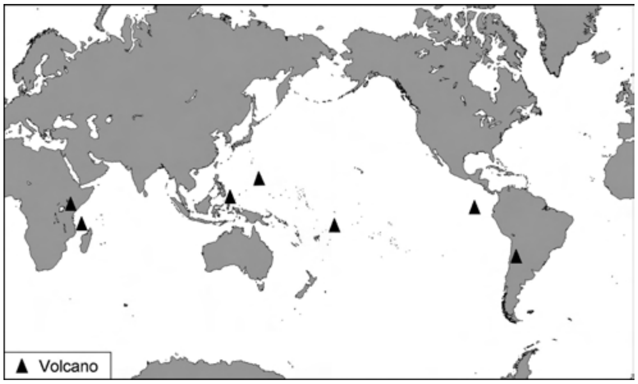
Bulletin of the Global Volcanism Network



Volume 30, Number 4, April 2005

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

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Lascar

northern Chile
23.37°S, 67.73°W; summit elev. 5,592 m
All times are local (= UTC - 3 hours)

Lascar, the most active volcano in northern Chile, erupted on 4 May 2005. Although the eruption was substantial, thus far there is an absence of reports from anyone who saw the eruption at close range. Preliminary assessments came mainly from satellite sensors and distant affects witnessed in Argentina. This report is based on one sent to us by Chilean Observatorio Volcanológico de los Andes del Sur (OVDAS) scientists José Antonio Naranjo and Hugo Moreno, discussing events around 4 May, with brief comments on some of Lascar's behavior in the past several years, and suggestions for future monitoring.

Lascar sits ~ 70 km SW of the intersection between Chile, Argentina, and Bolivia, ~ 300 km inland from the Chilean port city of Antofagasta. This part of the coast lies along the Atacama desert, and on flat terrain tens of kilometers W of Lascar resides a large salt pan, the Salar de Atacama (about 50 x 150 km). The settlement of Toconao is ~ 33 km NW of Lascar. Previous reports discussed field observations during 13 October 2002 to 15 January 2003, and fine ash discharged from fumaroles on 9 December 2003 (*Bulletin* v. 28, no. 3, and v. 29, no. 1).

Naranjo and Moreno concluded that at roughly 0400 on 4 May an explosive eruption ejected an ash cloud to a tentative altitude on the order of 10 km that dispersed to the SE. About 2 hours later the cloud began dropping ash on Salta, Argentina. Satellite images portrayed the ash cloud's dispersal. An aviation 'red alert' was issued by the Buenos Aires Volcanic Ash Center; they saw the plume over Argentina at altitudes of 3-5 km.

Shortly after atmospheric impacts of the 4 May eruption became apparent, the Buenos Aires VAAC notified OVDAS that NW Argentine cities had reported falling ash. These cities, all SE of Lascar, included Jujuy, Salta, Santiago del Estero, and Santa Fe–locations with respective approximate distances from Lascar of 260, 275, 580, and 1,130 km. The Argentine province of Chaco, along the country's NE margin, was also noted as receiving ash. Buenos Aires (~ 1,530 km SE of Lascar) remained ~ 400 km beyond the point of the farthest detected ashfall.

Patricia Lobera, a professor in Talabre, Argentina, 17 km E of Lascar, said that eruption noises were not heard there on the morning of 4 May. When observers saw the plume from Talabre that morning they reportedly thought the plume looked similar to those on previous days.

Remotely sensed hot spots were detected on a GOES satellite image for 0339 (0639 UTC) on 4 May, showing the first evidence of an eruption. In a later image, at 0409, the thermal anomaly had increased, and the image suggested a growing, ash-bearing cloud then trending ~ 23 km to the SE. The thermal anomaly diminished in intensity by 0439, remaining diminished thereafter, but by that time the plume's leading margin extended over ~ 100 km SE and its tail had detached from the volcano. At 0509 the plume reached 170 km SE. According to a press report, at around 0600 ash fell in Salta (~ 275 km SE of Lascar).

Rosa Marquilla, a geologist at the University of Salta, reported that residents there noticed a mist attributed to the eruption, which hung over the city until at least to 1600, after which, the sky gradually cleared. Preliminary description of the petrography of the ash that fell in Salta came from Ricardo Pereyra (University of Salta) who saw crystal fragments (pyroxenes, feldspars, and magnetite) and fragments of volcanic glass containing plagioclase mircrolites. Lithic fragments were not observed.

The OVDAS authors concluded that, apparently since the year 2000, Lascar underwent constant degassing from an open vent within the ~ 780-m-diameter active central crater. Sporadic explosions as in July 2000 and October 2002, and in this case, 4 May 2005, could be due to diverse causes. For example, there may have been temporarily obstructed conduits at depth, local collapses blocking the vent at the crater floor, or fresh magma injection contacting groundwater. Extrusion of a viscous dome lava also might explain the sudden explosions. That circumstance would presumably lead to visibly increased fumarolic output.

Naranjo and Moreno had several suggestions for ongoing monitoring. First, they suggested developing closer long-term contacts, including people able to visually monitor the volcano directly, as well as continued systematic contact with the Buenos Aires VAAC and their satellite analysts. They recommended ongoing relations with the University of Hawaii (MODVOLC) program to remotely sense hot-spots. They went on to suggest a campaign of stereo aerial photography to detect changes in the active crater. They advocated notifying local inhabitants of the possibility of ash falls before another explosive episode. They pointed out that mountaineers should be made aware of elevated risks within 8 km of the active crater.

Background. Lascar is the most active volcano of the northern Chilean Andes. The andesitic-to-dacitic stratovolcano contains six overlapping summit craters. Prominent lava flows descend its NW flanks. An older, higher stratovolcano 5 km to the E, Volcán Aguas Calientes, displays a well-developed summit crater and a probable Holocene lava flow near its summit (de Silva and Francis, 1991). Lascar consists of two major edifices; activity began at the eastern volcano and then shifted to the western cone. The largest eruption of Lascar took place about 26,500 years ago, and following the eruption of the Tumbres scoria flow about 9,000 years ago, activity shifted back to the eastern edifice, where three overlapping craters were formed. Frequent small-to-moderate explosive eruptions have been recorded from Lascar in historical time since the mid-19th century, along with periodic larger eruptions that produced ashfall hundreds of kilometers away from the volcano. The largest historical eruption of Lascar took place in 1993, producing pyroclastic flows to 8.5 km NW of the summit and ashfall in Buenos Aires.

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Gardeweg, M., and Lindsay, J., 2004, Lascar Volcano, La Pacana Caldera, and El Tatio Geothermal Field: IAVCEI General Assembly Pucón 2004, Field Trip Guide-A2, 32 p.

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Information Contacts: *José Antonio Naranjo* and *Hugo Moreno*, Programa Riesgo Volcanico, Servicio Nacional de Geologia y Mineria, Avda. Santa Maria 0104, Casilla 1347, Santiago, Chile; *Gustavo Alberto Flowers*, Buenos Aires Volcanic Ash Advisory Center (Buenos Aires VAAC), Servicio Meteorológico Nacional-Fuerza Aérea Argentina, 25 de mayo 658, Buenos Aires, Argentina (URL: http://www.meteofa.mil.ar/vaac/vaac.htm).

Fernandina

Galápagos Islands, Ecuador
0.37°S, 91.55°W; summit elev. 1,476 m
All times are local (= UTC - 6 hours)

On the morning of 13 May 2005, a new eruption started on uninhabited Fernandina volcano (figure 1). Fernandina last erupted in 1995 (figure 2), and had been quiet and seemingly unchanged when a team from the Ecuadorian Institute of Geophysics (IG) flew over it in late March 2005. On 11 May an M 5.0 earthquake occurred with an epicenter ~ 30 km E of Fernandina's center. Only two other earthquakes have been located by the U.S. Geological Survey (USGS) within 100 km of Fernandina in last 4.5 years (M 4.0 on 23 February 2005 and M 4.6 on 16 April 2005), both having epicenters ~ 70-80 km SE of Fernandina's center. A seismic station, installed by the IG in 1996 on the NE coast of the island, was out of service at the time of eruption.

Galápagos National Park workers in western Galápagos were apparently the first to witness the eruption, and IG technicians recognized it on satellite imagery. The University of Hawaii presents hotspot images on their website. Their GOES data lacked hotspots at 0930, but a clear and strong one had developed on the S flank by 0945. Francisco Dousdebes (of Metropolitan Touring) placed the eruption's start time at 0935. S-flank hotspots were comparatively extensive by 1015. The Washington VAAC issued their first full advisory at 1315. Their notices reported that the W-directed plume rose to ~ 5 km altitude, and the S-directed plume went to 9 km; both were visible as late as 1745 on 13 May, depicting the leading portions of Fernandina' s ash plume more than 200 km from the volcano

An overflight of the eruption on the 13th by the National Park resulted in a report by Patricio Ramón and Hugo Yepes, and the eruption was confirmed by Washington Tapia, director of the Galápagos National Park. That evening, Galápagos resident Greg Estes telephoned Dennis Geist to report that the eruptive source was a "circumferential vent near [the] summit, S side . . . 6 km long with an eruptive zone 50 m across." It was uncertain how this fissure was related to the 1981 eruption site (figure 2 and *Bulletin* v. 9, no. 3). IG also noted that tephra had fallen on neighboring Isabela Island, in the areas of the volcanoes Wolf and Ecuador (~ 40 km from the vent, figure 1).

At 0537 on the second morning, 14 May, the Washington VAAC reported low level ash/steam not visible in infrared imagery, but at 0746, 1½ hours after sunrise, a plume of ash extended ~ 130 km to the W and was moving at 18 km/hour at 1,800 m elevation. The GOES thermal anomaly was greatly diminished by 0930, and remained low to non-existent until resumption around 1415. That afternoon, an overflight by Godfrey Merlen, Wacho Tapia, and Alan Tye (Charles Darwin Research Station) resulted in the fullest report to date.

They said that although the vent area was obscured by clouds, topography suggested a 4.5 km long fissure vent near the S rim, with activity having progressed from SW (near the first and uppermost flows of the 1995 radial fissure eruption) to the E (figure 1). The lava flows "had begun to pond on the gentler outer skirt of the island," and were then 5.5 km from the coast (~ 5 km from the vents). They thought it unlikely that the flows would reach the sea. A follow-up news report in *El Comercio* (Quito) quoted Tapia as identifying five flows down the S flank. Only one remained incandescent. At 1745 on 14 May, Washington VAAC reported a plume remaining to the NW, but–lacking detectable ash–they discontinued advisories. Thermal anomalies on the GOES satellite remained strong, however, until the next morning.

The report also noted that, "As on previous eruptions, such as that on Cerro Azul in 1998, lava passing through vegetated areas has caused small fires, but these have not spread far from the lava tongues themselves before going out. Most of the new flows have passed over unvegetated older lava, and damage to Fernandina's vegetation is limited."

The team also flew over Alcedo volcano on Isabela, where Project Isabela staff had reported increased fumarole activity. Steam was rising from the "new" fumarole sites (active since the 1990s) and from the area of sulfur deposits and fumaroles in the southwestern area of the rim, but this activity did not appear unusual.

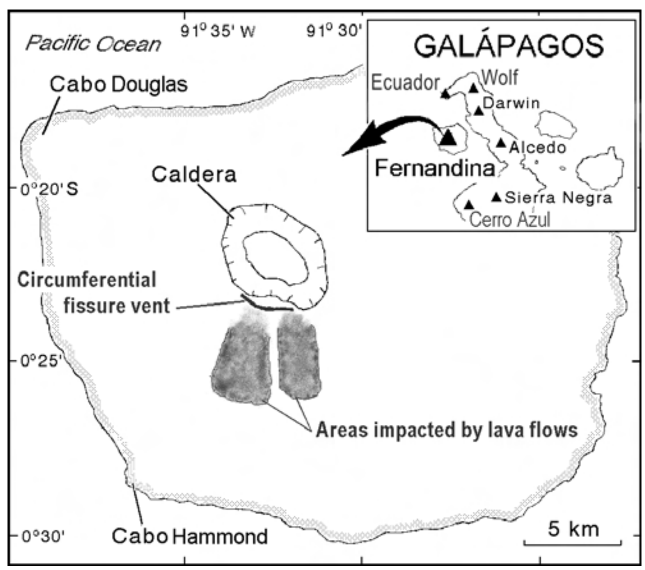

Figure 1. Sketch map of Fernandina, showing the conspicuous summit caldera, and indicating the flow fields and circumferential vent area from the 13 May 2005 eruption (as mapped on 14 May by airborne reconnaissance and reported by the Charles Darwin Research Station). Key features include the active circumferential fissure vent and two main areas impacted by lava flows. The eastern area contained lava flows still mobile on 14 May; flows to the W had already cooled by 14 May.

On the index map of the Galápagos Islands, the largest island, Isabela, is ~ 130 km long and lies to the E of Fernandina island. "La Cumbre"–Spanish for the summit, peak, or top–has been mistakenly applied to the volcano, apparently because the summit was so labeled on an old map. The island has also been called Narborough. The index map is incomplete in its portrayal of both volcanoes and islands of the archipelago. Revised from *Bulletin* v. 20, no. 1.

On 15 May, the GOES thermal anomaly was gone before noon, but returned near midnight (about 2330), over a smaller area, and it remained through sunrise (0615) on 16 May. Small anomalies were visible the next several nights (when contrast with adjacent cold flows was strongest), but there was no obvious evidence of continued feeding of the new flows.

The complex thermal anomalies detected in MODIS satellite imagery (provided by the University of Hawaii), were abundant around the time of eruption. They spread over Fernandina's rim, in some cases in the caldera, and broadly over the S flank. They continued through at least the rest of May.

The Washington VAAC reported that a weak hotspot started 29 May 2005 at 1945 (30 May at 0145 UTC) and a very short narrow plume of ash and gases appeared in multi-spectral imagery at 2145 (30 May at 0345 UTC). No ground confirmation of an eruption was available, and there was a layer of low-level weather cloud over the island. At that time, the plume appeared to dissipate as it moved away at ~ 18 km/hour.

Background. Fernandina, the most active of Galápagos volcanoes and the one closest to the Galápagos mantle plume, is a basaltic shield volcano with a deep 5 x 6.5 km summit caldera. The volcano displays the classic "overturned soup bowl" profile of Galápagos shield volcanoes. Its caldera is elongated in a NW-SE direction and formed during several episodes of collapse. Circumferential fissures surround the caldera and were instrumental in growth of the volcano. Reporting has been poor in this uninhabited western end of the archipelago and even a 1981 eruption was not witnessed at the time. In 1968 the caldera floor dropped 350 m following a major explosive eruption. Subsequent eruptions, mostly from vents located on or near the caldera boundary faults, have produced lava flows inside the caldera as well as those in 1995 that reached the coast from a SW-flank vent. Collapse of a nearly 1 km³ section of the E caldera wall during an eruption in 1988 produced a debris-avalanche deposit that covered much of the caldera floor and absorbed the caldera lake.

Information Contacts: *Patricio Ramón* and *Hugo Yepes*, Geophysical Institute (IG), Escuela Politécnica Nacional, Apartado 17-01-2759, Quito, Ecuador (URL: http://www.igepn.edu.ec/); *Alan Tye*, Charles Darwin Research Station, Puerto Ayora, Santa Cruz, Galapagos Islands, Ecuador (URL: http://www.darwinfoundation.org/); *Washington Volcanic Ash Advisory Center (VAAC)*, Satellite Analysis Branch, NOAA/NESDIS E/SP23, NOAA Science Center Room 401, 5200 Auth Road, Camp Springs, MD 20746 USA (URL: http://www.ssd.noaa.gov/); *Tom Simkin*, Dept. of Mineral Sciences, National Museum of Natural History, Smithsonian Institution, Washington, DC 20013-7012, USA (Email: simkin@nmnh.si.edu); *National Earthquake Information Center*, U.S. Geological Survey, Box 25046, DFC, MS 966, Denver, CO 80225-0046, USA (http://neic.usgs.gov/); *MODIS Thermal Alert System*; University of Hawaii and Manoa, 168 East-West Road, Post 602, Honolulu, HI 96822, USA (URL: http://modis.higp.hawaii.edu).

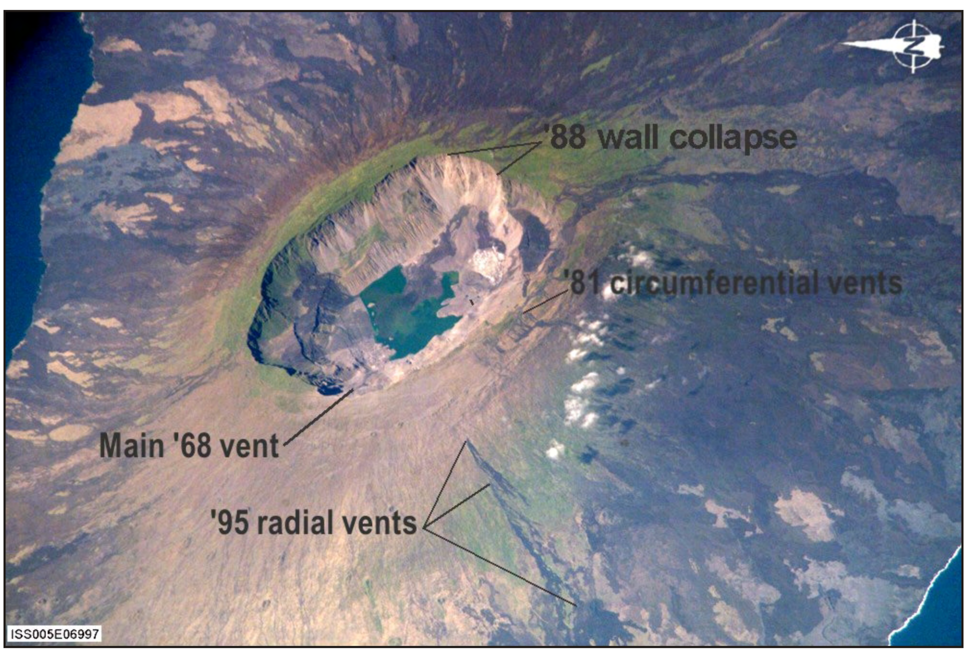

Figure 2. A 2002 International Space Station photograph of Fernandina, looking obliquely towards the E (N is towards the left). Labels show key features developed in 1995, 1981, and 1968 eruptions. Note the island's coastline in the lower-right corner and along much of the left margin. Despite the steep walls bounding the 850 m deep, 5 x 6.5 km central caldera, it supports both animal and plant populations. Image ISS05E06997 (Visible Earth v1 ID 18002) with contrast enhanced and labels added by *Bulletin* editors.

Anatahan

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

Anatahan's third historical eruption began on 5 January 2005, and is described in *Bulletin* v. 29, no. 12. Further details and satellite images were presented in *Bulletin* v. 30, no. 2, which covered events until mid-February 2005. A 5-6 April 2005 eruption cloud rose to at least 15 km altitude, which was the highest yet seen at the volcano.

Anatahan erupted almost continuously after 5 January 2005, when it started its third eruption in recorded history. An image collected by the Ozone Monitoring Instrument on NASA's Aura satellite shows atmospheric sulfur dioxide (SO_2) concentrations between 31 January and 4 February 2005 (figure 3). A long SO_2 plume extends NE and SW of Anatahan, and the edge of the plume covers Guam (the southernmost island) and the other Mariana Islands immediately to Anatahan's N and S.

Volcanogenic SO_2 combines with water to create a sulfuric acid haze. Called "vog," this haze can cause illness and make breathing difficult. Volcanic haze grew so thick during the first week of February that the National Weather Service issued a volcanic haze advisory for Guam, where several illnesses were reported.

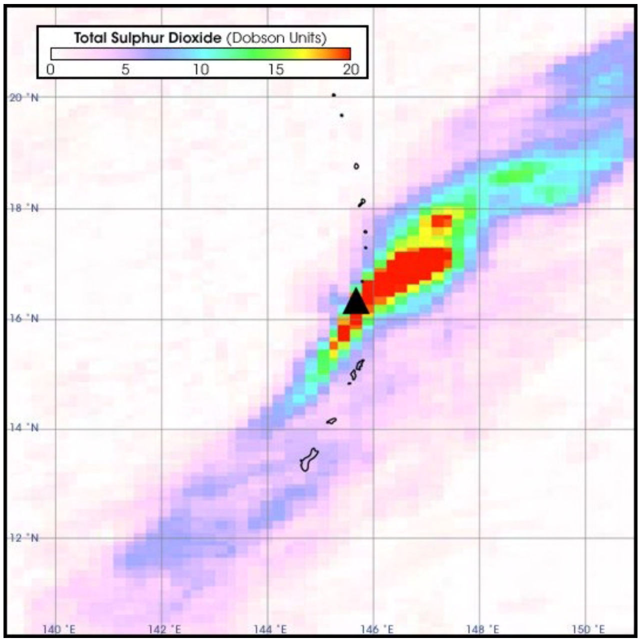

Figure 3. Anatahan's atmospheric SO_2 as imaged by Aura's OMI instrument on 31 January 2005. The OMI (Ozone Monitoring Instrument) measures SO_2 in Dobson Units. Dobson Units, which derive from spectroscopic measurement techniques, can be thought of as the mass of molecules per unit area of Earth's atmospheric column. One Dobson Unit equals 0.0285 grams of SO_2 per square meter. The Ozone Monitoring Instrument (OMI) that created this image tracks global ozone change and monitors aerosols like sulfates in the atmosphere. It was added to the Aura satellite as part of a collaboration between the Netherlands' Agency for Aerospace Programs and the Finnish Meteorological Institute. NASA describes the Eos system Aura as "A mission dedicated to the health of the Earth's atmosphere." NASA image courtesy Simon Carn (Joint Center for Earth Systems Technology (JCET), University of Maryland Baltimore County (UMBC)).

After mid-February 2005, eruptive activity at Anatahan steadily declined to less than 5% of the peak level attained since the eruption started on 5 January. Ash eruptions continued, and the 2003 crater floor was almost entirely covered by fresh lava out to a diameter of ~ 1 km. A MODIS image taken at 0115 on 18 February showed a plume of steam and vog extending about ~ 170 km SW of Anatahan. Seismic and acoustic records during the last week of February 2005 showed very low levels of activity. Seismic amplitudes during 23-28 February were similar to those recorded prior to the 5 January eruption. NASA MODIS (Moderate Resolution Imaging Spectroradiometer) imagery taken on 28 February showed a faint plume of vog and steam trending W of Anatahan.

During the first two weeks of March 2005 volcanic and seismic activity increased relative to the previous weeks. During 14-17 March, seismicity increased and steam rose a few hundred meters above the volcano. The inner E crater had been nearly filled with lava flows and lapilli since early January.

A small eruption began on 18 March at 1544 according to seismic data. On 19 March the Washington VAAC issued an advisory that an ash plume was visible on satellite imagery below 4 km altitude. Small explosions that began late on 20 March lasted for 14 hours. No emissions were visible on satellite imagery, but others were, later in March and April.

A strong outburst apparently began on 21 March, a day when seismicity increased significantly. Seismic amplitudes peaked on the 25th and faded out on the 26th. Near the peak on the 25th, the U.S. Air Force Weather Agency (AFWA) detected a hot spot on the island on satellite imagery and reported an ash plume briefly reaching ~ 5.8 km altitude. The plume height soon dropped to below 3 km altitude, and by near midday on the 27th the plume had changed from ash and steam to steam and vog. On the 27th the plume extended ~ 240 km SW.

On 5 April at about 2200 seismic signals began to increase slowly, and the Washington VAAC began to see increased ash on satellite imagery. On 6 April 2005 around 0300 an explosive eruption began and produced an ash plume to an initial height of ~ 15.2 km altitude, the highest in recorded history from the volcano. Seismicity peaked at the same time.

The AFWA reported an upper level ash plume at ~ 15.2 km altitude blowing E to SE and a lower level ash plume at ~ 4.6 km altitude blowing SW; the upper plume extended more than 465 km. Earth Probe TOMS data on 6 April at 1046 showed a compact sulfur-dioxide cloud drifting E of Anatahan following the eruption.

Chuck Sayon, the superintendent of American Memorial Park noted, "On Saipan at around 10 AM the skies darkened and light ash started falling . . . park operation[s] have been restricted to indoor activities due to irritation to eyes and breathing as ash starts to lightly coat the area. Schools are closed as well as the airport until further notice . . .."

On 6 April during 0400 to 0900 the seismicity at Anatahan decreased to near background. The seismicity surged for about 1 hour, with amplitudes about one-half those reached during the earlier eruption, and subsequently dropped again to near background. Prior to the 6 April eruption, during 31 March to 4 April the amplitudes of harmonic tremor varied, reaching a 2-month high on the 3rd. Small explosions occurred every one minute to several minutes, probably associated with cinder-cone formation. Steam-and-ash plumes drifted ~ 200 km, and vog drifted ~ 400 km at altitudes below ~ 2.4- 4.6 km.

The U.S. Geological Survey (USGS) (in conjunction with the Commonwealth of the Northern Mariana Islands) stated that the "eruption of 6 April 2005 was the largest historical eruption of Anatahan and expelled roughly 50 million cubic meters of ash. The eruption column and the amplitude of harmonic tremor both grew slowly over about 5 hours and both peaked about 0300 on 6 April local time . . .. The peak of the eruption lasted about one hour and then the activity declined rapidly over the following hour."

The 6 April 2005 eruption's plume was captured on satellite images. The image showed a plume that was tan or brown in color and clearly ash laden (figure 4).

Figure 5 shows SO_2 concentrations in the atmosphere on 7 April 2005, over 30 hours after the large 6 April eruption. SO_2 emissions from the eruption were measured by the Ozone Monitoring Instrument (OMI) on NASA's EOS/Aura satellite. OMI detects the total column amount of SO_2 between the sensor and the Earth's surface and maps this quantity as it orbits the planet. A new perspective on the vertical distribution of the SO_2 is revealed by combining the OMI data with coincident measurements made by the Microwave Limb Sounder (MLS), also part of the Aura mission.

The MLS data crisscross the OMI image and clearly show that some, but not all, of the SO_2 measured by OMI to the volcano's E was in the upper troposphere or above. At these altitudes, SO_2—and the sulfate aerosols that form from it—can stay in the atmosphere and affect the climate for a longer period of time. A weaker SO_2 signal was also measured in the same region during the nighttime MLS overpass, which crosses the image from upper right to lower left. The daytime data, running from upper left to lower right, coincide with the OMI measurements. The MLS data west of Anatahan show no significant SO_2 signal, indicating that the SO_2 measured by OMI in this region was in the lower troposphere.

MLS measures thermal emissions from the Earth's limb, so unlike the OMI sensor it also collects data at night. It is designed to measure vertical profiles of atmospheric gases that are important for studying the Earth's ozone layer, climate, and air quality, such as SO_2. These images, derived from preliminary, unvalidated OMI and MLS data, show MLS SO_2 columns (filled circles) measured every 165 km along the Aura orbit, plotted over the OMI SO_2 map. The MLS SO_2 columns shown here are derived from profile measurements made from the upper troposphere into the stratosphere (~ 215-0 hPa (hectoPascal, 10^2 Pa) or ~ 12 km altitude and above), and the circles do not represent the actual size of the MLS footprint, which is roughly 165 x 6 km.

Anatahan's morphological changes were highlighted in before (pre-eruption) versus after (post-eruption) images. Seismicity decreased at Anatahan after 6 April and during 7-11 April was at very low levels, near background. On 11 April, a steam-and-ash plume rose ~ 2.7 km altitude and drifted ~ 280 km WSW.

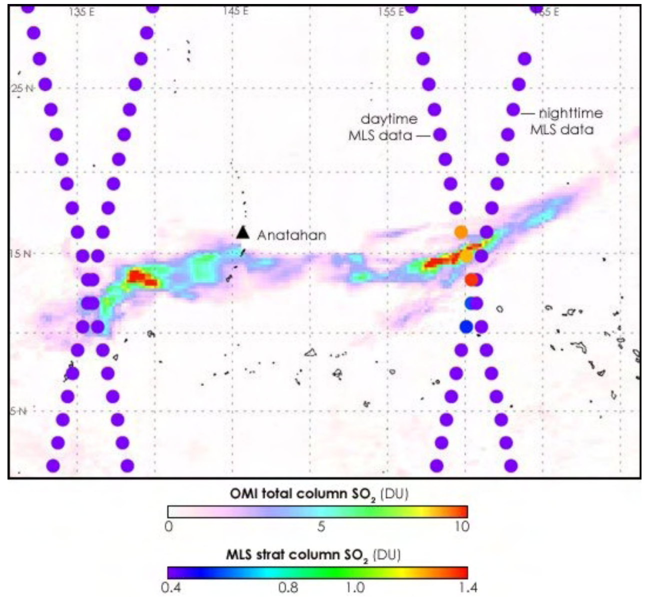

Figure 5. Anatahan's 5-6 April 2005 eruption injected significant SO_2 high into the atmosphere. This OMI image depicts the concentrations found over 30 hours after the eruption, a time when the SO_2 formed two separate zones at distance from the source. Analysis suggests that the westerly zone of SO_2 was probably in the lower troposphere and the eastern zone was probably in the upper troposphere or above. Courtesy of Simon Carn.

Occasional data from Anatahan revealed that seismicity appeared to increase during 24-25 April. During 20-25 April, a continuous thin plume of ash-and-steam rose to less than ~ 3 km altitude and drifted more than 185 km from the volcano. Harmonic tremor dropped dramatically on 1 May after being at high levels for several days. During 27 April to 1 May, the main ash-and-steam plume rose to ~ 3 km altitude According to a news article, the volcanic plume from Anatahan reached Philippine airspace on 4 May.

On 5 May an extensive ash-and-steam plume to 4.5 km altitude was visible in all directions. Ash extended 770 km N, 130 km S (to northern Saipan), and 110 km W. Vog extended in a broad swath from 3,000 km W, over the Philippines, to 1,000 km N of Anatahan. By 9 May harmonic tremor amplitude had decreased to near-background levels, with a corresponding drop in eruptive activity. As of 10 May AFWA was reporting ash to about 3 km altitude extending 400 km W and an area of vog less than half that noted on 5 May.

On 11 May AFWA reported thick ash rising to 4.2 km altitude and moving WNW. The thick ash extended in a triangular shape

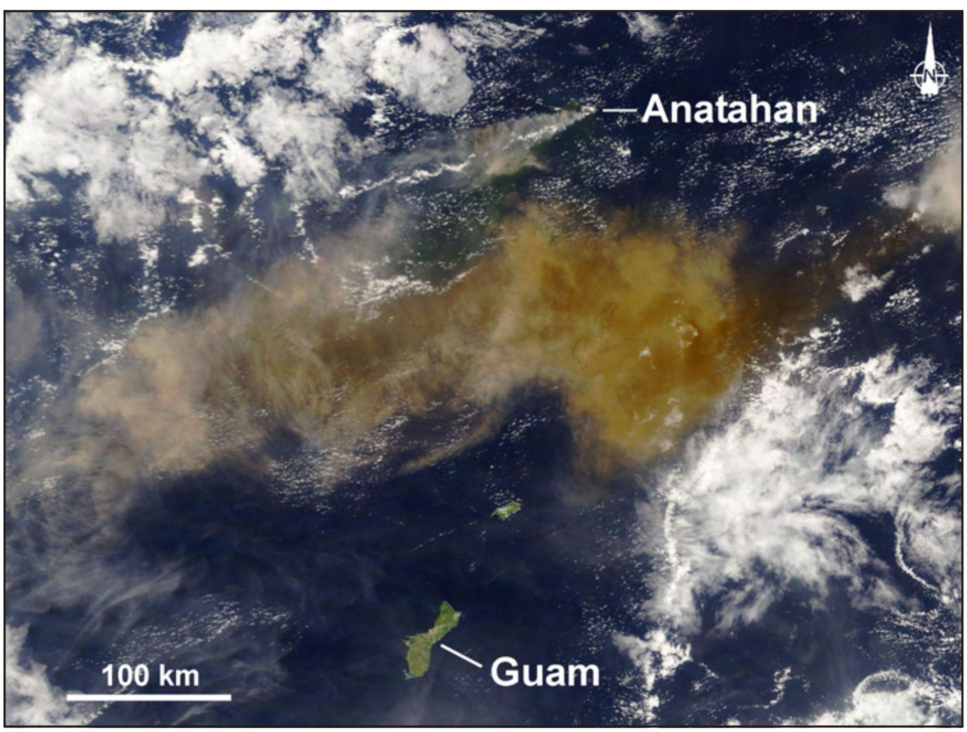

Figure 4. A major eruption from Anatahan on 6 April 2005 sent an ash plume to ~ 15 km. The eruption was considered the largest since Anatahan's first recorded eruption on 10 May 2003. This Moderate Resolution Imaging Spectroradiometer (MODIS) image was acquired by NASA's Terra satellite at 0035 UTC, about 8 hours after the eruption began. By this time, the ash plume had spread S to entirely cover Saipan and Tinian, islands immediately to the S. Courtesy of the MODIS Rapid Response Image Gallery, sponsored in part by NASA.

from the summit 444 km to the WSW through 510 km to the NW. A layer of thin ash at 3 km altitude extended another 1,000 km beyond the thick ash. A broad swath of vog extended over 2,200 km W nearly to the Philippines and over 1,400 km NNW of Anatahan. Although the ash plume diminished over the next few days and was not as thick, it remained significant, rising to 2.4 km and extending 370 km WNW on the 13th. Scientific personnel from the Emergency Management Office and the USGS working the next day at a spot 2-3 km W of the active vent heard a continuous roaring sound. They also saw ash and steam rising by pure convection, not explosively, to 3 km altitude.

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

Reference: Chadwick, W.W., Embley, R.W., Johnson, P.D., Merlea, S.G., Ristaub, S., and Bobbitta, A., 2005, The submarine flanks of Anatahan volcano, Commonwealth of the Northern Mariana Islands: Jour. of Volcanology and Geothermal Res. (In press, June 2005).

Information Contacts: *Juan Takai Camacho* and *Ramon Chong*, Emergency Management Office of the Commonwealth of the Northern Mariana Islands (CNMI/EMO), PO Box 100007, Saipan, MP 96950, USA (URL: http://www.cnmiemo.org/; Email: juantcamacho@hotmail.com and rcchongemo@hotmail.com); *Simon Carn*, Joint Center for Earth Systems Technology (JCET), University of Maryland Baltimore County (UMBC), 1000 Hilltop Circle, Baltimore, MD 21250, USA; *Hawaiian Volcano Observatory (HVO)*, U.S. Geological Survey, PO Box 51, Hawaii National Park, HI 96718, USA (URL: http://hvo.wr.usgs.gov/; Email: hvo-info@hvomail.wr.usgs.gov); *Charles Holliday*, U.S. Air Force Weather Agency (AFWA), Offutt Air Force Base, Nebraska 68113, USA (Email: Charles.Holliday@afwa.af.mil); *Randy White* and *Frank Trusdell*, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025-3591 USA (URL http://hvo.wr.usgs.gov/cnmi/update.html; Email: rwhite@usgs.gov; trusdell@usgs.gov,); *Saipan Tribune*, PMB 34, Box 10001, Saipan, MP 96950, USA (URL: http://www.saipantribune.com/); *Operational Significant Event Imagery (OSEI) team*, World Weather Bldg., 5200 Auth Rd Rm 510 (E/SP 22), NOAA/NESDIS, Camp Springs, MD 20748, USA (URL: http://www.osei.noaa.gov/, Email: osei@noaa.gov); *Washington Volcanic Ash Advisory Center* (VAAC), Satellite Analysis Branch, NOAA/NESDIS E/SP23, NOAA Science Center Room 401, 5200 Auth Road, Camp Springs, MD 20746 USA (URL: http://www.ssd.noaa.gov/); *Chuck Sayon*, American Memorial Park, Saipan, MP 96950, USA; *NASA's Earth Observatory* (URL: http://earthobservatory.nasa.gov/).

Vailulu'u

Samoan Islands, USA
14.21°S, 169.06°W; summit elev. -590 m

According to Hubert Staudigel (Scripps Institution of Oceanography) and Stanley Hart (Woods Hole Oceanographic Institute), Vailulu'u seamount, the most active Samoan submarine volcano, erupted between April 2001 and April 2005. It formed a 293-m-tall lava cone, which was named Nafanua after the Samoan Goddess of War. This new cone had been growing inside the 2-km-wide caldera of Vailulu'u at a minimum rate of about 20 cm/day since April 2001. Nafanua was discovered during a 2005 diving expedition with the National Oceanic and Atmospheric Agency (NOAA) research submersible *Pisces V*, launched from the University of Hawaii research vessel *Kaimikai O Kanaloa* (KOK). It is located in the originally 1,000-m-deep W crater of Vailulu'u (figures 6 to 9).

Seismic monitoring during April-June 2000 showed substantial seismicity, ~ 4 earthquakes per day with hypocenters beneath Nafanua (Konter and others, 2004; *Bulletin* v. 26, no. 6), which can now be interpreted as pre-eruption seismic activity. These observations are consistent with previous reports highlighting the volcanic and hydrothermal activity of Vailulu'u (Hart and others, 2000; Staudigel and others, 2004). The scientists suggested that

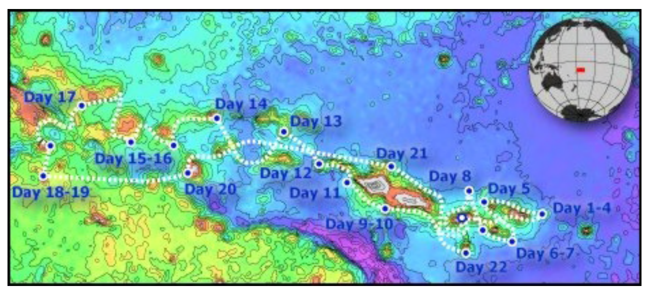

Figure 6. The route of the 2005 cruise of the research vessel *Kilo Moana*. Vailulu'u, towards the E end of the Samoan hotspot trail was visited on cruise days 1-4, 4-8 April 2005. Courtesy of H. Staudigel and S. Hart.

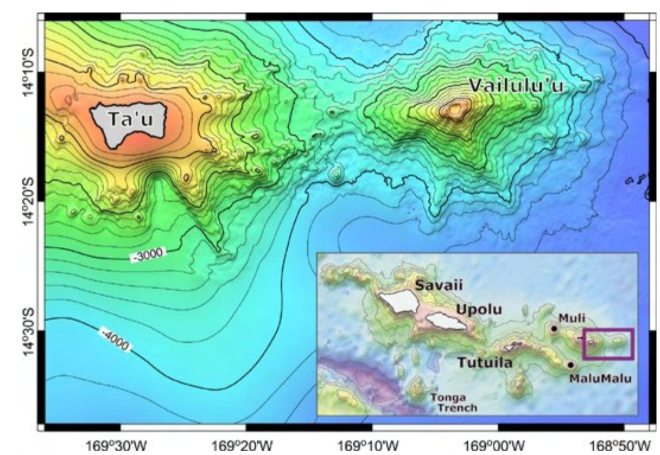

Figure 7. Bathymetry of Vailulu'u and nearby Ta'u Island, based on a SeaBeam bathymetric survey performed during R/V Melville's AVON 2 and 3 cruises, augmented with satellite-derived bathymetry from Smith and Sandwell (1996). The inset shows the general location of Vailulu'u with respect to the Samoan Archipelago; two other newly mapped and dredged seamounts (Malumalu and Muli, AVON 3 cruise) are shown as well. Scale: 10' = 18 km. From Hart and others (2000).

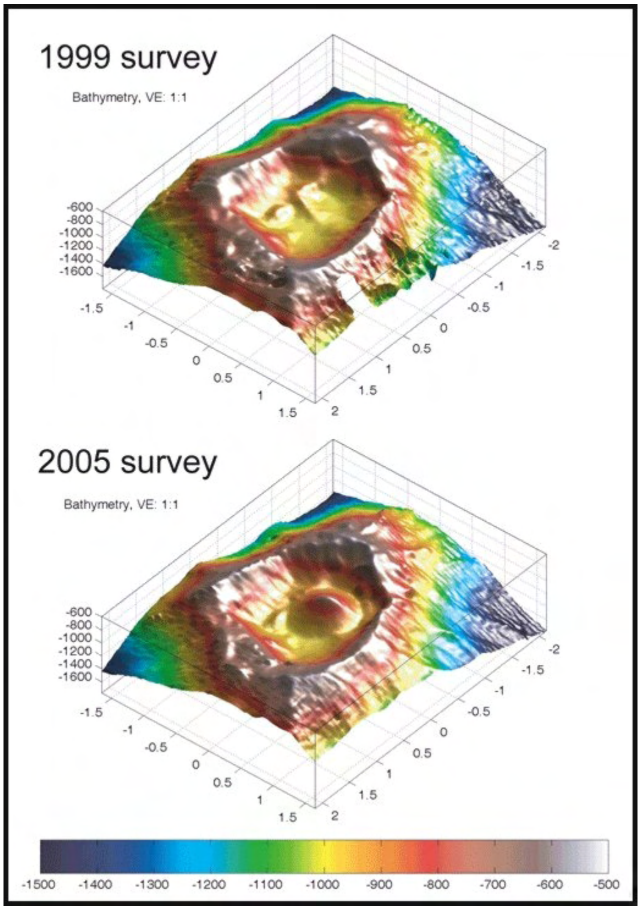

Figure 8. Bathymetry of the Vailulu'u crater between the 1999 and 2005 surveys, showing the emergence of Nafanua. Courtesy of H. Staudigel and S. Hart.

continued volcanic activity could bring the summit region of Vailulu'u to a water depth of ~ 200 m. At that point, Nafanua would overtop the crater rim and further growth would require a build-up of the lower flanks, areas that rise from the 5,000-m-deep floor of the ocean.

Staudigel and Hart teamed up in April 2005 on the Hawaiian Research Vessel *Kilo Moana* to study the Samoan hotspot thought to underlie Vailulu'u. They named their expedition ALIA after the ancient twin-hulled canoe that Samoan warriors used to explore the SW Pacific. The *Kilo Moana* left Pago Pago on 4 April 2005 to study active and extinct underwater volcanoes along the chain of Samoan islands. The expedition investigated previously uncharted seamounts and the submarine portions of some islands, scattered over almost 600 nautical miles, from its most recent and quite active Vailulu'u submarine volcano in the E to Combe Island in the W.

The Nafanua cone was first mapped by using the center beam of the research vessel KOK in several crossings of the W crater. An active hydrothermal system was apparent from evidence such as the murky water that limited visibility during two submersible dives, several microbial biomats covering pillow lavas that were centimeters thick, and a large number of diffuse vents. A dive on 30 March 2005 to examine Nafanua reported "that it must have grown in the last 4 years because CTD (conductivity-temperature-depth) crossings in 2001 still were consistent with the old crater morphology ... the basal portion of the cone displayed relatively large pillows, and higher up pillows look almost like very fluid pahoehoe that collapsed and/or transitioned into aa flows. Nafanua . . . grew very fast with abundant breccia material from collapsing and draining pillows, in particular in the summit region."

On 1 April, another dive along the outer flanks of Vailulu'u found that during the up-slope transit, observers saw a few additional areas of active venting and many sites where there had been venting in the past. Large and perfectly formed pillow lavas were present in most sites, with a few areas being dominated by broken talus fragments and some having completely black glassy pillows with no oxidation, apparent evidence for relatively recent formation. The topography was extremely rough, the slope being punctuated with numerous fissure systems and edifices of pillow lava.

A primary plan for the ALIA expedition was to study the water in and around the seamount for several days using a CTD probe. To sample the inside of the volcano for a full tidal cycle, the scientists varied the depth of the CTD between 40 and 930 m (almost to the crater floor), collecting various data, including visibility. At Vailulu'u, the particulates given off by hydrothermal venting are flushed out of its caldera during each tidal cycle into the surrounding water. In 2005, a dense layer of particulates was found in the water within the crater, but the water was clear outside the crater rim. This contrasts with observations seen from the cruise in 2000, when there was a dense ring of particulates around the whole volcano. It appears that in 2005 the particulates were rising above the crater and then

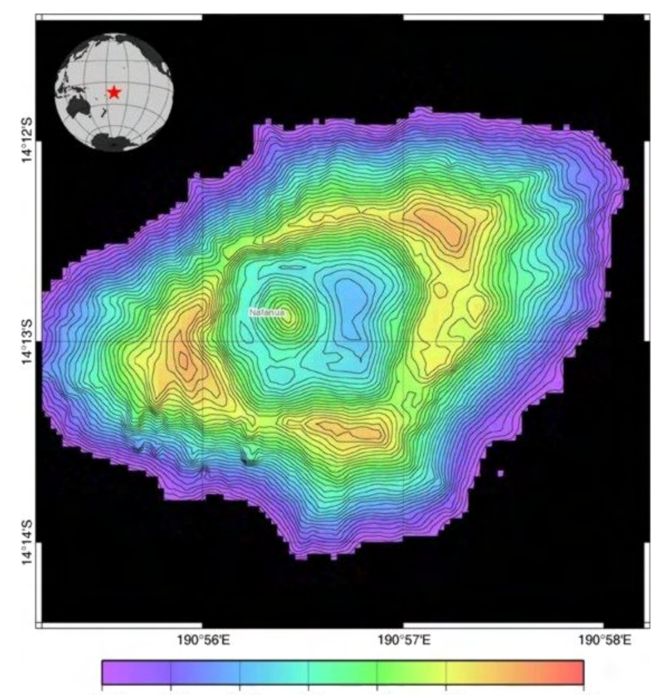

Figure 9. Bathymetric map of the Vailulu'u seamount from multibeam data during the April 2005 survey. Note the new inner cone named Nafanua. Contour interval is 20 m. Courtesy of H. Staudigel and S. Hart.

later sinking, instead of forming the widespread ring observed in 2000.

In addition, the expedition crew conducted dredging of the new summit of Nafanua. Staudigel and Hart noted that the rocks from the first dredge haul were quite newly formed, containing pristine olivine-phyric volcanic rocks. Abundant large vesicles in the rocks from Nafanua suggest a volatile-rich magma capable of submarine lava fountaining and explosive outgassing in shallower water. Dredging from a second site, outside of Vailulu'u, recovered rocks that were both much older and far less fragile.

Background. A massive volcanic seamount, not discovered until 1975, rises 4,200 m from the sea floor to a depth of 590 m about one-third of the way between Ta'u and Rose islands at the eastern end of the American Samoas. The basaltic seamount, named Vailulu'u, is considered to mark the current location of the Samoan hotspot. The summit of Vailulu'u contains a 2-km-wide, 400-m-deep oval-shaped caldera. Two principal rift zones extend east and west from the summit, parallel to the trend of the Samoan hotspot, and a third less prominent rift extends SE of the summit. The rift zones and escarpments produced by mass wasting phenomena give the seamount a star-shaped pattern. On July 10, 1973, explosions from Vailulu'u were recorded by SOFAR (hydrophone records of underwater acoustic signals). An earthquake swarm in 1995 may have been related to an eruption from the seamount. Turbid water above the summit shows evidence of ongoing hydrothermal plume activity.

References: Hart, S.R., Staudigel, H., Koppers, A.A.P., Blusztajn, J., Baker, E.T., Workman, R., Jackson, M., Hauri, E., Kurz, M., Sims, K., Fornari, D., Saal, A., and Lyons, S., 2000, Vailulu'u undersea volcano: The new Samoa: Geochemistry, Geophysics, Geosystems (G3), American Geophysical Union, v. 1, no. 12, doi: 10.1029/2000GC000108.

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Staudigel, H., Hart, S.R., Koppers, A., Constable, C., Workman, R., Kurz, M., and Baker, E.T., 2004, Hydrothermal venting at Vailulu'u Seamount: The smoking end of the Samoan chain: Geochemistry, Geophysics, Geosystems (G3), American Geophysical Union, v. 5, no. 2, QO2003, doi: 10.1029/2003GC000626.

Information Contacts: *Hubert Staudigel*, Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, Univ. of California, San Diego, La Jolla, CA 92093-0225, USA (Email: hstaudigel@ucsd.edu; URL: http://earthref.org/PACER/team/hstaudigel/hstaudigel.htm; http://igpp.ucsd.edu); *Stanley R. Hart*, Woods Holes Oceanographic Institute, Geology and Geophysics Dept., Woods Hole, MA 02543, USA (Email: shart@whoi.edu); *ALIA Expedition*, Samoan Seamounts, R/V Kilo Moana (KM0506), supported by the San Diego Supercomputer Center and the Scripps Institution of Oceanography (URL: http://earthref.org/ERESE/projects/ALIA/).

Awu

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

Awu's eruption on 6 June 2004 and its elevated seismicity in early August 2004 was previously reported (*Bulletin* v. 29, no. 10). This report covers the last half of August 2004, which had not been reported on previously. Since the 6 June eruption, observation of the summit failed to reveal any significant changes (table 1). The hazard status of Awu during this August report remained at Level 2, having been elevated to 4 (the highest on a scale of 1 to 4) at the time of the 6 June eruption and then lowered on 14 June.

Date	Volcanic A	Volcanic B	Tectonic
08 Aug-15 Aug 2004	—	—	75
16 Aug-22 Aug 2004	2	1	81
23 Aug-29 Aug 2004	2	—	102

Table 1. Seismicity at Awu during August 2004 as reported by DVGHM.

Background. The massive Gunung Awu stratovolcano occupies the northern end of Great Sangihe Island, the largest of the Sangihe arc. Deep valleys that form passageways for lahars dissect the flanks of the 1,320-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 contains a summit crater lake that was 1 km wide and 172 m deep in 1922, but was largely ejected during the 1966 eruption.

Information Contacts: *Dali Ahmad*, Directorate of Volcanology and Geological Hazard Mitigation (DVGHM), Jalan Diponegoro 57, Bandung 40122, Indonesia (Email: dali@vsi.dpe.go.id; URL: www.vsi.dpe.go.id).

Karthala

Grand Comore Island, Comoros
11.75°S, 43.38°W; summit elev. 2,361 m
All times are local (= UTC + 3 hours)

After a long period of quiescence following the 1991 phreatic eruption, Karthala's seismicity rebounded starting in July 2000 (*Bulletin* v. 25, no.10). In October 2000, more than 20 seismic events per day were recorded.

The local observatory and a key source for this report is the Karthala Volcano Observatory (KVO; Netter and Cheminée, 1997). They maintain close ties with the Centre National de Documentation et de Recherche Scientifique des Comores (CNDRS), Reunion Island University, the Institut de Physique du Globe de Paris, Piton de la Fournaise Volcanological Observatory, and various universities in France.

Activity during October 2000-March 2004. Between October 2000 and January 2003, relatively low seismicity was detected beneath Karthala's summit. The seismicity slowly increased. During January instruments recorded 51 earthquakes on the 5th, 58 on the 10th, and 50 on the 11th. During the month of April 2003 instruments registered 732 (i.e. averaging ~ 24 each day).

Seismic instruments detected several short earthquake swarms, each comprised of ~ 150 earthquakes. These swarms took place on 25 March and in April 2003, and each lasted several hours. Moreover, seismologists witnessed another swarm consisting of 183 events on 15 May. Except for that latter swarm, Karthala's seismicity was relatively quiet for 35 days after the 25 April swarm. A photo of the Chahalé crater from the year 2003, well before the April 2005 eruption, appears in figure 10. (For a map of Karthala's summit, see *Bulletin* v. 16, no. 8.)

During the time interval from early June 2003 to January 2004 instruments registered three periods with elevated seismicity. The first interval spanned 121 days from June until the end of September 2003 and included 6,315 earthquakes. Within that interval there was a major crisis on 6th September, comprised of 345 events, some being felt by local residents (*Bulletin* v. 28, no. 8).

The second interval began on 11 October 2003, reaching its peak on 4 January 2004 (253 events) and stopped on 31 January 2004. During this interval of 113 days, instruments registered 4,431 earthquakes. The third interval, during the time period of 3 February to 5 March 2004, contained fewer earthquakes. Instruments recorded 832 events in 31 days with a maximum of 143 events per day. After the third interval, KVO recorded only low seismicity until early 2005, when daily events rose to 50-60.

Eruption during April 2005. A seismic crisis began at 0812 on 16 April. Although instruments initially received only short-period events, starting at 0914 they also registered many long-period ones. From 1055 on 16 April a continuous signal was recorded, which was interpreted as tremor marking the beginning of the eruption. At around 1400 that day inhabitants heard a rumbling coming from the volcano. A few minutes later they observed an ash column above the summit. The first ash-fall deposits began to form around 1600, developing on the island's eastern side. According to the firsts reports, ash deposition increased and continued through the night accompanied by a strong smell of sulfur.

Figure 10. Karthala's ~ 300-m-diameter Chahalé crater as seen on 15 August 2003, more than a year prior to the April 2005 eruption. The photo was shot by the automatic camera located at the summit, looking from the NNE towards the SSW. The 2005 eruption dramatically changed this scene, replacing the green lake seen here with a lava lake, and blanketing considerable areas with tephra. Courtesy of Nicolas Villenueve.

Figure 11. A phreatic eruption as seen from Karthala's eastern slopes on the afternoon of 17 April 2005. The vent lies below the white-colored zone in the center-right portion of the photo. With enlargement, many parts of the image record the descent of large pieces of ejecta. Photo credit to school teacher Daniel Hoffschir.

On the morning of 17 April ash falls continued on the eastern part of the island and were heavy enough to require inhabitants to use umbrellas to get about. At midday, Jean-Marc Heintz, a pilot for *Comores Aviation*, flew over the west flank and observed a large plume in the direction of the Chahalé crater. He also clearly observed airborne molten ejecta.

Around 1300, observers saw a very dark plume, spreading into a mushroom shape and accompanied by lightning flashes. Some inhabitants panicked and fled the island's eastern villages. In the afternoon, residents heard rumbling. During the evening, significant rainfall generated small mudflows, and the rumbling became stronger.

At that time, authorities evacuated some eastern villages (according to Agence France Presse (AFP) this affected ~ 10,000 people). Ash there started to fall on the island's western and northern parts, notably, on the country's capital city of Moroni (~ 10 km NW of the summit) and on the Hahaya airport (~ 20 km N of Moroni, ~ 25 km NW of the summit). Figure 11 shows a photo with the base of a vigorous plume over the E flanks on the afternoon of 17 April.

KVO authorities sometimes witnessed a red color at the plume's base, interpreted as a sign of an ongoing magmatic eruption. At 2105 the KVO seismic network recorded a drastic decrease in the amplitude of the tremor. During the night of 17-18 April, wide variations of the tremor amplitude were recorded with a maximum at 0140 on 18 April and a minimum at 0430 on 18 April. Thereafter, the tremor amplitude did not increase. During the night of 17-18 April the plume and falling ash disappeared.

On an overflight of the Chahalé crater at 0830 on 18 April, KVO personnel observed major modifications at the summit (figures 12-14). A lava lake (figure 12) had replaced the water-bearing lake (figure 10) that had occupied the crater since 1991.

On 19 April a new overflight revealed the crater floor containing the lava lake, with its chilled surface emitting steam (figure 13). Lava remained confined to Chahalé crater. Around the caldera area, and particularly on its N, observers saw conspicuous tephra deposits; most of the vegetation had been destroyed (figure 14).

On 20 April a field excursion found that ash deposits varied in thickness from a few millimeters on the coast to ~ 1.5 m at the summit. Near the summit the observers recognized some post-eruptive evaporation and geothermal processes. Specifically, although the lava lake's surface had frozen, there remained sufficient heat under the surface that groundwater migrating towards to the crater's floor evaporated into steam. During another field survey on 8 May, observers noted the renewed presence of lake water inside the crater.

Figure 12. On 18 April 2005 the Karthala eruption generated a lava lake in the Chahalé crater. In this photo, taken the morning of 18 April, considerable portions of the lava lake's surface still remained molten and incandescent.. The lake's surface only remained molten for a few hours. This aerial photo was taken looking from the N. Courtesy of Hamid Soulé.

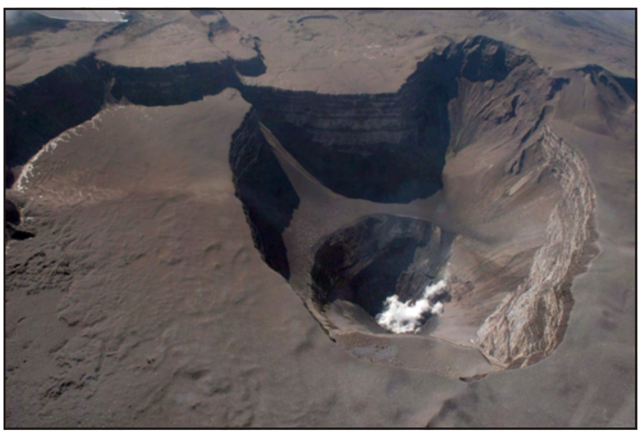

Figure 13. A 19 April 2005 aerial photograph of Karthala taken from the SE centered on Chahalé crater. The lava lake's surface had chilled and it emitted white vapor. Much of the summit area displays the recently deposited smooth-surfaced tephra blanket. Courtesy of Nicolas Villenueve.

Figure 14. Tephra deposits left by Karthala's mid-April 2005 eruption altered the landscape and destroyed vegetation. This picture was taken at the entrance to the first caldera on the western trail, viewed looking to the S. Courtesy of Nicolas Villenueve.

Background. The southernmost and largest of the two shield volcanoes forming Grand Comore Island (also known as Ngazidja Island), Karthala contains a 3 x 4 km summit caldera generated by repeated collapse. Elongated rift zones extend to the NNW and SE from the summit of the Hawaiian-style basaltic shield, which has an asymmetrical profile that is steeper to the south. The lower SE rift zone forms the Massif du Badjini, a peninsula at the SE tip of the island. Historical eruptions have modified the morphology of the compound, irregular summit caldera. More than twenty eruptions have been recorded since the 19th century from both summit and flank vents. Many lava flows have reached the sea on both sides of the island, including during many 19th-century eruptions from the summit caldera and vents on the northern and southern flanks. An 1860 lava flow from the summit caldera traveled ~ 13 km to the NW, reaching the western coast north of the capital city of Moroni.

Reference: Netter, C., and Cheminée, J. (eds.), 1997, Directory of Volcano Observatories, 1996-1997: World Organization of Volcano Observatories (WOVO), WOVO/IAVCEI/UNESCO, Paris, 268 p.

Information Contacts: *Nicolas Villeneuve* (CREGUR, Centre de Recherches et d'Etudes en Géographie de l'Université de la Réunion), *Hamidou Nassor*, and *Patrick Bachèlery* (LSTUR, Laboratoire des Sciences de la Terre), Université de La Réunion BP 7151, 15 Avenue, René Cassin, 97715 Saint-Denis, Reunion Island (Email: Nicolas.Villeneuve@univ-reunion.fr; Patrick.Bachelery@univ-reunion.fr); *François Sauvestre* and *Hamid Soulé*, CNDRS, BP 169, Moroni, République Fédérale Islamique des Comores (Email: obs_karthala@ifrance.com; URL: http://volcano.ipgp.jussieu.fr:8080/karthala/stationkar.html).

Ol Doinyo Lengai

Tanzania, eastern Africa
2.751°S, 35.902°E; summit elev. 2,960 m
Al times are local (= GMT + 3 hours)

Although lava venting at Ol Doinyo Lengai continued intermittently after February 2004 (*Bulletin* v. 29, no. 2), no significant changes were detected until July 2004, a time when vigorous venting emitted substantial amounts of the low-viscosity carbonatitic lava typical at this volcano ('flash floods' of lava). This summary report covers the time interval from February 2004 through early February 2005 based on observations made by Frederick Belton, Celia Nyamweru, Bernhard Donth, and Christoph Weber. Websites devoted to Ol Doinyo Lengai, including photographs, information on the evolution, recent history, and current status of the volcano are maintained by Belton, Nyamweru, and Weber.

A map, thermal data, and some new elevation estimates. In February 2005 Weber and others collected location data with a global positioning system (GPS) receiver. Weber used this to create a sketch map of the active crater (figure 15).

In July 2004 Belton completed the third of a series of distance measurements across crater outflow areas at the crater rim (table 2). Due to the unusually strong eruption on 15 July 2004 (figure 16), deposits comprising the E overflow widened by 3 or 4 m (growing from 44 to 47 m, figure 15). Later, in January 2005, observers noticed a fourth area of overflows had become established on the N crater rim, with lavas pouring over the rim at two adjacent points there (figure 15).

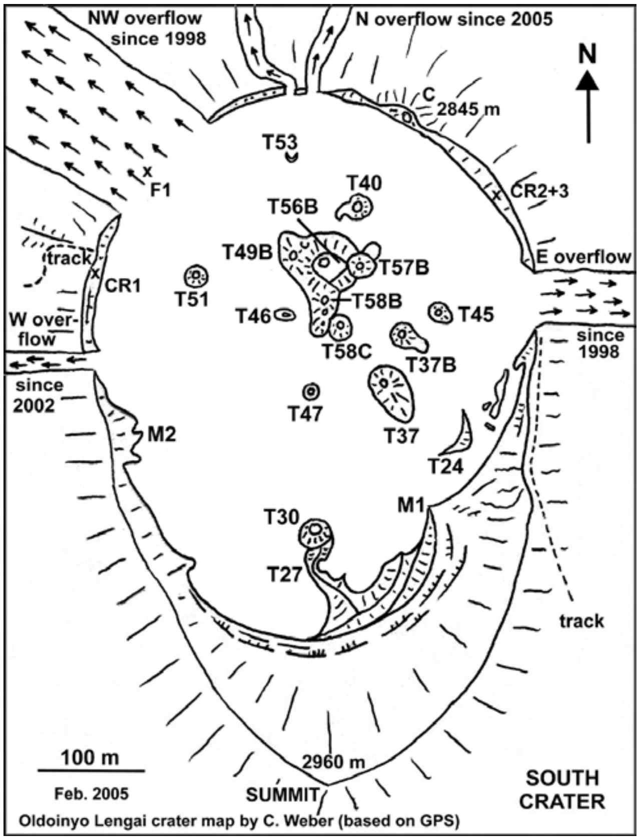

Figure 15. Sketch map of crater features at Ol Doinyo Lengai surveyed with a global positioning system (GPS) during 3-7 February 2005. During the course of the report interval, new vents developed at T49G and T58C (amid the N-central group of hornitos; T49G sits ~ 10 m E of T49B). These new vents produced comparatively vigorous eruptions. Courtesy of Chris Weber (Volcano Expeditions International, VEI).

Crater rim overflow area	Date of measurement	Width (m)
NW overflow	02 Aug 2003	135
NW overflow	29 Jun 2004	135
NW overflow	29 Jul 2004	135
E overflow	2 Aug 2003	44
E overflow	29 Jun 2004	44
E overflow	29 Jul 2004	47
W overflow	2 Aug 2003	17
W overflow	29 Jun 2004	18
W overflow	29 Jul 2004	18

Table 2. For Ol Doinyo Lengai, the width of the three extant lava outflows at the points where they spilled from the active crater ('overflows,' figure 15), as measured during 2 August 2003-29 July 2004. Two additional small overflows formed later, by January 2005, on the N crater rim. The 3-m E-overflow increase occurred during the eruption of T58C on 15 July 2004. Courtesy of Frederick Belton.

Figure 16. A time exposure photograph of Ol Doinyo Lengai taken just after sunset on 15 July 2004. At that time the newly formed vent T58C ("Charging Rhino") issued copious lava. This photo was taken looking approximately NW from the SE part of the crater rim. Courtesy of Frederick Belton.

During 3-7 February 2005 Weber and others completed a series of lava and fumarole temperature measurements that appear as tables 3 and 4. The tables indicate the hottest lava and fumarole temperatures at cracks were 588°C (at T49C, February 2004) and 150°C (at T49G, June 2004), respectively. The hornitos T49C and T49G both lie near T49B, a hornito delineated on figure 15.

Weber's team GPS measurements suggested a summit elevation of 2,960 ± 5 m. This is consistent with GPS measurements taken in October 2000, by a scientific group led by Joerg Keller, of 2,950-2,960 m (*Bulletin* v. 25, no. 12). In addition, the tallest hornito in the N-central crater rises to nearly this elevation (see discussion of T49/T56B, below).

During observations in February 2004, Weber measured the tallest hornito at the T49 location (part of T56B) in the center area of the active crater. GPS readings on top of T56B yielded an elevation of 2,886 m. This is only 4 m below the elevation of the summit and within the stated, ± 5m uncertainty of that measurement. The top of T49 is also ~ 33 m above the adjacent crater floor to the N. In addition, when he measured on 3-7 February, Weber found hornito T58C (a then recent feature) had grown to reach an elevation of ~ 2,870 m.

Observations during February 2004 to February 2005. During February 2004 visits, T56B did not erupt, but instead a new vent erupted at the T49 location (~ 10 m E of T49B, see also *Bulletin*, v. 29, no. 2). This new vent was called T49G (figure 15).

A group from Volcano Expeditions International (VEI) spent 24-30 June 2004 on Lengai and found much of the scene at the vents in the crater similar to that noted in February 2004. They noted that half of the upper 10 m of hornito T56B had collapsed on its E side, and an active lava lake had formed inside this hornito with lava escaping several times through the collapsed opening to its E and flowing out ~ 200 m. The lava was rich in gas with a temperature of 560°C. The hornito T58B was also active and spattered

Date	Location	Temperature (°C)
28 Aug 1999	T40 lava lake	529
01 Sep 1999	Pahoehoe flow in a tube near T40	519
01 Sep 1999	Aa flow still in motion at flat terrains (60 cm thick)	516
03 Oct 2000	Pahoehoe flow in a tube near T49B	507
03 Oct 2000	Aa flow still in slow motion at flat terrain (25 cm thick)	496
11 Feb 2004	Pahoehoe flow in a tube near T49G	588
12 Feb 2004	Pahoehoe flow in a tube near T49B	579
13 Feb 2004	Aa flow not in motion anymore at flat terrain (15 cm thick)	490
26 Jun 2004	Pahoehoe flow in slow motion (10 cm thick) flat terrain	560
03 Feb 2005	Pahoehoe flow (15 cm thick) in motion traveling within a levee.	561
03 Feb 2005	Aa flow not in motion anymore at flat terrain (15 cm thick)	520

Table 3. Repeated maximum lava temperatures measured at Ol Doinyo Lengai during 28 August 1999 to 3 February 2005. The measurements were made employing a digital thermometer (TM 914C with a stab feeler of standard K type). The instrument was used in the 0-1200°C mode, and at least four replicate measurements were made at any one spot. Calibration was by the delta-T method; uncertainties were ± 6°C in the 0-750°C range. Courtesy of C. Weber.

Date	Location	Temperature (°C)
28 Aug 1999	F1	70
28 Aug 1999	Near T49	82
03 Oct 2000	Near T49C	75
03 Oct 2000	F1	69
20 Oct 2002	The hottest cracks in the crater floor	124
20 Oct 2002	F1	78
30 Jun 2003	F1	86
30 Jun 2003	Near T49C	76
12 Feb 2004	F1	88
26 Jun 2004	F1	78
26 Jun 2004	Near T49C	150
04 Feb 2005	F1	84

Table 4. Maximum fumarole temperatures measured at cracks in Ol Doinyo Lengai's crater floor over a series of visits during 28 August 1999 to 4 February 2005. Collected using the digital thermometer with procedures and parameters noted with the previous table. For locations, see map (figure 15). Courtesy of C. Weber.

lava many times during these days of observation. Some lava flows from T58B reached about 150 m to the S.

During 2-3 July 2004, Belton observed T58B erupt repeatedly, emitting lava and strombolian displays. The escaping lava flowed S, passing near the base of hornito T47. On 4 July, Belton saw some of the most intense activity of the month. A sequence of lavas erupted on that day and over the next few days. However, events in mid-July and later were also unusually vigorous.

The 4 July 2004 activity included strong strombolian eruptions at T58B and several collapses of its vent area, which released large cascades of lava onto the crater floor. Simultaneously, a tube-fed eruption of pahoehoe lava from the new vent T49G flowed across the NW crater rim to spill down that flank. Early on 5 July numerous eruptions of T58B sent lava flowing toward T47 at an estimated velocity of 10 m/sec. On 6 July, lava flowed out of the lake in T56B and onto the crater floor moving E and entering a cave in T45 for a short distance.

After very low activity during 7-10 July 2004, renewed flows and spatter came out on 11 July from T58B, and frequent but short (usually ~ 2 minute) episodes of loud degassing and spattering issued from the lava lake in T56B. At night, this vent emitted incandescent gas. This pattern continued until the morning of 14 July, when eruptions at T58B became more explosive and it expelled small ash clouds. On the morning of 15 July a collapse in the vent area of T58B released large rapid lava flows to the E. The episodes of degassing and spattering from T56B increased in frequency until 1500 on 15 July, when a small hole formed in the crater floor just E of T58B.

Called T58C, the hole became a newly opened vent. It began emitting visible gas puffs mixed with spatter. At this time the degassing episodes from T56B ceased. T58C then began strong degassing and squirted up intermittent lava fountains. The fountains soon fed a large lava stream moving toward the S crater wall.

By 1600 on 15 July 2004 a paroxysm at T58C was in progress, with lava forming 10- to 12-m-tall fountains and 'flash floods' that completely inundated the central-eastern crater floor (in the area between T56B, T58B, T37, T37B, T45, and T57). T58C also ejected strong jets of ash and gas. Turbulent rivers of lava flowing at more than 10 m/sec swept toward the crater's S wall and its E overflow and completely surrounded T37B and T45. Flow rate from the vent was estimated to peak at 10 m^3/s.

The momentum of the rapidly outflowing lava carried it nearly 3 m up the W (upstream) side of T45 and obliterated the large cave within that cone. The associated surge of lava poured over the E crater rim and down the flank. It flooded over a 3 m wide swath of vegetation. This triggered a huge cloud of steam and smoke that resembled a small pyroclastic flow. The smoke cloud was accompanied by a loud sizzling sound. A brush fire burned along the crater rim overflow as additional floods of lava arrived. These larger-than-normal flows lasted for little more than 30 sec and were separated by periods of repose of 5 to 6 min. After sunset, incandescent gas flared from the vent during the repose periods. Weak strombolian activity was seen in T56B.

Early on 16 July 2004 the newly formed T58C was a circular pit ~ 2 m in diameter with lava sloshing violently at a depth of ~ 2 m. Two small sub-vents on the N and S edges of the pit interconnected with the main vent. Activity continued sporadically at T58B and T56B with strombolian activity and lava flows. On 21 July there was an exceptionally strong eruption of T58B with loud explosions, jetting of ash-poor clouds, and spatter thrown to above-average heights. Explosions blasted a new vent in the upper E side of T58B. At least four oval bombs 9-12 cm in length flew through the air, along with a great deal of lapilli and ash. Later examination of the bomb's interiors revealed that they all had an outer zone ~ 1.5- to 2-cm thick and a distinctive inner core.

On 23 July 2004, a sloping ~ 4 m^2 oval section of the crater floor immediately SW of the new spatter cone T58C began to steam and vibrate. Tremor increased and ground movement was visible, manifested as a small section of crater floor rapidly pushed outward and then inward several centimeters, like a membrane vibrating in time to the degassing sounds of lava in T58C just behind it. Abruptly this portion of the crater floor broke outward, and a flood of lava ensued. T58C was observed to grow in height through the time when Belton left the crater on 29 July 2004.

Observations during January and February 2005. Donth reported that during his visit on 10 January 2005, hornito T49B erupted to form many effusive lava flows. For the first time, lava escaped over the northern edge of the crater (see figure 15).

During Weber's crater visit, 3-7 February 2005, the hornito T49B actively emitted lava flows that traveled to the N. Pahoehoe lava flows in motion within small levees on flat terrain were measured from 520°C up to a maximum of 561°C (table 3). The fumaroles at F1 had a maximum temperature of 84°C, and at hornito T46, a maximum of 91°C (table 4). No change in distance was measured across the CR1, CR2, and CR3 cracks cutting the upper crater walls. Adding to visitor safety concerns, which include altitude sickness, burns, falls, and impact from ejecta, Weber's team saw a spitting cobra close to the summit. An overflight by plane on 14 February showed no subsequent change, but did give an excellent view of the crater and its central hornitos (figure 16).

A flight on 14 February failed to reveal subsequent changes. But the effort provided an excellent view of the crater and its central hornitos (figure 17).

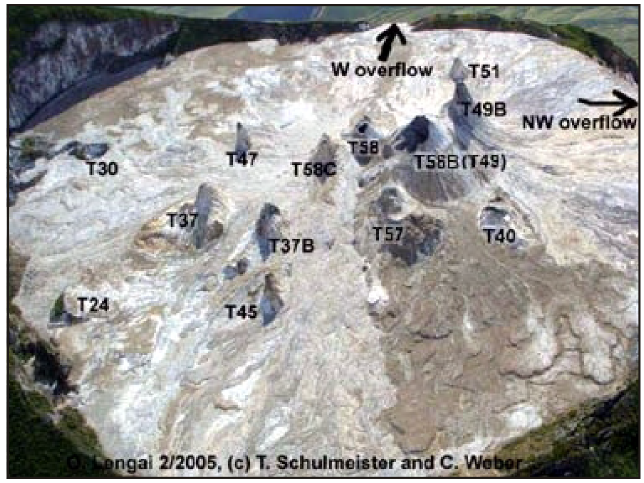

Figure 17. An aerial photograph taken looking towards the WSW at the summit crater of Ol Doinyo Lengai on 14 February 2005. The summit, which lies in the upper left corner has a revised elevation based on GPS (see text). In addition, GPS elevations and uncertainties suggest that in 2005 the summit was only marginally higher than the top of the tallest hornito (T56B). Copyrighted photo provided courtesy of T. Schulmeister and C. Weber.

Background. The symmetrical Ol Doinyo Lengai stratovolcano is the only volcano known to have erupted carbonatite tephras and lavas in historical time. The prominent volcano, known to the Maasai as "The Mountain of God," rises abruptly above the broad plain S. of Lake Natron in the Gregory Rift Valley. The cone-building stage of the volcano ended about 15,000 years ago and was followed by periodic ejection of natrocarbonatitic and nephelinite tephra during the Holocene. Historical eruptions have consisted of smaller tephra eruptions and emission of numerous natrocarbonatitic lava flows on the floor of the summit crater and occasionally down the upper flanks. The depth and morphology of the northern crater have changed dramatically during the course of historical eruptions, ranging from steep crater walls about 200 m deep in the mid-20th century to shallow platforms mostly filling the crater. Long-term lava effusion in the summit crater beginning in 1983 had by the turn of the century mostly filled the northern crater; by late 1998 lava had begun overflowing the crater rim.

Information Contacts: *Christoph Weber*, Volcano Expeditions International, Muehlweg 11, 74199 Untergruppenbach, Germany (URL: http://www.v-e-i.de, Email: mail@v-e-i.de); *Celia Nyamweru*, Department of Anthropology, St. Lawrence University, Canton, NY 13617, USA (URL: http://it.stlawu.edu/~cnya/; Email: cnyamweru@stlawu.edu); *Frederick Belton*, Developmental Studies Department, PO Box 16, Middle Tennessee State University, Murfreesboro, TN 37132, USA (URL: http://www.oldoinyolengai.org, Email: oldoinyolengai@hotmail.com); *Bernard Donth* (Email: b.donth@saarschmiede.com).

Subscriptions: The *Bulletin of the Global Volcanism Network* (ISSN: 1050-4818) is available by subscription from the American Geophysical Union (2000 Florida Avenue NW, Washington, DC 20009, phone 202:462-6900 or 800:966-2481, fax 202:328-0566, Email: service@agu.org). Annual subscription price (2005) is $26 to US addresses and $43 to all other countries. Back issues can be ordered through AGU Separates; contact AGU for current pricing information. Orders must be prepaid; make checks payable to AGU; VISA/MC are accepted. The Smithsonian does not handle any *Bulletin* orders.

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