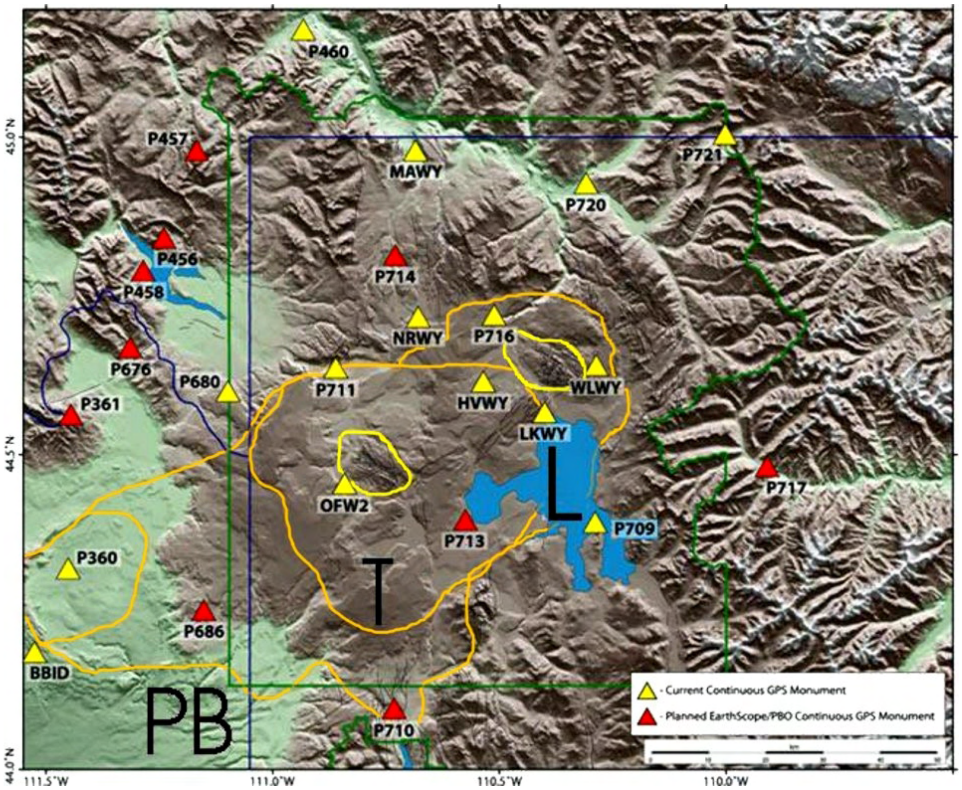

Figure 7. GPS stations at Yellowstone caldera, including those both existing (light triangles) and planned (dark triangles). The irregular loops near stations OFW2 and WLWY outline the two active resurgent domes within the 0.64 million-year-old Yellowstone caldera (the Mallard Lake dome and the Sour Creek dome, to the W and E, respectively). The figure also includes Yellowstone caldera topographic margins (T), Yellowstone Lake (L), the National Park boundary (PB), and some state boundaries. Courtesy of YVO-USGS.

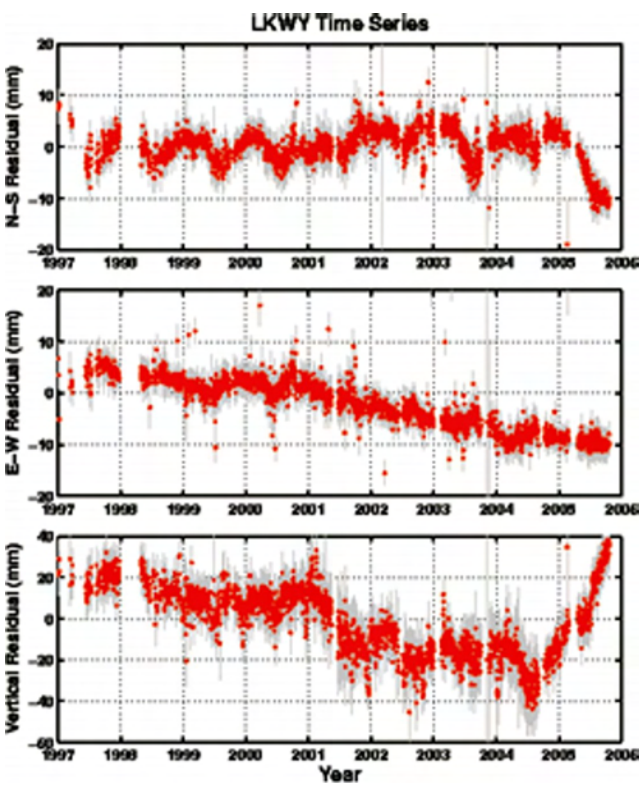

Figure 8. Relative movement of GPS station LKWY (located in the central part of the caldera, at the N end of Yellowstone Lake) recorded during 1997 to late 2005. The top panel shows N-S movement, the middle, E-W movement, and the bottom, vertical movement. During 2001-2004 station LKSY moved downward (subsided) on the order of 20 mm. After mid-2004, LKWY moved upward ~ 80 mm. Courtesy of YVO-USGS.

Tenerife

Canary Islands, Spain
28.271°N, 16.641°W
summit elev. 3,715 m

Juan Carlos Carracedo notified *Bulletin* editors that seismic activity in Tenerife during April and May 2004 was not followed by any volcanic activity. More than 200 earthquakes from magnitude 1 to 3 were recorded, but residents felt only three of them. Most of the epicenters were localized around the NW rift zone of Tenerife and in the strait between Gran Canaria and Tenerife. The crisis was probably related to dike emplacement at 3-4 km depth.

On 12 January 2005, an increase in unrest at Tenerife's Teide volcano over the previous 2 weeks was reported. Carbon dioxide emissions rose from 75 to 354 tons per day, and hydrogen sulfide emissions rose from 35 to 152 tons per day. Seismic activity remained elevated under the volcano. Fumaroles increased in pressure, and emitted sounds. No significant ground deformation was observed.

In a recent article in *Eos*, scientists from Spain and The Netherlands (Garcia et al., 2006), described a monitoring program for the Canary Islands. They noted that the Canary Islands started to show signs of seismo-volcanic activity at the end of 2003. In spring 2004, there was a significant increase in the number of seismic events (a mixture of regional, volcano-tectonic, and volcanic events such as tremor and long-period signals) located beneath Tenerife Island. The authors also noted an increase of fumarolic activity, an increase in carbon dioxide emissions in the NW part of the island, and changes in the gravimetric field on the N flank. After several seismic events had been felt by the population, the first alert level was declared by the civil protection division of the local government.

The volcano has a history of large eruptions destructive to populated areas. The authors reported that in 1992, the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) identified Teide, with its high-risk level, as one of the European Laboratory Volcanoes, thus receiving special consideration from the European Union concerning research proposals.

In the spring of 2005, the Spanish National Research Council (CSIC) initiated the TEGETEIDE project (Geophysical and Geodetic Techniques for the Study of the Teide-Pico Active Volcanic Area). It will monitor the seismicity of the volcano and include background noise analysis. The system's main goal is to detect precursors to a potentially dangerous eruptive episode at an early stage. The scheme is to use signals in both the time and the spectral domains.

References. Garcia, A., Vila, J., Ortiz, R., Macia, R., Sleeman, R., Marrero, J.M., Sanchez, N., Tarraga, M., Correig, A.M., 2006, Monitoring the reawakening of Canary Islands' Teide Volcano: EOS Transactions, American Geophysical Union, v. 87, no. 6, p. 61, 65.

Background. The large triangular island of Tenerife is composed of a complex of overlapping Miocene-to-Quaternary stratovolcanoes that have remained active into historical time. The NE-trending Cordillera Dorsal volcanic massif joins the Las Cañadas volcano on the SW side of Tenerife with older volcanoes, creating the largest volcanic complex of the Canary Islands. Controversy surrounds the formation of the dramatic 10 x 17 km Las Cañadas caldera, which is partially filled by 3715-m-high Teide stratovolcano, the highest peak in the Atlantic Ocean. The origin of the caldera has been considered to be due entirely or in part to either a massive landslide (in a manner similar to the earlier formation of the massive La Orotava and Guimar valleys in the Cordillera Dorsal) or due to major explosive eruptions. The most recent stage of activity beginning in the late Pleistocene included the construction of the Pico Viejo and Teide edifices. Tenerife was perhaps observed in eruption by Christopher Columbus, and several flank vents on the Canary Island's most active volcano have been active during historical time.

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