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## Sierra Negra

Galápagos Islands, Ecuador  
 0.83°S, 91.17°W; summit elev. 1,490 m  
 All time are local (= UTC - 6 hours)

Our last report (*BGVN* 30:09) described the first five days of this eruption, and was taken largely from a valuable joint report of Ecuador's Instituto Geofísico and Parque Nacional Galápagos. Here we report information from several sources on these topics: (a) initial observations of the eruption, (b) caldera-floor deformation prior to the eruption, (c) observations of the eruption's progress during 26 to 30 October (when it ended), and (d) satellite infrared observations of thermal fluxes associated with the eruption.

**Eruption's start and subsequent plumes.** As noted previously (*BGVN* 30:09), the eruption began around 1730 on 22 October 2005, when an explosion was heard by many residents of the volcano's S flank. Satellite images showed no activity at 1715, but revealed a large eruption at 1745 local time (2345 UTC). The eruption cloud reached an estimated altitude of at least 15 km (50,000 ft) and was moving SW.

At about this time, passengers and crew on Lindblad Expeditions' 80 passenger vessel *M/N Polaris* had an excellent view of the eruptive plume (figure 1). Lucho Verdesoto, the expedition leader, reported that the ship was then at Cerro Dragon, Santa Cruz island. Sunset was at 1753. As night fell they sailed to a position ~ 18 km NE of the volcano, where they had clear views of flows descending the volcano's upper NE flank (figure 2).

Naturalist Carman Guzman wrote, "After sunset the show was fascinating so we decided to move the *Polaris* to a much closer location. After dinner, we were only eleven miles from the eruption itself. What a thrill! The darkness of the night enhanced the beauty of the fiery reds and oranges that were seen at the top of the caldera. We spent several hours enjoying this rare and fantastic event. Rivers of lava were running down the slopes of the volcano and enormous flames were lighting up the sky."

According to NASA MODIS imagery and VAAC/NOAA reports, on 25 October 2005 a large plume of gases and steam was observed in GOES 12 imagery for 1545 lo-



Figure 1. Early photo of the Sierra Negra plume from the cruise ship *Polaris*, anchored off NW Santa Cruz island around sunset on 22 October 2005. Courtesy of Lucho Verdesoto.



Figure 2. Lava spews skyward from circumferential fissure vents near the N rim of Sierra Negra caldera as flows descend the upper N flank. The photos were taken on 22 October, during the first few hours of the eruption, from the *Polaris*. Courtesy of Lucho Verdesoto.

cal time (2145 UTC). The plume extended ~ 460 km W and SW of the summit at an altitude of ~ 4.6 km. Figure 3 shows the average concentration of SO<sub>2</sub> over the Sierra Negra plume as imaged by NASA's Aura satellite for the period 23 October-1 November.

**Deformation monitoring.** In the early stages of this eruption, Bill Chadwick (NOAA) submitted a report on pre-eruption deformation (figure 4). The plot shows both Synthetic Aperture Radar (InSAR) and GPS data on vertical deformation of the caldera floor. Chadwick wrote that he, Dennis Geist (University of Idaho), and Dan Johnson (University of Puget Sound, recently deceased) installed a 27 station GPS network at Sierra Negra in 2000, that was reoccupied in 2001 and 2002 (Geist and others, in press). With help from UNAVCO (a consortium supporting high-precision deformation measurements), the group then added a 6-station, continuous GPS network in 2002. Since then, there occurred a change from caldera subsidence to caldera uplift in March 2003. During this uplift, an M 4.6 earthquake on 16 April 2005 marked trapdoor faulting. The continuous GPS network measured a surface displacement of 85 cm within 10 seconds. Both this event and the previous case of trapdoor faulting in 1997-98—documented by satellite measurements using Interferometric Synthetic Aperture Radar (InSAR) (Amelung and others, 2000)—were preceded by over a meter of inflation (Jónsson and others, 2005). Both the 1997-98 and 2005 trapdoor movements occurred along the caldera floor's S side.

Aside from its immediate effects, the April 2005 earthquake left the later inflation rate unchanged. Caldera-centered uplift has continued since then without pause at about the same high rate. During the interval from March 2002 to April 2005 there was about ~ 1.2 m of uplift. Rates after the April 2005 earthquake are not plotted but were roughly the same as those during the interval March 2002-April 2005. The only other large earthquakes at Sierra Negra in the last year were an M 4.0 on 23 February 2005, which was associated with a small (2 cm) displacement near the trapdoor fault, an M 4.6 on 19 September 2005 that caused no obvious displacements, and an M 5.5, just 3 hours before the 22 October eruption started. The GPS data has not yet been processed.

**Field descriptions of the eruption.** The eruption began on 22 October with venting along a 2-km fissure near the caldera's N rim (figure 2). The fissure descended the caldera's inner wall at its E end. Flows were fed both northward down the outer N flank and southward onto the NE caldera floor. Although flows reached 5 km down the outer flank, flow into the caldera soon dominated, with strong channels descending inner caldera slopes before combining to form a wide aa flow banked against the caldera's E wall and moving steadily southward (see figures and discussion, *BGVN* 30:09).

Figure 5 is a photo taken by Greg Estes on 24 October. It highlights the vigorous venting and intracaldera flows at that point in the eruption. Figure 6, a post-eruption satellite photo, illustrates the broad pattern of still-cooling, erupted lavas (which appear as light colored areas on this 2 Novem-

ber thermal-infrared image). Although this may represent the best overview of the new lavas at this time, some of the thinnest flows or chilled flow features may not appear on this image.

By 26 October, fissure activity had narrowed to one major vent very near the N rim, but at 0830 on the 27th, eyewitness Godfrey Merlin reported that a second vent opened downslope and SE of the first. This new vent did not diminish the activity of the first, meaning that the total flux of erupting lava nearly doubled.

By about 1400 on the 27th, a team including Dennis Geist (University of Idaho), Terry Naumann (University of Alaska), and Karen Harpp (Colgate University) had arrived at the E caldera rim and began sending back a series of valuable reports. Their first report noted a major vent immediately below GPS station SN12 on the rim NE of the caldera's center. This vent emitted a large intracaldera aa flow.

Some active N-flank vents stood about 300-400 m NW of a station (GV01) on the caldera's N rim. There, two major vents fed lava fountains up to 50 m high. Most lava being erupted was flowing into the caldera, although some of the scoria from the fountains was falling outside the caldera and then forming a short, sluggish flow. Lava inside the caldera was cascading from the vents down the slope on the N edge of the caldera in 3 main channels, each 30-40 m across, with lava flowing at ~10 m/s (36 km/h) and in some cases over 10 m/s, and coalescing into a major aa flow to the S. On the caldera floor these channels merged into one big aa channel about 100 m wide that flowed more slowly both to the S, clockwise along the base of the E caldera wall, and into the moat along the S edge of the caldera floor. Pahoehoe outbreaks occurred along the margins of the major aa flow. New aa lava covered an estimated one-third of the caldera floor.

The report for 28 October noted that the eruption was still going strong. There were no significant new events on this day, but it appeared that the lava flux had increased because the vents looked wider and there seemed to be a lot more gas emitted. The lava continued to feed from the vents to the caldera floor in two large streams, each ~20 m across with lava traveling at 5-10 m/s, adding up to probably hundreds of millions of cubic meters of lava per day. The aa field continued to

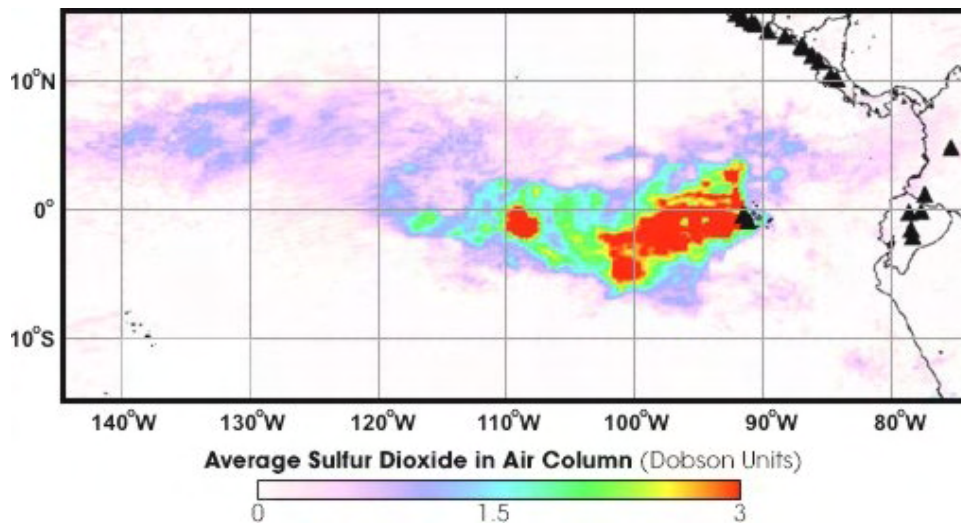


Figure 3. The average concentration of sulfur dioxide (SO<sub>2</sub>) over Sierra Negra from 23 October-1 November measured by the Ozone Monitoring Instrument (OMI) on NASA's Aura satellite. In agreement with reports from the ground, OMI stopped seeing measurable sulfur dioxide coming from the volcano on 31 October. The column abundances of SO<sub>2</sub> appear on the associated key (in Dobson Units, DU, a product of concentration and pathlength that reflects the number of SO<sub>2</sub> molecules in a unit area of the atmospheric column). Courtesy of NASA Earth Observatory/Natural Hazards website.

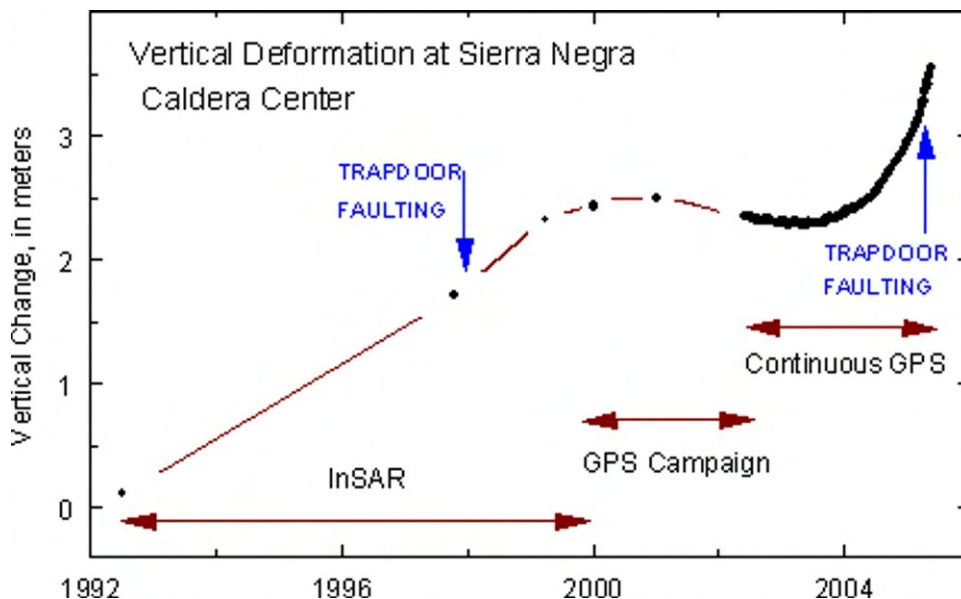


Figure 4. Recent history of uplift at the center of Sierra Negra's caldera. The data plotted are only through April 2005 when the trapdoor faulting event occurred. Although not plotted, GPS data since April has continued to indicate robust deformation. Courtesy Bill Chadwick, NOAA.

grow. The group reached the caldera floor and were able to sample both lava and tephra.

By 0700 on the 29th some of the vents had shut down and the two lava channels to the W (previously fed by the upper vent) stopped moving. The lower vent still emitted lava and fed one channel E of the others. The team estimated the channel to be ~ 10 m wide and moving ~5 m/s.



Figure 5. The Sierra Negra eruption setting as viewed from the E caldera rim. The fissure vent was vigorously emitting fountains, and there were several anastomosing lava flows pouring into the caldera. Photo was taken at night on 24 October 2005, day 3 of the eruption. The scattered glow in the foreground was due to ponded lava covering the caldera's E floor. Courtesy of Greg Estes (Galápagos resident and Park Guide).

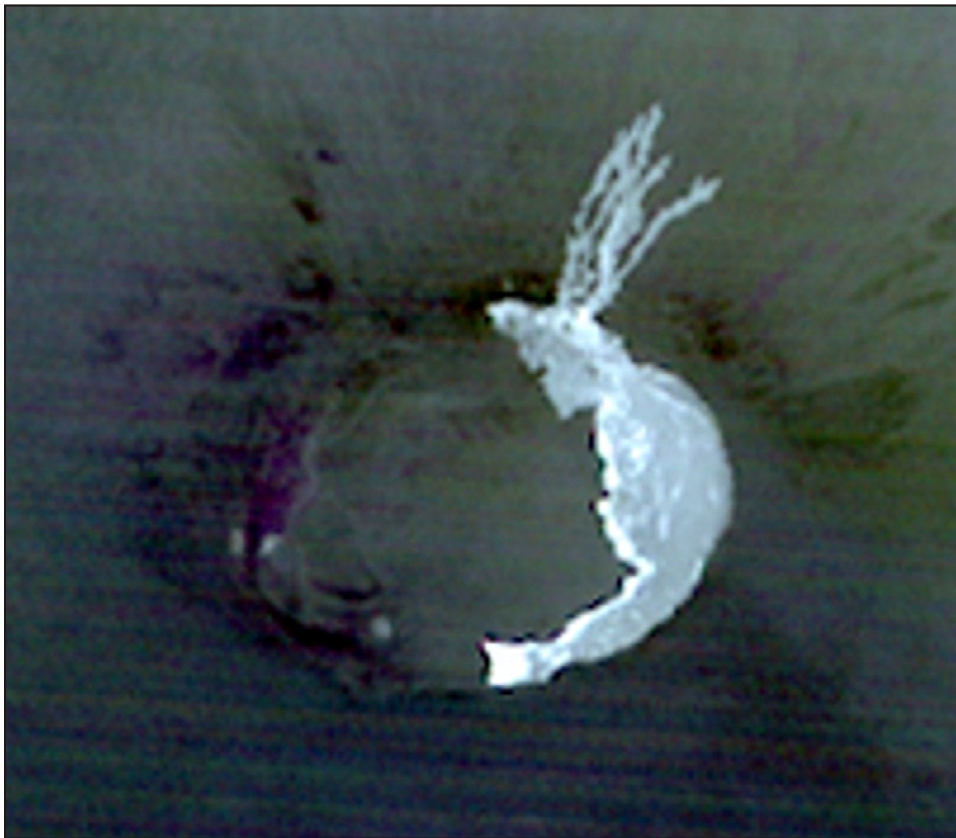


Figure 6. The Sierra Negra eruption setting as viewed from space in a false color ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) infrared image taken at night on 2 November, ~ 3 days after the eruption ended. N is towards the top. Caldera is 7 x 10.5 km across. Note the extra-caldera, N-flank lava flows, the lunate zone of ponded lavas along the E caldera. NASA image created by Jesse Allen, Earth Observatory, using data provided courtesy of Eric Fielding (NASA/JPL), the NASA/GSFC/METI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team.

Assuming a 2-m depth, the lava flux was 5 to 10 million cubic meters per day, about half that seen the morning of the 29th

The emission rate continued to diminish throughout the 29th and by the evening it was only 10-20% of that seen on the 28th. In addition, the amount of gases emitted decreased such that the gas plume only rose ~ 1 km, whereas earlier plumes had risen to several kilometers. The lower vent was no longer fountaining continuously as it had on the 28th; instead the fountaining came in bursts at intervals of about 1-30 seconds. A lava lake sloshed around in the lower vent's crater; some lava escaped this crater along a breach in the crater rim. The upper vent (the one that shut off) was still incandescent with a lot of gas coming out, so it was possible that there was a lava lake there too.

The eruption appeared to end on the 30th. Glow was observed at 0200, but had ceased by 0400. The vents still emitted gas, but not fresh lava. However, it was possible that there was still N-flank activity. There were reports of lava flows there, and while it was certain that at least some of these flows were clastogenic (composed of spatter from fire fountains that accumulated and then began to flow), it was uncertain whether there were also actively erupting flank vents. The team remained separated from this area by hot lava, thwarting reconnaissance. Initial estimates of the coverage of the caldera floor were an area of ~ 14 km<sup>2</sup>. Assuming a 3-4 m average flow thickness, this was ~ 0.05 km<sup>3</sup> (50,000,000 m<sup>3</sup>) of lava. There were obviously high error bars on this estimate, but it was clearly much less than the ~ 1 km<sup>3</sup> extruded in the 1979 eruption.

#### **MODVOLC Thermal Alerts.**

A large set of thermal hotspots in multispectral imagery was observed beginning late 22 October (local time and date) and continuing through 16 November 2005 (figure 7). Although MODVOLC data were missing for some days and reduced for others (presumably due to cloud cover screening the radiation from the satellite) these hot-spot pixels dramatically document the course of the eruption. Data on figure 7 appear consistent with *in-situ* observations, in that by the second day, lava was at least 5 km down the outer N slope and covering much of the E caldera floor. By the 8th day (30 October), the outer slope flows had cooled significantly, but flows inside the caldera had continued their clockwise advance, filling all low points to the extreme SW corner of the caldera. Ten days later (9 November), the eruption had ended and only flows from the vents to the SE caldera floor were still emitting detectable heat. The last pixels observed, two above the original vent area on the N rim, were on 16 November.

**References:** Amelung, F., Jónsson, S., Zebker, H., and Segall, P., 2000, Widespread uplift and 'trapdoor' faulting on Galápagos volcanoes observed with radar interferometry: *Nature*, v. 407, p. 993-996.

Geist, D.J., Chadwick, W.W., Jr., and Johnson, D.J., in press, Results from new GPS monitoring networks at Fernandina and Sierra Negra volcanoes, Galápagos, 2000-2002: *Journal of Volcanology and Geothermal Research* (in press).

Jónsson, S., H. Zebker, and F. Amelung, 2005, On trapdoor faulting at Sierra Negra volcano, Galápagos; *Journal of Volcanology and Geothermal Research*, v. 144, p. 59-71.

**Background.** The broad shield volcano of Sierra Negra at the southern end of Isabela Island contains a shallow 7 x 10.5 km caldera that is the largest in the Galápagos Islands. The 1,490-m-high volcano is elongated in a NNE direction. Although Sierra Negra is the largest of the five major Isabela volcanoes, it has the flattest slopes, averaging less than 5 degrees and diminishing to 2 degrees near the coast. A sinuous, N-S-trending ridge occupies the W part of the caldera floor, which lies only 100 m below its rim. Volcán de Azufre, the largest fumarolic area in the Galápagos Islands, lies within a graben between this ridge and the W caldera wall. The 1979 lava flows from Sierra Negra extend all the way to the N coast from circumferential fissure vents

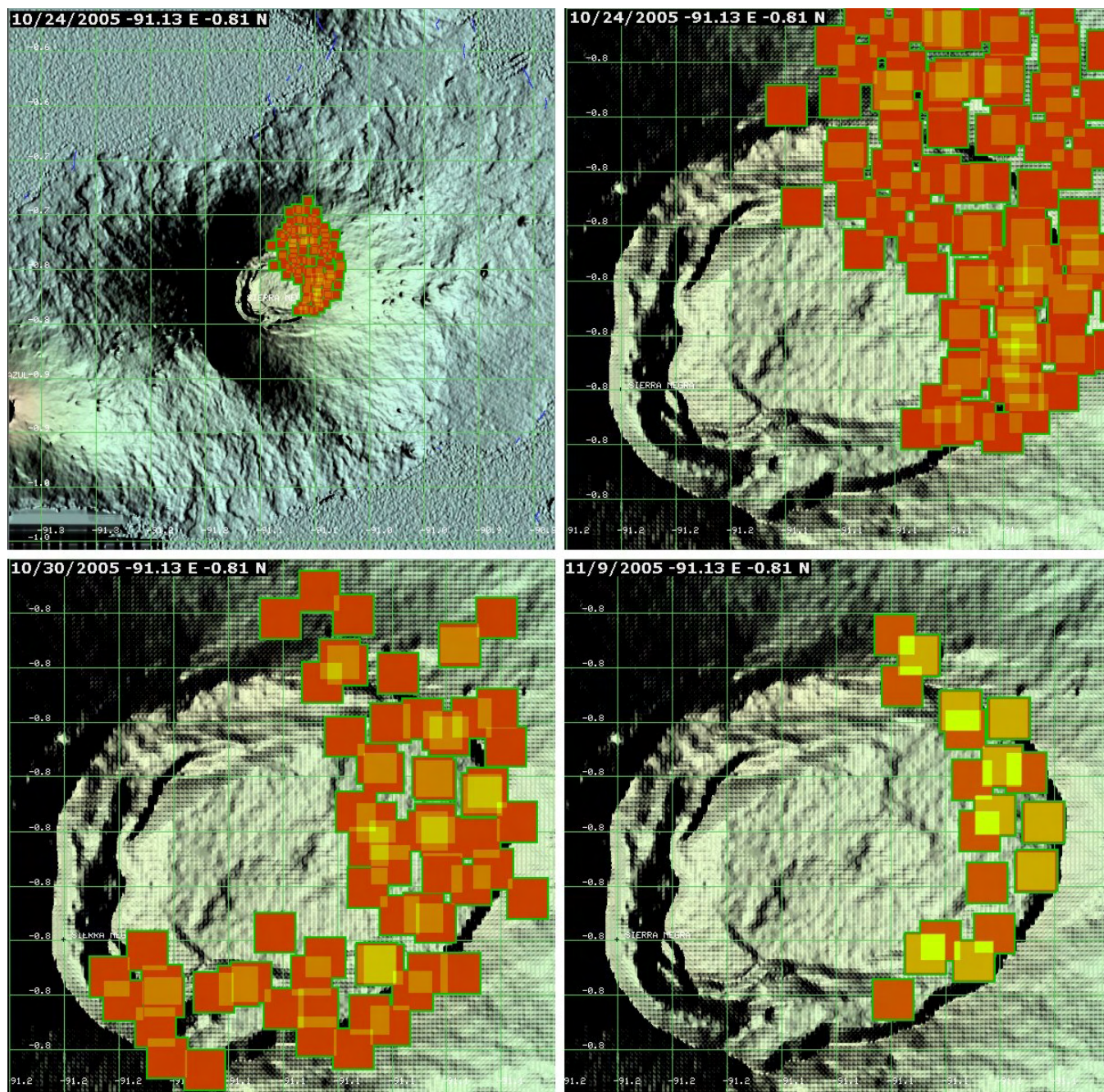


Figure 7. Selected images of MODVOLC thermal anomalies for Sierra Negra measured from satellite (MODIS) data at three days during and after the 2005 eruption. Part A presents an overview of the region (smaller scale than the other images) on 24 October. Parts B-D give a zoom-in on the 7 x 10.5 km caldera. Part B represents 24 October; Part C, 30 October; and part D, 9 November 2005. Since the eruption ended 30 October, the latter two images must thus portray the post-eruptive thermal inertial of the cooling lavas. Courtesy of Hawai'i Institute of Geophysics and Planetology, University of Hawai'i.

on the upper northern flank, an area dotted with cinder and spatter cones. Sierra Negra, along with Cerro Azul and Volcán Wolf, is one of the most active of Isabela Island's volcanoes.

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## East Pacific Rise at 10°44'N

Pacific Ocean  
10.73°N, ~105°W

In a recent publication, Rubin and van der Zander (2005) discuss radiometric methods for dating lavas as one means to establish eruption chronologies. Some of their techniques were applied to samples of fresh lava (erupted September-October 2003) found on the East Pacific Rise (EPR) at 10°44'N (Voight and others, 2004). This location lies ~1,900 km WNW of the Galápagos Islands. During a November 2003 biological sampling visit to the EPR at 10°44'N, divers in the submersible *Alvin* expected to be revisiting an established hydrothermal vent field. Instead, they found indicia all of which were consistent with a recent eruption, notably fresh lava, bacterial mats, and diffuse snow-blower vents issuing from lava collapses. The team acted immediately after the cruise by sending the lava samples to the University of Hawai'i for dating. Researchers there determined that an eruption had occurred within 1 to 2 months prior to the site visit. A hydrophone array (designated N-EPR) nominally monitored this part of the EPR since 1996, but not in real time. Unfortunately, the system failed to record data during the 2002-2004 interval due to a hardware problem.

Ages for lavas erupted within the past 1.5-2 years were determined with the  $^{210}\text{Po}$ - $^{210}\text{Pb}$  dating method (Rubin and others, 1994). To use this method, analyses should begin as

soon as possible after samples are collected from suspected eruption locales. Radioactive disequilibrium is largest, and temporal resolution of the method is highest, immediately following eruption. According to Rubin and van der Zander (2005, p. 28) "Polonium is volatile at magmatic temperatures and degasses from magmas when they erupt. This creates an initial  $^{210}\text{Po}$  (half-life = 138.4 day) deficit relative to grand parental  $^{210}\text{Pb}$  in freshly erupted magmas. This deficit is subsequently erased with time via radioactive ingrowth toward secular equilibrium."

**References:** Rubin, K.H., Macdougall, J.D., and Perfit, M.R., 1994,  $^{210}\text{Po}$ - $^{210}\text{Pb}$  dating of recent volcanic eruptions on the seafloor: *Nature*, v. 368, p. 841-844.

Rubin, K., and van der Zander, I., 2005, Obtaining high-resolution chronologies of submarine lava eruptions: Better dating through radiochemistry: *Ridge 2000 Events*, v. 3 (Spring 2005), p. 28-30.

Voight, J. R., Zierenberg, R.A., McClain, J., and the Science Party: Batson, P., Beers, K., Daly, M., Dushman, B., Gollner, S., Govenar, B., Haney, T.A., Hourdez, S., Liow, L.H., Parker, C., Von Damm, K., Zekley, J., and Zelnio, K.A., 2004, FIELD cruise to the northern EPR: Discoveries made during biological investigations from 8°37'N to 12°48'N: *Ridge 2000 Events*, v. 2(1), p. 22-24.

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## Arenal

Costa Rica  
10.463°N, 84.703°W; summit elev. 1,657 m  
All times are local (= UTC - 6 hours)

As described in the previous Arenal report (*BGVN* 29:08), on 6 July 2004 a series of pyroclastic flows descended the NE flank. These flows resulted from the collapse of the upper portions of a lava flow, and affected areas beyond those affected by pyroclastic flows during 1999-2003. Similar events have been common in recent years on the volcano's N and NE sides, as Crater C continued to emit gases, lava flows, and sporadic Strombolian eruptions through 2004 and at least as late as November 2005. Throughout the period of this report (August 2004-September 2005) the lava flow that began to be emitted towards the NE flank in June 2004 remained active. Occasional blocks spalled off the N edge of the crater towards the NE. The NE and SE flanks continued to be affected by pyroclastic flows and acid rain. Crater D displayed fumarole activity from July 2004 through September 2005. The seismograph station VACR (2.9 km NE of the active Crater C) was out of service from 24 June 2004 until 20 August 2004. Table 1 summarizes the seismicity registered at VACR from August 2004 to September 2005.

During July 2004-January 2005, pyroclastic flows were produced by the collapse of the active lava flow front. In August 2004 some eruptions generated ash columns higher than 500 m above Crater C.

Through most of February 2005 Arenal was hidden by storm clouds, but late in the month it could be observed that the lava flow formerly active on the NE flank had stopped,

Month	Eruption earthquakes	Daily average	LP Events	Tremor (hours)	Comments
Aug 2004	414	35	—	147	VACR not operating 24 Jun-20 Aug.
Sep 2004	1125	37	—	330	
Oct 2004	1155	37	32	293	
Nov 2004	584	34	—	153	
Dec 2004	—	—	—	—	
Jan 2005	540	22	5	357	VACR operated for 25 days
Feb 2005	941	35	12	448	
Mar 2005	903	29	15	458	
Apr 2005	567	19	13	592	
May 2005	618	20	3	600	
Jun 2005	697	23	10	606	
Jul 2005	827	27	23	560	
Aug 2005	597	20	33	548	
Sep 2005	548	18	16	576	

Table 1. Seismic activity registered at Arenal's station VACR, August 2004 - September 2005. From 24 June to 20 August 2004 VACR was not operating. No data were reported for December 2004. Courtesy of OVSICORI-UNA.

and no other active flow was seen. The number of eruptions and the amount of ejected pyroclastic material were both reduced in February, and few eruptions produced plumes as high as 500 m. The dome in Crater C continued to grow.

At the beginning of March a SW-trending lava flow was observed, and blocks were ejected to the W. During April 2005 this flow continued, and ejected blocks caused small fires in the surrounding vegetation. A new lava flow began on the SE flank, and blocks ejected to the S and SE again caused fires. In May and June 2005 the SW flow continued. In July the SW lava flow deposited blocks towards the SW, the W and the NW. The SE lava flow released small avalanches off its front and sides. Occasional eruptions produced ash columns higher than 500 m above Crater C.

In August 2005 the SE lava flow stopped. Few eruptions produced ash columns higher than 500 m above Crater C. During September 2005 the SW lava flow was active and deposited blocks to the SW, the W and the NW. The NE and SE flanks continued to be affected by the fall of pyroclastic material and acid rain.

Observatorio Vulcanológico y Sismológico de Costa Rica -Universidad Nacional (OVSICORI-UNA) reported that around 1500 on 2 November a pyroclastic flow was observed on the SE flank of Arenal. On 3 November researchers from OVSICORI-UNA visited the affected area and, contrary to what witnesses had reported, determined that the 2 November event took place on the W flank of the volcano. The mid-size pyroclastic flow produced gas, dust, and ash that were carried by strong winds towards the SE.

Despite the rainy and hazy conditions during the fieldwork it was possible to confirm the affected area and deposits. The movement of lava flows on the SW flank had been observed for the last several months. Materials descending from the summit bifurcate, covering a wide fan that ranges from the W to the SW flank. The main pyroclastic flow affected an area from the summit down to ~ 1000 m altitude. A smooth alley was carved in the steep walls of upper W flank by the transport of incandescent material. Most of the material was deposited in a distal zone 75 m wide, at the break in the steep upper cone slope.

Samples were taken from hot loose blocks spalled from the lava flow; one block was still at 154 °C, and was accompanied by several other massive blocks that were fractured by rapid cooling and rough transport. There is evidence that the fine fall material was only deposited in the upper and middle part of the edifice towards the SE.

Given the sustained deposition of material in the area, visitors were advised to follow instructions and safety measures and adhere to the advice of the Park Rangers and tour guides.

**Background.** Conical Volcán Arenal is the youngest stratovolcano in Costa Rica and one of its most active. The 1,657-m-high andesitic volcano towers above the E shores of Lake Arenal, which has been enlarged

by a hydroelectric project. Arenal lies along a volcanic chain that has migrated to the NW from the late-Pleistocene Los Perdidos lava domes through the Pleistocene-to-Holocene Chato volcano, which contains a 500-m-wide, lake-filled summit crater. The earliest known eruptions of Arenal took place about 7,000 years ago, and it was active concurrently with Cerro Chato until the activity of Chato ended about 3,500 years ago. Growth of Arenal has been characterized by periodic major explosive eruptions at several-hundred-year intervals and periods of lava effusion that armor the cone. Arenal's most recent eruptive period began with a major explosive eruption in 1968. Continuous explosive activity accompanied by slow lava effusion and the occasional emission of pyroclastic flows has occurred since then from vents at the summit and on the upper W flank.

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## Pacaya

Guatemala

14.381°N, 90.601°W; summit elev. 2,552 m

All times are local (= UTC - 6 hours)

Frequent steam plumes through 2002 and 2003 indicated that Pacaya was active, although incandescence from the long-term lava lake ended after June 2001. During the latter half of October 2003 constant steam and abundant emissions of water and gas were being blown to the NNW and W of the volcano (*BGVN* 28:10). All of the following information is derived from the reports of Instituto Nacional de Sismología, Vulcanología, Meteorología e Hidrología (INSIVUMEH).

Throughout November and December 2003 and the first half of 2004, abundant clouds and columns of white and

off-white gases and steam were expelled from Pacaya, generally reaching less than 400 m above the volcano and dispersing mostly to the W and SW; these were occasionally visible from Guatemala City, 30 km to the NNE.

During June, July, and August 2004, near-continuous tremor and frequent long-period earthquakes were recorded at seismograph station PCG (~ 1.4 km to the W of Pacaya). On 14 June, weak incandescence was observed in the central crater of MacKenney Cone for the first time since August 2000. Pacaya continued to expel off-white smoke and/or steam which usually drifted to the S and SW and rose to 150-300 m above the volcano. On 19 July, ejection of small lava fragments began to form a cone in the bottom of the central crater of MacKenney Cone.

During September-November 2004, tremor increased somewhat (from ~ 2mm in June, July, and September to 4-7 mm in December), and white steam and/or gas plumes rose 300-500 m above MacKenney Cone. Incandescence was observed throughout this time and lava clasts were expelled from the MacKenney Cone on 7-9 December.

On 3 January 2005, small expulsions of incandescent lava clasts rose from the central crater, and a narrow lava flow from the S rim of the crater reached 75-100 m down the flank. Station PCG continued to register tremor, and incandescence and white plumes persisted. On 10 January, lava flowed ~ 30 m from the SW rim of the central crater of MacKenney Cone. On 12 January, two lava flows, one to the S (~ 125 m) and one to the SW (~ 50 m) left the central crater. Observers saw incandescent lava fragments rising <10 m above the mouth of the intra-crater cone, and "smoke" whiffs rising from the MacKenney Cone. During the last 5 days of January 2005, numerous small lava flows descended the S and SW flanks of the volcano.

During February, March, and April 2005, incandescence, tremor, and minor lava flows continued. On 2 February observers reported that avalanches from the lava flow fronts during the previous days formed a debris fan covering about 2/3 of the SW flank. On 28 February expulsion of incandescent lava fragments reached heights of 10-50 m for brief periods. On 1 March INSIVUMEH recommended that park officials prevent tourists from climbing Pacaya because of avalanches, lava expulsion, and gas emissions. In March and April explosions of lava reached 100 m in height, and smoke/gas emissions continued.

Lava emission continued during May. On 4 May, three flows were active, extending up to 100 m down the SW flank and 150 m W in the direction of Cerro Chino. On 9 May two active flows from the base of the intracrater cone reached 200 m down the W flank. Plumes from the MacKenney Cone rose as high as 800 m above the crater. Ejection of incandescent material continued throughout the month. Lava flows moving to the SW and W in the direction of Cerro Chino reached lengths of 150-250 m.

During early June, incandescent lava clasts were ejected as high as ~ 75 m above Pacaya's crater. An intra-crater lava flow extended ~ 300 m from the SW base of the central cone. On 6 June, a lava flow traveled ~ 200 m down the volcano's W flank. By 27 June a lava flow extended ~ 300 m down the SW flank. A white steam column rose ~ 150 m over the central crater and drifted SW. Incandescent lava expulsions reached heights of 15-50 m. On the night of 27 June two rivers of lava, 75 and 150 m long, were observed in front of Cerro Chino. Constant expulsions of pyroclastic material rose 20-30 m above the crater.

Lava flows in July traveled 200-300 m down the SW flank. Small plumes emitted from the volcano's central crater rose to low altitudes. Avalanches of incandescent volcanic blocks produced small ash clouds to low levels.

During 7-11 September, occasional Strombolian activity occurred. Volcanic bombs from two craters rose up to 30 m above their rims. Incandescence from lava flows on the SE flank was visible on several nights.

**Background.** Eruptions from Pacaya, one of Guatemala's most active volcanoes, are frequently visible from Guatemala City, the nation's capital. Pacaya is a complex basaltic volcano constructed just outside the S topographic rim of the 14 x 16 km Pleistocene Amatitlán caldera. A cluster of dacitic lava domes occupies the S caldera floor. The post-caldera Pacaya massif includes the Cerro Grande lava dome and a younger volcano to the SW. Collapse of Pacaya volcano about 1100 years ago produced a debris-avalanche deposit that extends 25 km onto the Pacific coastal plain and left an arcuate somma rim inside which the modern Pacaya volcano (MacKenney cone) grew. A subsidiary crater, Cerro Chino, was constructed on the NW somma rim and was last active in the 19th century. During the past several decades, activity at Pacaya has consisted of frequent strombolian eruptions with intermittent lava flow extrusion that has partially filled in the caldera moat and armored the flanks of MacKenney cone, punctuated by occasional larger explosive eruptions that partially destroy the summit of the cone.

**Information Contacts:** *Instituto Nacional de Sismología, Vulcanología, Meteorología e Hidrología* (INSIVUMEH), 7a Av. 14-57, Zona 13, Guatemala City, Guatemala (URL: <http://www.insivumeh.gob.gt/>); *Washington Volcanic Ash Advisory Center* (VAAC), Satellite Analysis Branch (SAB), NOAA/NESDIS E/SP23, NOAA Science Center Room 401, 5200 Auth Rd., Camp Springs, MD 20746 USA (URL: <http://www.ssd.noaa.gov/>).

## Santa Maria

Guatemala

14.756°N, 91.552°W; summit elev. 3,772 m

All times are local (= UTC - 6 hours)

Prior to the period covered by this report, recent activity at Santa María was characterized by weak-to-moderate explosions producing ash, crater-rim collapses and avalanches of block lava and ash, pyroclastic flows, and an active lava flow (*BGVN* 28:10). Activity was similar from October 2003 to June 2004, consisting mostly of explosions from Santiaguito, a lava-dome complex that includes the Caliente vent. The explosions produced ash plumes, and there were numerous block-lava-and-ash avalanches from Caliente collapses (*BGVN* 29:06). From July 2004 until October 2005, these types of activity continued.

**Activity during July-September 2004.** During July to September 2004, weak-to-moderate explosions at Santiaguito produced plumes to a maximum height of ~ 1.5 km above the volcano. Frequent avalanches of volcanic material including blocks and ash traveled SE and SW down Caliente cone. In early September 2004, several weak-to-moderate explosions produced ash clouds to a maximum height of 2 km above the volcano. Partial col-



lapses of the lava dome caused pyroclastic flows to travel down the volcano's NE and SW flanks. On 27 September, several avalanches of volcanic material from active lava-flow fronts traveled SW.

**Activity during October 2004.** During October 2004 moderate explosions produced ash-and-gas plumes that rose to a maximum altitude of 9 km. Explosions on 4 October produced small pyroclastic flows to the SW. On 11 October, a partial lava-dome collapse to the SW produced a pyroclastic flow that traveled toward the Nimá Segundo River. An ash cloud formed that rose to a height of ~ 500 m and covered most of the dome complex. The collapse was preceded by an explosion that produced an ash-and-gas cloud to ~ 1.5 km above the volcano. Small explosions on 12 October produced small lava-dome collapses to the SW that generated avalanches of lava blocks and ash.

Small lahars traveled down San Isidro ravine on 14 and 15 October. A small collapse of the SW edge of the lava dome in the Caliente crater produced a pyroclastic flow on 17 October. The flow traveled down the S flank and produced a steam-and-ash plume to a height of ~ 800 m upon contact with dammed water. Instituto Nacional de Sismología, Vulcanología, Meteorología, e Hidrología (INSIVUMEH) reported that this collapse, like those that occurred on previous days and weeks, was associated with a new cycle of magmatic injection. The Washington VAAC reported that hot spots and plumes possibly containing ash were occasionally visible on satellite imagery on 21 October; imagery on 31 October showed a possible ash-bearing plume at ~ 4.5 km altitude.

**Activity during November 2004.** During November, weak-to-moderate explosions produced gas-and-ash plumes to ~ 1 km above the volcano. Many explosions were accompanied by block-and-ash avalanches from the NE and SW edges of Caliente dome. The Washington VAAC reported that satellite imagery on 3 November showed a possible ash-bearing plume at a height of ~ 5 km altitude. On 12 November, the collapse of a small sector of the SW edge of the Caliente dome produced a pyroclastic flow. On 14 November at 2012, a tectonic earthquake caused a lava-flow collapse SW of the Caliente dome, triggering a pyroclastic flow that descended to the head of San Isidro ravine, an area of abundant accumulation of pyroclastic material and a known area for lahar initiation. During December, weak-to-moderate explosions produced plumes to a maximum height of 1.3 km above the crater. Frequent block-lava avalanches traveled down the SW flank of Caliente dome. A moderate explosion on 4 December caused a partial lava-dome collapse and a pyroclastic flow that traveled SW. On 22 December small collapses occurred from lava-flow fronts on the SW side of Caliente dome. According to the Washington VAAC, ash plumes were visible on satellite imagery on several days during 22-27 December.

**Activity during January-October 2005.** During January 2005, frequent explosions (table 2) produced columns of gray and white ash up to 2 km in height, ash fall in towns near the volcano and frequent blocky avalanches. Early in the month, avalanches of incandescent blocks were released from lava flow fronts towards the NE and SE flanks of Santiaguito.

During February 2005, frequent explosions and avalanches continued. On 10 February 2005 the Washington VAAC reported that satellite imagery showed a plume of

ash and steam moving SW from the summit and ash extending 55 km after an eruption around 0645. A continuous plume of ash and steam was emitted after an eruption around 0745 and ash extended around 230 km from the summit moving at 2-50 km/hour.

During March 2005, several weak-to-moderate explosions produced ash plumes to a maximum height of ~ 1.3 km above the dome. Avalanches of volcanic blocks traveled down the E and SW flanks of Caliente dome. On 16 March, small amounts of fine ash fell in Xepax, Xecavioc, Llanos de Pinal, Las Majadas, and Quetzaltenango. During 19-20 March, ash fell to the E in the town of Zunil.

During 21-25 April several explosions at Santiaguito produced ash plumes that rose to ~ 1.2 km above the dome. Lava avalanches occurred down the SW flank of Caliente dome. Explosions on 25 April produced pyroclastic flows that traveled S down Caliente.

Continuing explosive activity from Santiaguito during 4-9 May sent ash columns as high as 1.3 km above the vent. Small collapses at the Caliente dome generated pyroclastic flows 500-3,000 m long. Constant avalanches were reported on 10 May from the lava-flow front and the Caliente dome, along with one small ash explosion. Minor explosions on 13 May sent gray ash plumes 400-600 m high. Avalanches from the SW-flank lava flow continued. Explosions during 17-20 May produced ash clouds to ~ 1 km above the volcano; ash fell 7-10 km from Caliente dome.

During the first week of June 2005, moderate explosions produced plumes that rose to ~ 1.2 km above the volcano. On 2 June, the partial collapse of the lava dome in the crater of Caliente dome generated a pyroclastic flow that traveled ~ 4 km SW. On 22-24 June explosion columns reached ~ 900 m above the crater and extended several kilometers to the SSW and W. On 27 June, in the region of Palajunoj on the SW flank, constant avalanches of lava blocks were observed. During 6-18 July, weak-to-moderate explosions continued, with plumes rising to ~ 1.3 km above the volcano. Throughout July avalanches of volcanic material were produced at the front of an active lava flow, and from the SW edge of Caliente dome.

August and early September reports were unavailable, but during 7-11 September, small-to-moderate explosions at Santiaguito produced plumes that rose to a maximum height of ~ 1.5 km above the volcano on 8 September. On 7 September, a moderate lahar traveled down the volcano's

Date	Number of events
04 Jan 2005	93
07 Jan 2005	62
10 Jan 2005	31
11 Jan 2005	20
12 Jan 2005	14
13 Jan 2005	13
14 Jan 2005	15
24 Jan 2005	16
25 Jan 2005	56
26 Jan 2005	16
27 Jan 2005	52
28 Jan 2005	65

Table 2. Explosions recorded at the Santiaguito cone of Santa María in January 2005. Missing dates were not reported. Courtesy of INSIVUMEH.

flank. About a dozen pyroclastic flows, and avalanches of volcanic material occurred from the SW edge of the lava dome, and from the front of lava deposits on the SW flank of Caliente dome.

On 26 October 2005 a small eruption produced an ash plume that drifted SW to the Pacific and was recorded on MODIS satellite imagery (figure 8). The Washington VAAC reported a hot spot that lasted for about 6 hours with an estimated plume height of 4.5 km. On 28 October a plume rose to an altitude of ~ 4.9 km.

**Background.** Symmetrical, forest-covered Santa María volcano is one of the most prominent of a chain of large stratovolcanoes that rises dramatically above the Pacific coastal plain of Guatemala. The 3,772-m-high stratovolcano has a sharp-topped, conical profile that is cut on the SW flank by a large, 1.5-km-wide crater. The oval-shaped crater extends from just below the summit of Volcán Santa María to the lower flank and was formed during a catastrophic eruption in 1902. The renowned plinian eruption of 1902 that devastated much of SW Guatemala followed a long repose period after construction of the large basaltic-andesite stratovolcano. The massive dacitic Santiaguito lava-dome complex has been growing at the base of the 1902 crater since 1922. Compound dome growth at Santiaguito has occurred episodically from four westward-younging vents, the most recent of which is Caliente. Dome growth has been accompanied by almost continuous minor explosions, with periodic lava extrusion, larger explosions, pyroclastic flows, and lahars.

**Information Contacts:** *Instituto Nacional de Sismología, Vulcanología, Meteorología e Hidrología (INSIVUMEH)*, Unit of Volcanology, Geologic Department of Investigation and Services, 7a Av. 14-57, Zona 13, Guatemala City, Guatemala (URL: <http://www.insivumeh.gob.gt/>); *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/>); *NASA's Earth Observatory* (URL: <http://earthobservatory.nasa.gov/>).

## Endeavour Segment

Juan de Fuca Ridge  
48.24°N, 128.96°W

All times are local (= UTC - 8 hours)

At 1631 on 26 February 2005 (0031 UTC on 27 February), a hydroacoustic network detected the start of what became an intense earthquake swarm (Ridge 2000 TCS (Time Critical Studies) Oversight Committee, 2005). The source of the swarm was on the Endeavour segment of the northern Juan de Fuca Ridge (JdFR) (figure 9).

More than 3,740 earthquakes were detected over a 5-day period (figure 10). Event counts were as high as

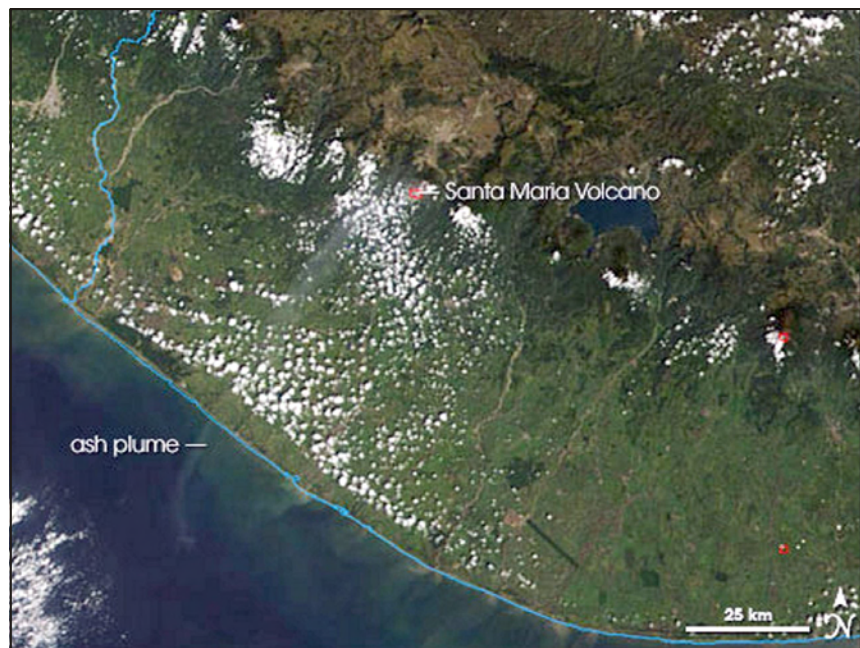


Figure 8. MODIS (Moderate Resolution Imaging Spectroradiometer) image showing a Santa María eruption plume on 26 October 2005. The volcano's summit is identifiable by a small red outline indicating an area hotter than its surroundings. Wafting away from the summit is a thin, faint ash plume that heads SW toward the Pacific. NASA image courtesy the MODIS Rapid Response Team at NASA GSFC.

50-70 per hour, which is similar in scale to event counts associated with sea-floor-spreading events on the ridge at both the Middle Valley segment in September 2001 and at the Endeavour segment in 1999. The hydroacoustic array is the Sound Surveillance System (SOSUS) of the National Oceanic and Atmospheric Administration (NOAA).

The preliminary location of the swarm's epicenters was 48°14.5'N, 128°57.6'W (figure 10), ~ 36 km NNE of the Main Endeavour vent field and a few kilometers E of the intersection of the Heck Seamounts with the JdFR axis. The sequence also produced three large earthquakes (mb 4.5, 4.8, and 4.9) detected by instruments of the National Earthquake Information Center (NEIC), the University of Washington, and the Pacific Northwest Seismograph Network (PNSN). The February-March 2005 seismic swarm also maintained an elevated, nearly constant rate of similar-magnitude earthquakes for several days, behavior consistent with magma intrusion and in contrast to the "mainshock-aftershock" sequence characteristic of tectonic events.

Research response personnel were on station by 6 March, just six days after notification of the seismic swarm, a task that often requires a lead time of over a year. Results from the response cruise indicate that it is unlikely that the February-March 2005 earthquake swarm (figure 11) induced any corresponding expression at the sea floor (i.e., eruption of a lava flow) or in the water column (i.e., formation of new hydrothermal venting, either chronic or event plumes).

In-situ and shipboard physical and chemical data from the three long tow-yo casts and seven vertical casts revealed no water-column signal that can be clearly associated with the recent earthquake swarm, whether magmatic or tectonic. Initial calculations of methane to hydrogen ratios from the Main Endeavour Field, and from Mothra, High Rise, or Salty Dawg vent fields along the Endeavour

segment are comparable to historical (2003) values from vent fluids. No evidence of any temperature or optical anomalies was seen in the near-bottom camera tow data (CTD or MAPR) overlying an axial magma chamber reflector, close to the region of the February/March swarm. Camera images of the sea floor revealed no fresh basalt; rather, the entire camera tow track documented lavas with moderate to heavy sediment cover. Finally, no bathymetric anomalies were detected as the cruise scientists searched for evidence of new lava flows in the earthquake area by comparing before and after high-resolution multibeam bathymetry data. The earthquake swarm was thus thought to reflect a magmatic intrusion that failed to generate measurable changes in the sea floor or an intrusive magmatic event that did not reach sufficiently shallow crustal depths to lead to extrusion (eruptive flows) or stimulate venting at new or existing vent fields as discernable via surface-ship sampling.

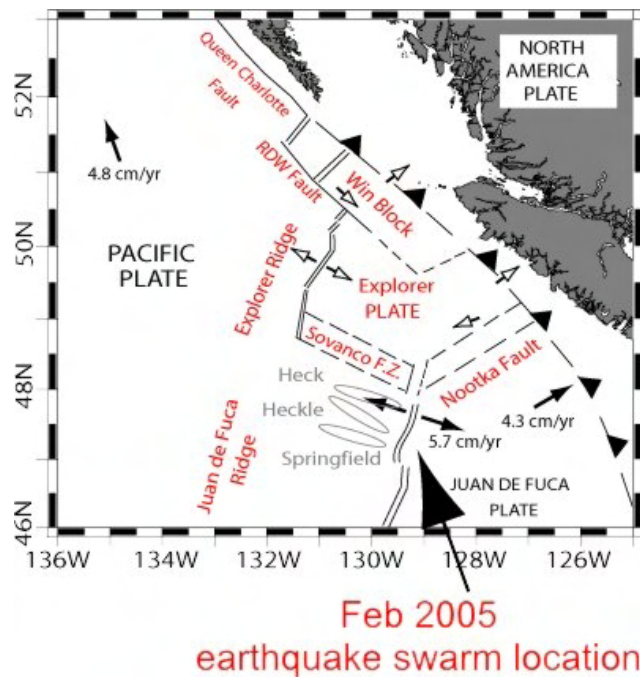


Figure 9. Location map of the February 2005 earthquake swarm on the Juan de Fuca ridge along the Endeavour Segment. Courtesy Ridge 2000 TCS Oversight Committee, 2005.

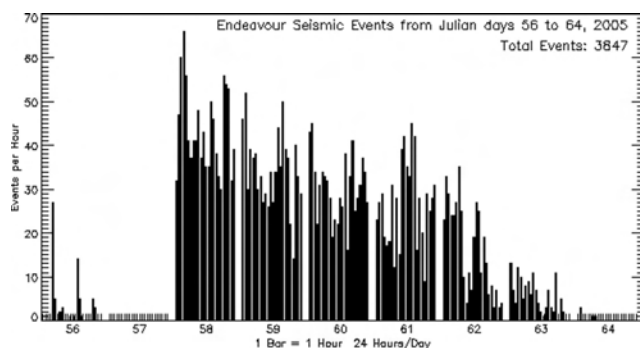


Figure 10. Histogram showing the number of seismic events per hour on the Endeavour segment of the Juan de Fuca ridge. The x-axis extends over Julian days 56-64, 2005 (25 February-5 March 2005). Courtesy National Oceanic and Atmospheric Agency (NOAA) Vents web site, 2005.

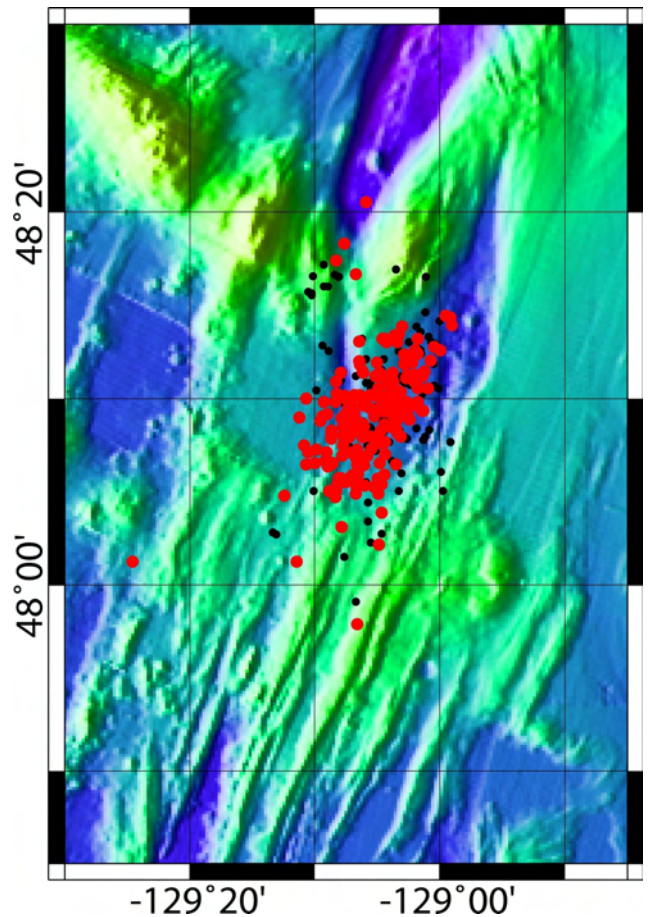


Figure 11. Epicenters of the 305 larger earthquakes along the Endeavour Segment. Those indicated by the larger red dots were located using 4 or more hydrophones. The epicenters indicated by the smaller black dots were smaller events located using three hydrophones, and they may not be as well constrained. Epicenters are plotted through 1 March 2005 and comprise 305 events. Courtesy National Oceanic and Atmospheric Agency (NOAA) Vents web site, 2005.

**References:** Ridge 2000 TCS (Time Critical Studies) Oversight Committee, 2005, Recent detected events on the Juan de Fuca Ridge, Status report on time critical studies: Ridge 2000 Events, v. 3 (Spring 2005), p. 14-15.

Davis, E.E., and Currie, R.G., 1993, Geophysical observations of the northern Juan de Fuca Ridge system: Lessons in sea-floor spreading: Canadian Journal of Earth Sciences, v. 30 (2), p. 278-300.

**Background.** The Endeavour Segment of the Juan de Fuca Ridge is a first order intermediate-rate spreading segment lying within 500 km of the NW United States and SW Canada.

**Information Contacts:** Pacific Marine Environmental Laboratory (PMEL), National Oceanic and Atmospheric Agency (NOAA), 7600 Sand Point Way NE, Building 3, Seattle, WA 98115-6349, and Hatfield Marine Science Center, 2115 SE Oregon State University Drive, Newport, OR 97365 (Vents web site URL: <http://www.pmel.noaa.gov/vents/acoustics/seismicity/nepac/endeav0205.html>); Robert Dziak, NOAA PMEL, Hatfield Marine Science Center, 2115 SE Oregon State University Drive, Newport, OR 97365 (Email: [Robert.p.dziak@noaa.gov](mailto:Robert.p.dziak@noaa.gov)).

## Ol Doinyo Lengai

Tanzania

2.751°S, 35.902°E; summit elev. 2,960 m

All times are local (= UTC + 3 hours)

Vigorous eruptive activity was observed in July 2004, and visitors in January 2005 noted that a new crater rim overflow area had developed along the N rim (see report and map in *BGVN* 30:04). The mountain guide for Martin Haigh reported on 15 May that last lava flows had occurred in March.

**Activity during 3-5 July 2005.** During 3-5 July 2005 Bernard Marty and others visited the crater to conduct gas sampling. His report follows.

At the time of arrival (0800 on 3 July), sporadic lava flows of the aa type were emitted from a vent at the base of T56B, which was itself disrupted by an explosion, leaving an open cavity about 15 m in diameter. The lava was flowing toward the E overflow, but never reached the crater rim. At about 1130, lava was spilling violently from T58B and flowing towards the E overflow.

Sampling had to be interrupted at T46 due to the risk of a sudden lava flood in the sampling area, a real possibility if the thin W wall of T58B fractured following thermal erosion of the wall by molten lava in the lava lake. One hundred meters S of T46, close to the base of T47, a deep hole ~ 1.5 m diameter and bordered by lava splashes emitted a piercing sound. A pahoehoe lava flow was emitting high temperature gases with no visible steam.

A lava pond, not directly observed but for which bubble explosions were clearly visible, was discharging surges of lava towards the E rim while the adjacent T58C cone, now higher than T58B, was discharging high-velocity gases that occasionally splashed lava. The eruption lasted all day and the following night, with variations from steady-state outpouring with lower degassing, to bursts of large bubbles with enhanced lava emission. By the afternoon of 4 July the lava, which was then overflowing the E slope of the volcano, ignited a bush fire. The lava emission rate was estimated at about 0.3 m<sup>3</sup>/s, with a speed of ~ 2 m/s in the flat area toward the volcano's flank.

At 0500 on 5 July lava flows suddenly invaded the mountain camp's kitchen area to a depth of one meter. Fortunately no one was hurt, but the episode illustrated that there was no safe area within the N crater.

**Activity during 19 July-9 August 2005.** During 19 July-9 August a team of observers led by Fred Belton camped in the inactive S crater. They submitted the following report of the active N crater as viewed from the SE crater rim.

Activity during the past year was confined to the crater's central portion. Since its initial violent eruption from a hole in the crater floor on 15 July 2004, T58C has grown to a height of ~ 12 m and is at the time of this report the second highest cone in the crater, tall and narrow with large blocks scattered about the crater floor below, indicating that it has undergone some flank collapses in the preceding months. T49B has grown significantly taller since July 2004 and is the tallest feature in the crater, rising at least 15 m above its base.

T56B, which has remained open to the SE since July 2004, has grown a small cone on its SE flank. The new

cone, which has not been named because it is so high on the flank of T56B, is being undermined by a large tunnel. The tunnel begins at the SE base of the small unnamed cone and extends under it to the open vent of T56B. Clearly the tunnel was a recent active feature, and the tunnel entrance appears to be the result of collapse during or after an eruption.

T58B contained a large and deep (10-12 m) open pit, which clearly indicated the presence of past lava-lake activity at two levels. The solid crust of a former lava lake about 4 m below the rim contained a hole near its center that opened into a much deeper chamber. At some point during the night of 4 August this deeper pit was filled by lava so that only the upper level remained.

T57B appeared unchanged from July 2004 until its S half was covered by a thick layer of fused spherical lapilli from a short but powerful eruption of T58C on 20-21 July (figure 12).

Spatter cones T40, T46, T47, T51, T45, T37, T37B, and the ash cones have continued to be gradually covered by lava flows from the active cone group in the central crater. In particular, T40, which was the primary active cone during much of 1999, is now well on its way to disappearing under the lava. Lava flows from the central cone area have continued to build up the height of the mound in the central crater so that several cones are easily visible from Engare Sero village. T53 (~ 80 m NW of T40) no longer existed. A deep hole in the crater floor, just N of T47 and surrounded by recent pahoehoe flows from T58B, is possibly all that remains of the summit vent of T39. The hole was degassing at a high temperature but did not show any evidence of recent effusive activity. An area in the E part of the crater, which is sheltered by outcroppings and sometimes used by campers, had been covered by a thick flow of slabby pahoehoe lava from T58B. A large amount of vegetation on the E flank of Lengai had also been burned by lava flowing through the E-crater-rim overflow (figure 13). Several locations on the N crater rim had become crossed by small lava flows.

Table 3 shows a multi-year set of measurements of the width of crater rim overflows. The N rim overflow was first measured on 7 August 2005.



Figure 12. At 0100 on 21 July a short but powerful eruption from Ol Doinyo Lengai's T58C vent produced these fresh black lava flows and a lapilli field on the flank of T57B. This view is looking NW and the various features are labeled as follows. Labels a-h indicate the following. a: T58C (most recently formed of the cones), b: T49B, c: T37B, d: T57B, e: T40, f: T45, g: C (rim cone), h: T37. Courtesy of Fred Belton.

Although there was no activity on 19 July, an unobserved eruption may have begun around 2300 on 20 July and probably ended by 0130 on 21 July, according to reports by a camping group in the W portion of the crater floor. The activity reached its peak between 0100 and 0130 and involved strong lava fountains from a vent about halfway up the E side of T58C. The fountains deposited a deep (at least 0.5 m) bed of lapilli around the base and on the S flank and top of cone T57B, and sent pahoehoe and aa flows to the E. One of the flows traveled tens of meters down Lengai's E slopes. The lapilli consisted mostly of hollow spheroids with diameters up to 1.2 cm. Many of the lapilli were fused, and sections of the field broke apart under their own weight, leaving a blocky, fissured surface.

On 21 July at 1511 lava flowed from T58B's active vent during a 12-minute eruption. At 2100 on the same day a third eruption sent strong surges of lava from the same vent and continued throughout the night. Atmospheric clouds prevented detailed observations, but clear conditions at 0500 on 22 July revealed that a large lava channel had formed just E of T58B and had been thermally eroded to a depth of more than one meter. Maximum flow rate during the eruption was estimated to be 0.5 m<sup>3</sup>/s. The eruption continued until about 1800 and deposited pahoehoe flows over a large part of the SE crater floor.

With the exception of a very minor lava flow from T58C at 1930 on 26 July and the brief (unobserved) appearance of a lava lake in T58B on the night of 4 August, no further activity occurred through 9 August. There were frequent sounds of lava at depth near the base of T58C and inside the open vent of T58B. The lava lake that briefly occupied T58B filled up its deep inner pit and then solidified, leaving a flat surface of new lava about 4 m below the lowest place on the cone's rim. During 4-9 August lava could be heard moving near the surface somewhere inside T58B's vent, but it never became visible. Observations ended at 0800 on 9 August 2005.

**Activity during September and October 2005.** Kees DeJong reported the following, which was posted on Belton's website: "We climbed Oldonyo Lengai 13 September 2005, arriving at the crater rim [at 0710]. Tourists that had camped in the crater said that eruptions began at midnight (and that there were no eruptions the previous days). Lava kept flowing until about [0846]; we left the crater at [1300] that day."

Photos that Kees made indicated that lava was flowing from about halfway up the side of T48B and across the

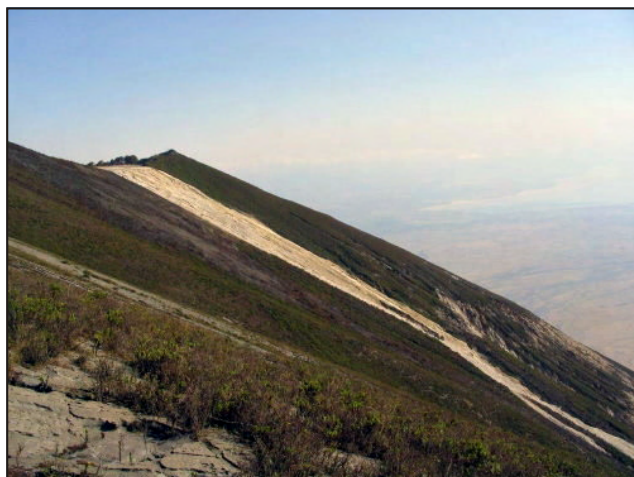


Figure 13. The light-colored stripe represents the overflow of recent lavas from Ol Doinyo Lengai down the E flank, as photographed on 7 Aug 2005 from the S crater. The blackened area represents burned vegetation from the bush fire reported by Bernard Marty on 4 July 2005. The lavas, termed natrocarbonatites, turn light colored on the surfaces upon cooling and absorbing moisture. Courtesy of Fred Belton.

crater floor toward the W, but that it was not a particularly large eruption. Earlier, probably on 11 September, a small amount of lava flowed down the N flank of T49B and a short distance across the crater floor. Other photos indicated (by comparing specific lava flows on the crater floor with the same lava flows in 7 August photos) a high probability that there were no lava flows at all between 9 August and 11 September. On 19 September Burra Gadiye reported to Roger Mitchell that he had seen no activity that day.

Anatoly Zaytsev climbed on 30 September and reported that they did not see eruptive activity during their visit (between 1100 and 1500). They did see some natrocarbonatite lavas with estimated ages of 2-3 weeks. These were probably the flows from 13 September described above.

Following a visit during 1-3 October, Jaco de Borst reported the following. "During the first of October there was also no activity, only 'smoke' from several cones and cracks. On the second of October there were several 'small' eruptions. In daylight and at night, the cone that was erupting was the biggest and close to the overflow where the trail reaches the crater. Lava only reached the foot of the cone [Belton noted that he was describing T49B]. We left in the morning of 3 October, I think at about 1000. When we left there was no activity, . . . [other] than some noise and 'smoke.' The night eruptions we saw . . . I think [occurred] about 5 o'clock in the morning [on 3 October]."

**Background.** The symmetrical Ol Doinyo Lengai stratovolcano is the only volcano known to have erupted carbonatite tephra 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

Date	NW Overflow	E Overflow	W Overflow	N Overflow
Jul 2000	60 m	38 m	—	—
23 Jul 2001	106 m	38 m	—	—
05 Aug 2002	135 m	39 m	12 m	—
02 Aug 2003	135 m	44 m	17 m	—
07 July 2004	135 m	44 m	17 m	—
16 Jul 2004	135 m	47 m	17 m	—
07 Aug 2005	135 m	72 m	20 m	~1 m at each of three locations

Table 3. Measurements of the widths of lava overflowing the crater rim at Ol Doinyo Lengai. The values represent the arc length of the crater rim covered by lava flows on the various dates. Measurements were made by pacing the distance several times and averaging the results. The dashes mean that the overflow had not yet come into existence on the date indicated. The lengths of the flows beyond the crater rim are not shown on this table. Courtesy of Fred Belton and Chris Weber.

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 N 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 N crater; by late 1998 lava had begun overflowing the crater rim.

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