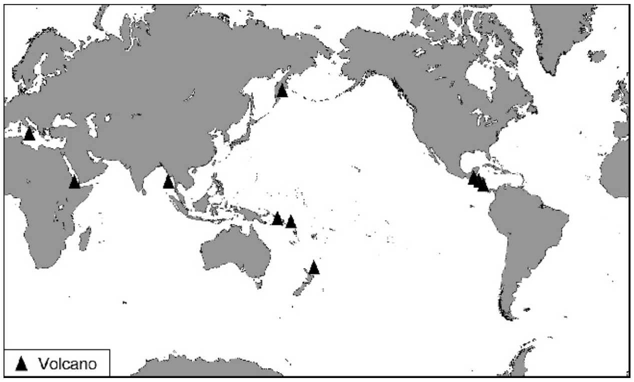
Bulletin of the Global Volcanism Network



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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@si.edu · URL: http://www.volcano.si.edu/

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

Manda Hararo

Ethiopia
12.17°N, 40.82°E; summit elev. 600+ m
All times are local (= UTC + 3 hours)

On 13 August at 1315 a large sulfur-dioxide (SO_2) cloud was detected over Ethiopia and Sudan by the Ozone Monitoring Instrument (OMI) on NASA's Aura satellite. This was presumed to be the result of a volcanic eruption in western Afar, Ethiopia, though the source was then unclear. Preliminary analysis indicated that the cloud contained ~ 8,000 tons of SO_2, although a more precise estimate depends on the altitude of the cloud, which was not known.

MODIS satellite imagery, interpreted at the University of Hawaii, showed the presence of a cluster of hot-spots centered at 12.25ºN, 40.65ºE late on 12 August, presumably corresponding to an active lava flow. The eruption site appears to lie within the Manda Hararo volcanic complex around 40 km SSE of Dabbahu volcano, which had its first historical eruption in September 2005. The massive 105-km-long, 20-30 km-wide Manda Hararo complex consists of basaltic shield volcanoes cut by regional fissures with no previously recorded historical eruptions. It is the southernmost axial range of the western Afar region. OMI data on 14 August showed continuing SO_2 emissions, although by that day the extent of the MODIS thermal anomaly had diminished.

Local residents reported that there had been no precursory activity of any kind during the days preceding the eruptions. The first sign of activity was noted on 12 August when a sudden heavy cracking sound was heard in the affected area. The sound was heard first in the N part and propagated continuously toward the S. Only a small ground tremor was felt at that time. At about 1730 on 13 August, "fire" started to be seen from the N in the direction of Gommoyta and continued to the N, lighting up the entire area. A curtain of "fire and smoke" rose high into the sky in the area and this activity continued with variable intensity until it subsided on the morning of 16 August. The frightened local inhabitants evacuated the area and therefore did not observe effusion of the lava flows. So far no damage to life or property has been reported.

Figure 1. Location of the Manda Hararo fissure eruption (round dot). Other features shown include the Gabho and Dabbahu volcanoes, and the city of Semera. Courtesy of Gezahegn Yirgu, Addis Ababa University.


Figure 2. Steam rises from new fissures that fed lava flows at Manda Hararo, as seen on 20 August 2007. Courtesy of Gezahegn Yirgu, Addis Ababa University.

A field team was able to investigate the area of new eruptions in the Manda Hararo region on 20 August (figure 1). Karbahi is the name given to the rift's axial segment/graben, a region with numerous active normal faults, fissures, and recent basalt flows, bounded by large normal faults. Prominent features in the Karbahi graben area include Gommoyta and Diyyilu felsic volcanoes, which are found immediately to the N of this locality.

Aerial observations showed isolated spots where intense emission of gas (with distinct smell of sulfur dioxide) was taking place. In few places, white and yellowish deposits of sulfur were visible. Long, discontinuous fissures, arranged *en echelon*, from which lavas had flowed on either side, predominantly traveling W to the graben floor (figure 2). Numerous small spatter and scoria cones were aligned on the fissures. Reddish glow and rare flames were also observed on top of some of the tiny craters of these cones. Fault scarps with fresh breaks and rock falls were also visible from the air, probably showing evidence of recent movement. A narrow graben-like collapse structure oblique to one of the fissures was also observed. The segment affected by tectonic and volcanic activity was estimated (with the help of a helicopter pilot) to measure 5-7 km long and 1 km wide.

Ground investigations found basalt lava flows and steam emissions ongoing on 20 August. While walking on top of the lavas, scientists felt immense heat emanating from the flow surface. Each fissure was covered by a continuous row of small and closely spaced spatter and scoria cones. Many of the cones themselves had tiny pits from which both heat and gas escaped. The pits could not be entered due to the heat and high noxious gas concentrations.

As seen from the air, a reddish glow and flames were seen at some distant cones. One fissure with its row of cones is oriented about N7°W to N10°W.

The observed aa and pahoehoe flows were relatively viscous and did not travel beyond a few hundred meters from their fissure vents (figure 3). The overall thickness of the flows was variable and reached several meters in places. Lava channels and tubes were abundant. The spatter ramparts and scoria cones varied in height from 2 to 10 m. Spatter and scoria fragments varied from coarse lapilli to bombs. The new lava was moderately porphyritic with small and sparse plagioclase phenocrysts. Field observations found that the older lavas at the site exhibited the same features. Representative lava samples were collected.

Geologic Summary. The southernmost axial range of western Afar, the Manda Hararo complex is located in the Kalo plain, SSE of Dabbahu volcano. The massive complex is 105 km long and 20-30 km wide, and represents an uplifted segment of a mid-ocean ridge spreading center. A small basaltic shield volcano is located at the N end of the complex. An area of abundant fissure-fed lava flows is located to the S. Two basaltic shield volcanoes, the largest of which is Unda Hararo, occupy the center of the complex. The dominant part of the complex lies to the N, where the Gumatmali-Gablaytu fissure system is located. Voluminous fluid lava flows issued from these NNW-trending fissures, and solidified lava lakes occupy two large craters. The small Gablaytu shield volcano forms the SE-most end of the Manda Hararo complex. Lava flows from Gablaytu and from Manda overlie 8,000-year-old sediments. Hot springs and fumaroles occur around Daorre lake.

Information Contacts: *Gezahegn Yirgu*, *Atalay Ayele*, *Shimeles Fisseha*, *Tadiwos Chernet*, and *Ato Kifle Damtew*, Department of Earth Sciences, Addis Ababa University, Addis Ababa, Ethiopia (Email: gezahegnyirgu@yahoo.com); *Simon Carn*, Joint Center for Earth Systems Technology (JCET), University of Maryland Baltimore County (UMBC), 1000 Hilltop Circle, Baltimore, MD 21250, USA (URL: http://www.volcarno.com/, http://so2.umbc.edu/omi/); *Hawai'i Institute of Geophysics and Planetology (HIGP) Thermal Alerts System*, School of Ocean and Earth Science and Technology (SOEST), Univ. of Hawai'i, 2525 Correa Road, Honolulu, HI 96822, USA (URL: http://hotspot.higp.hawaii.edu/).

Figure 3. A closer view of the August 2007 lava at Manda Hararo. The dark-colored basaltic flows display aa and pahoehoe textures. Courtesy of Gezahegn Yirgu, Addis Ababa University.

Etna

Italy
37.734°N, 15.004°E; summit elev. 3,350 m
All times are local (= UTC + 1 hours)

According to Sonia Calvari of the Istituto Nazionale di Geofisica e Vulcanologia Sezione di Catania (INGV-CT), on 15 August the South-East Crater (SEC) at the summit of Mount Etna began to produce ash emissions. They emerged at the depression that cuts the SEC's E flank. The ash cloud was very diffuse, rising for just a few ten's of meters above the source, and it was quickly dispersed by the wind. Reddish-colored ashfall deposits were observed only on the flanks of the SEC cone.

During the night of 21 August the summit web-camera of INGV-CT recorded incandescent blocks erupted during the most energetic emissions. A field survey on 22 August observed few very energetic events (about 20% of the total), cases where the ejection of hot, lithic blocks fell on the E flank of the cone. On 24 August, researchers from INGV on the summit with a thermal camera recorded the first short Strombolian sequence. Strombolian explosions increased in intensity and became more common through August, slowly amassing material to create a cinder cone within the depression on the SEC's E flank. Etna's emissions continued through August (figure 4) and into at least early September. Later INGV reports noted a strong eruption during 4-5 September. Those events will be the subject of a future *Bulletin* report.

Geologic Summary. Mount Etna, towering above Catania, Sicily's second largest city, has one of the world's longest documented records of historical volcanism, dating back to 1500 BC. Historical lava flows of basaltic composition cover much of the surface of this massive volcano, whose edifice is the highest and most voluminous in Italy. The Mongibello stratovolcano, truncated by several small calderas, was constructed during the late Pleistocene and Holocene over an older shield volcano. The most prominent morphological feature

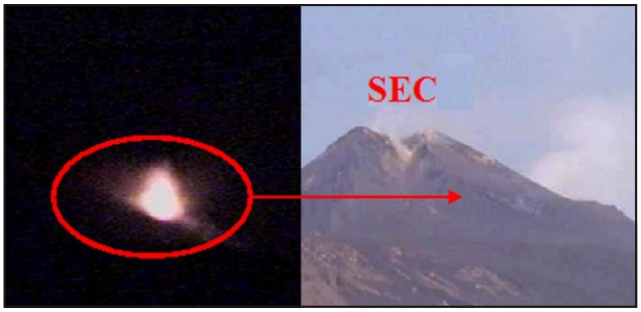

Figure 4. Cropped images from the INGV-CT webcamera of a night eruption at Etna at 0300 on 31 August 2007 showing a Strombolian eruption (left) and a daylight photo five hours later (0800 on 31 August) of the same region (right). The arrow indicates the point of emission. Courtesy of INGV-CT.

of Etna is the Valle del Bove, a 5 x 10 km horseshoe-shaped caldera open to the E. Two styles of eruptive activity typically occur at Etna. Persistent explosive eruptions, sometimes with minor lava emissions, take place from one or more of the three prominent summit craters, the Central Crater, NE Crater, and SE Crater (the latter formed in 1978). Flank vents, typically with higher effusion rates, are less frequently active and originate from fissures that open progressively downward from near the summit (usually accompanied by Strombolian eruptions at the upper end). Cinder cones are commonly constructed over the vents of lower-flank lava flows. Lava flows extend to the foot of the volcano on all sides and have reached the sea over a broad area on the SE flank.

Information Contact: *Sonia Calvari*, Istituto Nazionale di Geofisica e Vulcanologia Sezione di Catania, Piazza Roma 2, 95123 Catania, Italy (Email: calvari@ct.ingv.it; URL: http://www.ct.ingv.it/).

Barren Island

Andaman Islands, Indian Ocean
12.278°N, 93.858°E; summit elev. 354 m

According to news reports of Indian Coast Guard statements, the eruptive activity that began in late May 2005 (*BGVN* 30:05) at Barren Island had diminished by late September 2006 (*BGVN* 31:09). Since then, based upon pilot and satellite data, the Darwin Volcanic Ash Advisory Centre (VAAC) reported multiple ash-and-steam plumes. The plumes reached an altitude of 1.5 km (drifting WNW) on 19 and 20 October 2006, 3 km (drifting SW and W) on 8 November 2006, an unreported altitude and direction on 27 November 2006, 3 km (drifting SW) on 8 February 2007, and 2.1 km (drifting S) on 3 March 2007. The Darwin VAAC had not issued further advisories on Barren Island activity through August 2007.

A compilation of MODIS thermal anomaly data from the Aqua and Terra satellites (figure 5) shows that the eruption began on 26 May 2005 (*BGVN* 31:01) and has continued through at least 1 September 2007. The level of lava emissions remained high between May 2005 and mid-March 2006. On 17 March 2006 the MODVOLC system identified nine hot pixels in Aqua MODIS data. After that time detectable lava activity decreased and became intermittent, though explosive activity may have been present. More frequent anomalies were detected during April 2006, October-November 2006, and May 2007.

Geologic Summary. Barren Island, a possession of India in the Andaman Sea about 135 km NE of Port Blair in the Andaman Islands, is the only historically active volcano along the N-S-trending volcanic arc extending between Sumatra and Burma (Myanmar). The 354-m-high island is the emergent summit of a volcano that rises from a depth of about 2250 m. The small, uninhabited 3-km-wide island contains a roughly 2-km-wide caldera with walls 250-350 m high. The caldera, which is open to the sea on the W, was created during a major explosive eruption in the late Pleistocene that produced pyroclastic-flow and -surge deposits. The morphology of a fresh pyroclastic cone that was constructed in the center of the caldera has varied during the course of historical eruptions. Lava flows fill much of the caldera floor and have reached the sea along the western coast during historical eruptions.

Information Contacts: *HIGP MODIS Thermal Alert System*, Hawai'i Institute of Geophysics and Planetology (HIGP), University of Hawaii and Manoa, 168 East-West Road, Post 602, Honolulu, HI 96822, USA (URL: http://modis.higp.hawaii.edu/); *Darwin Volcanic Ash Advisory Centre*, Bureau of Meteorology, Northern Territory Regional Office, PO Box 40050, Casuarina, Northern Territory 0811, Australia (URL: http://www.bom.gov.au/info/vaac/).

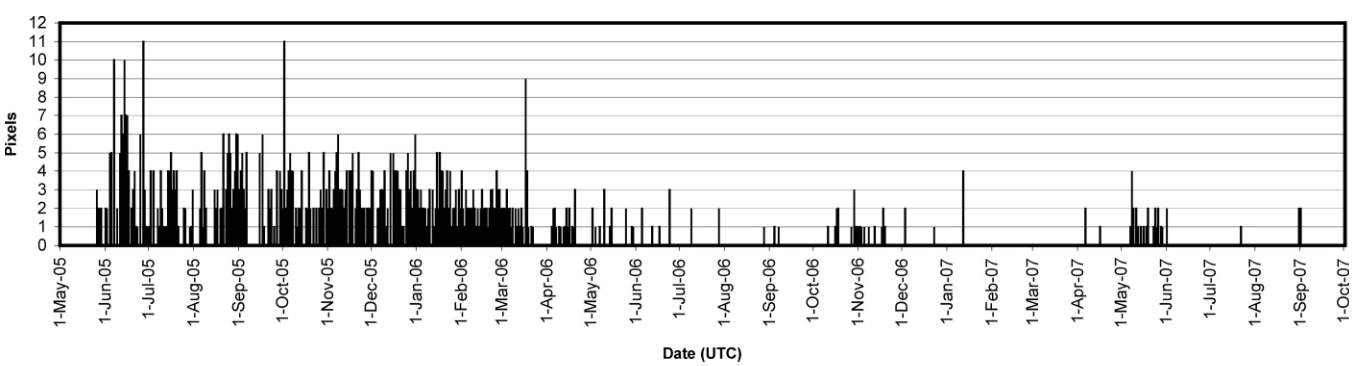

Figure 5. Daily thermal anomalies at Barren Island from the MODIS/MODVOLC satellite observations, May 2005 to early September 2007. Vertical scale indicates the daily number of alert pixels detected n a specific thermal image, generally a reflection of the extent of hot lava flows. Anomalies are from both the Aqua and Terra satellites and were accessed for this report in early September 2007. Courtesy of the HIGP MODIS Thermal Alert System.

Kavachi

Solomon Islands, SW Pacific
9.02°S, 157.95°E; summit elev. -20 m
All times are local (= UTC + 11 hours)

A large earthquake (M 8.1) occurred in the Solomon Islands on 2 April 2007, centered about 126 km NW of Kavachi. Following the earthquake, Corey Howell of The Wilderness Lodge on Gatokae Island received several reports from residents on Gatokae and Vangunu Islands describing noises attributed to Kavachi (~ 35 km WSW of Gatokae). A confirmed report from Marila Timi of Biche Village (on the S coast of Gatokae) stated that around the time of the 2 April earthquake, Kavachi emitted an eruption column visible from her garden above the village.

On 6 April Howell traveled to Kavachi to observe the volcano. Howell spent 2.5 hours on location within 200 m of the active vent, and dove down to within tens of meters of the vent. The volcano exhibited its usual vigorous upwelling, producing a plume of discolored mud- and sulfur-laden water several hundred meters wide and at least 3 km in length downcurrent (figure 6). He measured a temperature of 40°C in the subsurface plume, which appeared normal as compared with his previous 30 visits to Kavachi since 1999. The only explosive activity observed or felt was occasional thudding detonations and sea-surface percussions, with shockwaves producing spray and billows of ash-laden water (figures 7 and 8). Kavachi lacked a significant explosive eruption column or signs of ejected pyroclastic materials, behavior witnessed on many previous visits. On this visit, Howell found nothing out of the ordinary following the 2 April earthquake.

Geologic Summary. Kavachi, one of the most active submarine volcanoes in the SW Pacific, occupies an isolated position in the Solomon Islands far from major aircraft and shipping lanes. Kavachi, sometimes referred to as Rejo te Kvachi ("Kavachi's Oven"), is located S of Vangunu Island only about 30 km N of the site of subduction of the Indo-Australian plate beneath the Pacific plate. The shallow submarine basaltic-to-andesitic volcano has produced ephemeral islands up to 1 km long many times since its first recorded eruption during 1939. Residents of the nearby islands of Vanguna and Nggatokae (Gatokae) reported "fire on the water" prior to 1939, a possible reference to earlier submarine eruptions. The roughly conical volcano rises from water depths of 1.1-1.2 km on the N and greater depths to the S. Frequent shallow submarine and occasional subaerial eruptions produce phreatomagmatic explosions that eject steam, ash, and incandescent bombs above the sea surface. On a number of occasions lava flows were observed on the surface of ephemeral islands.

Information Contacts: *Corey Howell*, The Wilderness Lodge, Peava Village, Gatokae Island, Western Province, Solomon Islands (URL: http://thewildernesslodge.org/).

Figure 7. Some of the stronger activity observed at Kavachi on 6 April 2007 included very turbulent ash-laden water above the vent, explosive and percussive noises, and discolored water downcurrent of the vent. Courtesy of Roy Hall (posted on The Wilderness Lodge website).

Figure 6. Photograph showing a mud-and sulfur-laden plume downcurrent of Kavachi's upwelling vent on 6 April 2007, forming a discolored area several hundred meters wide and several kilometers long. Howell noted that such plumes are frequently seen at Kavachi. Courtesy of Roy Hall (posted on The Wilderness Lodge website).

Figure 8. Some of the stronger activity observed above the vent at Kavachi on 6 April 2007 consisted of shockwaves producing dancing spray, accompanied by staccato bursts of sound. These noises also reverberated through the bottom of the boat. Courtesy of Roy Hall (posted on The Wilderness Lodge website).

Tinakula

Santa Cruz Islands, SW Pacific
10.38°S, 165.80°E; summit elev. 851 m
All times are local (= UTC + 11 hours)

MODIS thermal anomaly data for Tinakula (table 1) suggests continuing eruptive activity during the period mid-April through mid-July 2007, but no validation by field observations has become available. Similar intermittent anomalies have been detected since mid-February 2006 (*BGVN* 31:03 and 32:03).

Several photographs were taken offshore of the island during the February 2006 eruption (*BGVN* 31:03); figure 9 is an example of some activity during that eruption.

Geologic Summary. The small 3.5-km-wide island of Tinakula is the exposed summit of a massive stratovolcano that rises 3-4 km from the sea floor at the NW end of the Santa Cruz islands. Tinakula resembles Stromboli volcano in containing a breached summit crater that extends from the 851-m-high summit to below sea level. Landslides enlarged this scarp in 1965, creating an embayment on the NW coast. The satellitic cone of Mendana is located on the SE side. The dominantly andesitic Tinakula volcano has frequently been observed in eruption since the era of Spanish exploration began in 1595. In about 1840, an explosive eruption apparently produced pyroclastic flows that swept all sides of the island, killing its inhabitants. Frequent historical eruptions have originated from a cone constructed within the large breached crater. These have left the upper flanks of the volcano and the steep apron of lava flows and volcaniclastic debris within the breach unvegetated.

Information Contacts: *Hawai'i Institute of Geophysics and Planetology (HIGP) Thermal Alerts System*, School of Ocean and Earth Science and Technology (SOEST), Univ. of Hawai'i, 2525 Correa Road, Honolulu, HI 96822, USA (URL: http://hotspot.higp.hawaii.edu/); *Bill Yeaton* (URL: http://www.billyeaton.com/).

Date	Time (UTC)	Pixels	Satellite
12 Apr 2007	1420	1	Aqua
17 Apr 2007	1140	1	Terra
19 Apr 2007	1425	1	Aqua
03 May 2007	1440	2	Aqua
05 May 2007	1125	1	Terra
05 May 2007	1425	1	Aqua
10 May 2007	1145	2	Terra
10 May 2007	1445	2	Aqua
15 May 2007	1200	1	Terra
18 Jun 2007	1150	2	Terra
27 Jun 2007	1145	1	Terra
27 Jun 2007	1445	1	Aqua
29 Jun 2007	1130	1	Terra
11 Jul 2007	1155	4	Terra
11 Jul 2007	1455	4	Aqua
13 Jul 2007	1145	1	Terra

Table 1. MODIS/MODVOLC thermal anomalies at Tinakula for mid-April through mid-June 2007 (continued from table in *BGVN* 32:03); note particularly the anomalies recorded on 11 July 2007. Courtesy of the University of Hawai'i Institute of Geophysics and Planetology (HIGP) MODIS Hotspot Alert website.

Figure 9. Lava blocks tumbling into the ocean on at Tinakula on the morning of 21 February 2006. Courtesy of Bill Yeaton.

Brothers

New Zealand
34.875°S, 179.075°E; summit elev. -1,350 m
All times are local (= UTC + 12 hours)

In the latest of several investigations since 1996, scientists again explored Brothers submarine volcano, working there during 28 July-16 August 2007 (figure 10). The German research ship *R.V. Sonne* provided the platform for these 2007 investigations, which included bathymetric mapping, measurements of the water column, and observations of hydrothermal activity. This report summarizes some of the mapping and basic observations made at Brothers on this recent and past cruises.

Brothers rests along the active Kermadec arc at a point ~ 450 km NE offshore of New Zealand's North Island (figure 10). For reference, the volcano White Island lies ~ 50 km off the coast in the Bay of Plenty at the N end of North Island ("W," figure 10). Parts of Brothers have been explored previously from surface ships and submersibles, documenting the volcano as hydrothermally active but not in eruption.

Earlier surveys at Brothers. In February 1996, the first sulfide samples from the southern Kermadec arc were dredged from Brothers. On a cruise in late 1998, New Zealand scientists confirmed that Brothers hosted active hydrothermal vents. Using towed cameras and videos, scientists observed tall chimneys perched on the NW caldera's steep walls. On that 1998 cruise, scientists also saw clear evidence of hot, metal- and sulfur-rich fluids expelled from inside the caldera. Numerous samples from Brothers have been acquired and analyzed (for example, see de Ronde and others, 2005).

Other cruises during 1999, 2002, and 2004 mapped and sampled black smokers and other hydrothermal plumes that emanated from the numerous active chimneys. In late 2004, scientists dove four times on vent sites with the Japanese manned submersible *Shinkai 6500*, followed in 2005 by five dives with the American submersible *Pisces V*.

2007 report of investigations. The 2007 cruise (called the *New Zealand American Submarine Ring of Fire 2007*) represented a collaboration between the Geological and

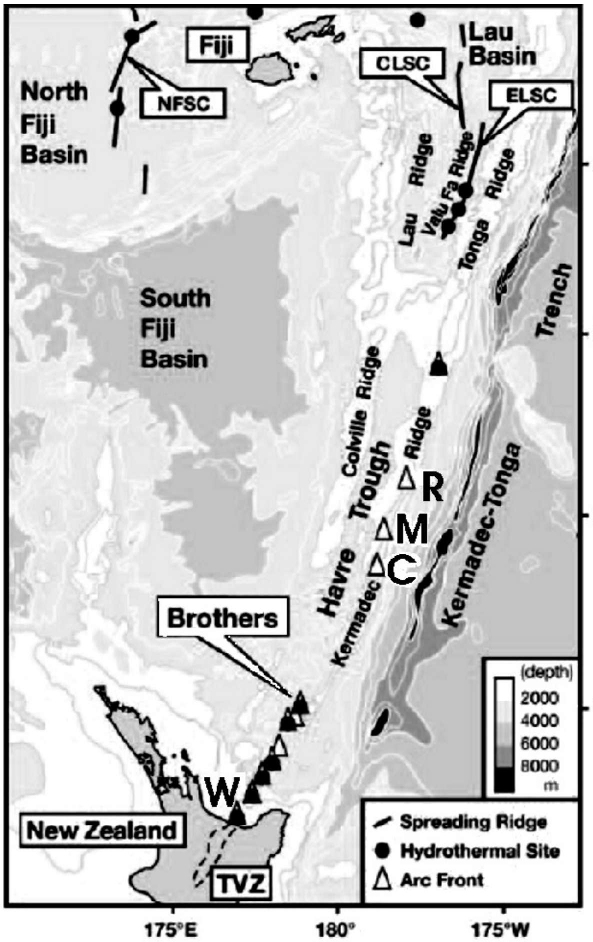

Figure 10. Regional tectonic map indicating the location of Brothers submarine volcano along the active volcanic front. Abbreviations: C = Curtis Island; CLSC = Central Lau spreading center; ELSC = Eastern Lau spreading center; M = Macauley Island; NFSC = North Fiji spreading center; R = Raoul Island, TVZ = Taupo volcanic zone; W = White Island. After de Ronde and others (2005).

Nuclear Sciences–GNS (New Zealand), the Leibniz Institute for Sea Sciences at the University of Kiel (das Leibniz-Institut für Meereswissenschaften an der Universität Kiel—IFM GEOMAR) (Germany), the National Oceanic and Atmospheric Administration's Ocean Exploration (NOAA-OE) program (USA), and the Woods Hole Oceanographic Institution (USA). Logs of the cruise, available on a NOAA website, and the paper by de Ronde and others (2005) provided much of the information for this preliminary report.

Bathymetric information was used to create an oblique relief image of the 350-m-high intracaldera cone with the caldera floor and walls in the background (figure 11). A hydrothermal area lies along the caldera's NW wall and hydrothermal chimneys were seen there (figure 12). Diffuse venting was also reported from the prominent and smaller cones.

The existence of active thermal features at Brothers also comes from observations of seawater turbidity (i.e., cloudiness of the water column, analogous to the plume in figure 12). Basically, areas of high turbidity signify hydrothermal venting (figure 13). In more detail, turbidity, when considered along with collateral data (such as seawater velocity over the ocean floor, electrical conductivity, temperature, and samples of water and rock) may provide clues about the strength, chemistry, and location of the hydrothermal venting.

Metal deposits. One goal of the 2007 expedition was to better understand hydrothermal venting and its relation to metal-bearing deposits at Brothers. Hydrothermal vents, which might be active for periods from months to decades, may contribute to mineral deposits along the Kermadec arc. Investigators developed a hypothetical diagrammatic cross section through Brothers presenting a model of its internal intrusive processes and thermal and hydrothermal evolution (de Ronde and others, 2005).

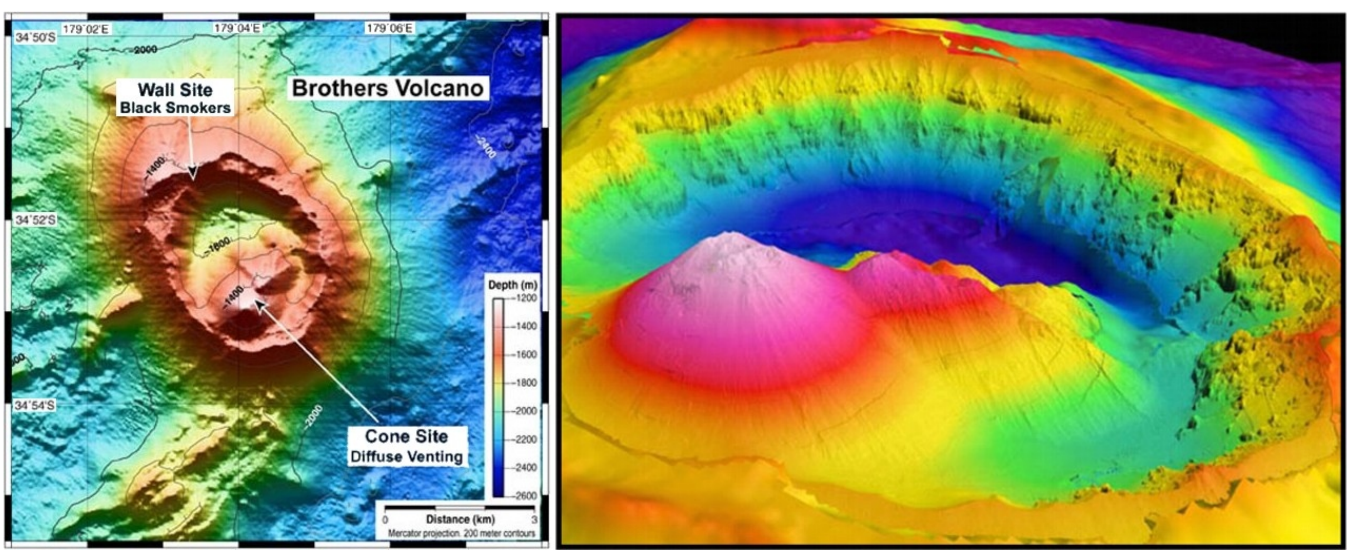

Figure 11. (Left) A bathymetric map based on EM 300 multibeam soundings and depicting Brothers with a contour interval of 200 m. Much of the sea floor surrounding the edifice at distances of several kilometers away lies below 2,200 m depth. Much of the volcano's rim lies at ~ 1,400 m depth. Fluids as hot as 300°C vented at the two identified hydrothermal areas. (Right) An oblique, three-dimensional view of Brothers looking NW (with 3-fold vertical exaggeration) in a graphic prepared at the end of the 2007 cruise. The caldera's dimensions are 3-by-4 km. Although a vertical scale corresponding to the shading is absent, the large cone in the left foreground rises ~ 350 m above the caldera floor. Both that summit crater and the smaller cone to the NE (right) discharged hydrothermal emissions. The rough, sometimes blocky material exposed along the caldera wall consists of older, pre-caldera lavas and other volcanic rocks. Courtesy of New Zealand American Submarine Ring of Fire 2007 Exploration.

Figure 12. An active hydrothermal chimney (commonly known as a “black smoker”) photographed at Brothers at the NW caldera hydrothermal site during the 2007 cruise. The dark color of the vented material is thought to result from particulates. Image courtesy of New Zealand American Submarine Ring of Fire 2007 Exploration.

Submersibles. Technology used to study Brothers included two well-instrumented submersibles.

One submersible was a torpedo-like autonomous underwater vehicle known as the *Autonomous Benthic Explorer* (*ABE*, from Woods Hole Oceanographic Institution). *ABE* was intended to ‘fly’ above the surface of the crater in a grid pattern. *ABE*’s instrumentation includes a fluxgate magnetometer, swath (wide-angle) bathymetry using multibeam sonar, and instruments to measure conductivity, temperature, depth, and water chemistry. *ABE* assesses its relationship to the sea floor to within several meters by using sonar and satellite guidance systems. Typically it operates ~ 25 m above the sea floor on a programmed path for up to 16 hours before surfacing to recharge its batteries.

The other submersible was a new remotely operated, tethered vehicle–the *SeaQuest 6000.* It connects to the ship by a fiber-optic cable, contains numerous instruments, and carries manipulator arms and video cameras. Available reports noted that on the cruise, *SeaQuest 6000* examined previously identified seafloor features in more detail.

References: de Ronde, C. E. J. , Hannington, M.D., Stoffers, P., Wright, I.C., Ditchburn, R.G., Reyes, A.G., Baker, E.T., Massoth, G.J., Lupton, J.E., Walker, S.L., Greene, R.R., Soong, C.W.R., Ishibashi, J., Lebon, G.T., Bray, C.J., and Resing, J.A., 2005, Evolution of a Submarine Magmatic-Hydrothermal System: Brothers Volcano, Southern Kermadec Arc, New Zealand: Economic Geology, v. 100, no. 6, p. 1097-1133.

Smith, W. H. F., and Sandwell, D.T., 1997, Global seafloor topography from satellite altimetry and ship depth soundings: Science, v. 277, p. 1957-1962, 26 Sept. 1997.

Geologic Summary. The submarine Brothers volcano, located NE of the Healy submarine volcano, contains an oval-shaped summit caldera 3-3.5 km wide. The volcano is elongated in a NW-SE direction, and the high point of the dominantly dacitic volcano lies on the NW caldera rim at about 1,350 m below the sea surface. The caldera floor is at about 1,850 m depth, and a post-caldera lava dome was constructed on the southern caldera floor and partially merges with the southern caldera wall. Brothers volcano displays major submarine hydrothermal activity, including a large field of "black smoker" vents on the NW caldera wall and vents on the post-caldera dome.

Information Contacts: *Institute of Geological and Nuclear Sciences (GNS)*, Private Bag 2000, Wairakwi, New Zealand (URL: http://www.gns.cri.nz/); *The Leibniz Institute for Sea Sciences at the University of Kiel, IFM-GEOMAR*, Kiel, Germany; *US National Oceanic and Atmospheric Agency (NOAA)* (URL: http://www.oceanexplorer.noaa.gov/explorations/); *Woods Hole Oceanographic Institution*, Woods Hole, MA 02543 USA (URL: http://www.whoi.edu).

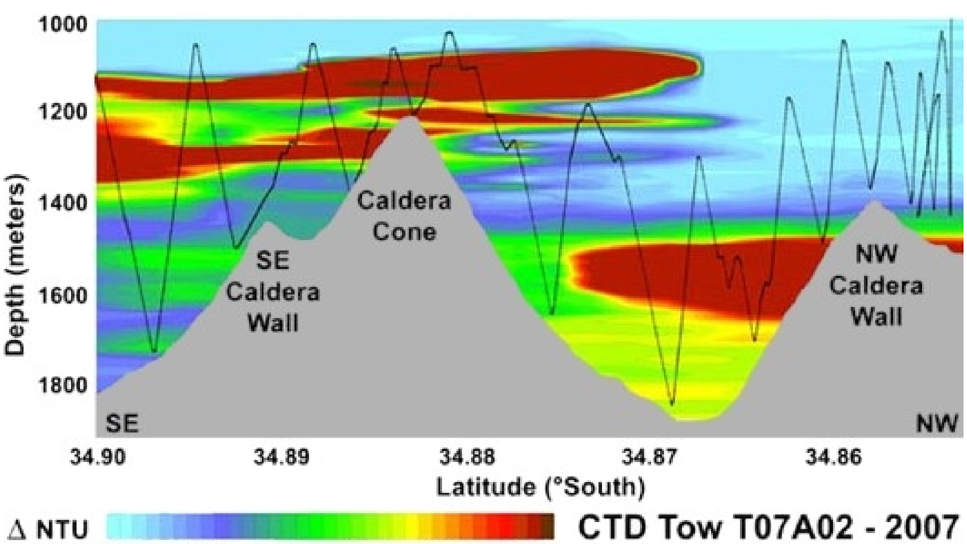

Figure 13. A cross-section depicting the sea-floor topography and the result of light-scattering measurements (turbidity of the water column) at Brothers, drawn from SE to NW. Bottom topography (exaggerated) is shown corresponding to the scale at left. Shading indicates the level of turbidity (i.e., cloudiness, haziness, or lack of clarity) as measured in the change in (delta) nephelometric turbidity units (△NTU), a nondimensional optical standard contrasting measured turbidity to that of local ambient water. High △NTU values indicate increased particulate within the hydrothermal plume. Note the regions of high △NTU adjacent the NW caldera wall and the summit of the caldera cone, areas indicated as focal points for hydrothermal venting. The thin black line traces the path of the CTD (conductivity/temperature/depth) sensors towed at various depths along the cross-section. Image courtesy of New Zealand American Submarine Ring of Fire 2007 Exploration.

Poás

Costa Rica
10.20°N, 84.233°W; summit elev. 2,708 m
All times are local (= UTC - 6 hours)

Minor phreatic eruptions occurred during 25-26 September 2006 (*BGVN* 31:08). This report provides more information compiled by the Observatorio Vulcanologico y Sismologico de Costa Rica-Universidad Nacional (OVSICORI-UNA). At the beginning of September, the level of the lake had dropped 5 cm from that of early August, it was light gray in color with sulfur particles floating on the surface, and the temperature was 41º C. On 21 September, the lake had a milky, light blue color.

On 25 September at 2148, seismic station POA2 (2.7 km SW of the active crater) registered a high-frequency signal. The phreatic event that caused the signal ejected a column of fine materials (lake sediments) that were blown SW to a distance of 12 km from the crater. Afterwards the lake color was a darker gray with dark particles floating on the surface; the temperature was 46ºC.

New points of fumarolic activity appeared in the SE and NE walls and in the floor of the crater with deposition of sulfur and gas discharge. The temperatures in these areas fluctuated between 90 and 108ºC, with gas columns that reached the edge of the crater. Existing cracks in the crater terrace and the NE edge of the crater continued to widen with gas discharge and sulfur-rich sublimate deposition.

Geologic Summary. The broad, well-vegetated edifice of Poás, one of the most active volcanoes of Costa Rica, contains three craters along a N-S line. The frequently visited multi-hued summit crater lakes of the basaltic-to-dacitic volcano, which is one of Costa Rica's most prominent natural landmarks, are easily accessible by vehicle from the nearby capital city of San José. A N-S-trending fissure cutting the 2708-m-high complex stratovolcano extends to the lower northern flank, where it has produced the Congo stratovolcano and several lake-filled maars. The southernmost of the two summit crater lakes, Botos, is cold and clear and last erupted about 7500 years ago. The more prominent geothermally heated northern lake, Laguna Caliente, is one of the world's most acidic natural lakes, with a pH of near zero. It has been the site of frequent phreatic and phreatomagmatic eruptions since the first historical eruption was reported in 1828. Poás eruptions often include geyser-like ejections of crater-lake water.

Information Contacts: *Observatorio Vulcanologico Sismologica de Costa Rica-Universidad Nacional (OVSICORI-UNA)*, Apartado 86-3000, Heredia, Costa Rica. (URL: http://www.ovsicori.una.ac.cr/).

Concepción

Nicaragua
11.538°N, 85.622°W; summit elev. 1,700? m
All times are local (= UTC - 6 hours)

An eruption in late July 2005 caused ashfall on the island and adjacent mainland (*BGVN* 30:07). Intermittent eruptions were ongoing through 10 November 2005. After that time the Nicaraguan Institute of Territorial Studies (INETER) did not report further volcanism again until September 2006. The following information is from INETER.

Activity during August-November 2005. On 19 August, an explosion of gas and ash resulted in ashfall in nearby communities. One official stated that the explosion was felt throughout the entire island. Scientists using a correlation spectrometer (COSPEC) on loan from the Institute of National of Seismology Volcanology, Meteorology and Hydrology of Guatemala (INSIVUMEH) measured an SO_2 flux of 400 metric tons per day. The sulfur dioxide levels did not pose an immediate risk to the population. Two explosions on 29 August were followed by seismic tremor and the discharge of gas and ash. The ash reached a height of at least 1 km and ashfall was reported in the community of Altagracia, 5-6 km NE from the summit.

No activity was reported during September, but on 12 October another explosion ejected gas and ash, and ashfall was reported in several communities. In Altagracia, a strong smell of sulfur was reported. The next activity was reported on 4, 6, 8, and 10 November, when explosions and seismic tremor occurred with strong and prolonged discharge of gas and ash. Ashfall was reported in a number of nearby communities. On some days in early November island residents observed the ejection of incandescent material from the crater.

Activity during September 2006-July 2007. On 1 September 2006 the seismic station located on the island N of the volcano detected four seismic events possibly related to explosions in the crater. The earthquakes were not felt by the population, but inhabitants of La Flor (5 km NW) and San Marcos (6 km NNW) reported the smell of sulfur and noted minor ashfall. During the night of 19 September 2006 the seismograph on the Island of Ometepe registered volcanic activity from the NW slope that lasted approximately 40 minutes. On 21 September INETER reported three explosions. A seismic event of low magnitude at 1321 was registered that served as a precursor to a series of three explosions. The three explosions occurring from 1330 (nine minutes after the seismic event) to 1337 produced a column of gases and ash seen across southern Nicaragua, including the city of Granada (56 km NW), and local authorities reported ashfall in Moyogalpa (8 km W), Bethlehem, and Potosí (28 km W).

After almost four months with no reported activity, on 9 February 2007 INETER noted that increased volcanic activity began at 1045. Explosions in the crater ejected gas and ash. The plumes drifted WSW at low altitudes. Activity continued the next day with small explosions of gas and ash from the crater. The plumes again remained at low levels and dropped ash on the WSW flanks. No seismic events were registered by the seismic station.

The seismic station recorded a crater explosion on 8 April that sent a gas-and-ash plume to a height of ~ 1 km and drifted W. On 22 April, two successive evening explosions recorded seismically expelled gas and volcanic ash that drifted SW. More than two months of quiet was again broken by an explosions on 10 July that expelled a moderate amount of gas and ash NW, depositing ash in Moyogalpa and La Flor .

Geologic Summary. Volcán Concepción is one of Nicaragua's highest and most active volcanoes. The symmetrical basaltic-to-dacitic stratovolcano forms the NW half of the dumbbell-shaped island of Ometepe in Lake Nicaragua and is connected to neighboring Madera volcano by a narrow isthmus. A steep-walled summit crater is 250 m deep and has a higher western rim. N-S-trending fractures on the flanks of the volcano have produced chains of spatter cones, cinder cones, lava domes, and maars located on the NW, NE, SE, and southern sides extending in some cases down to Lake Nicaragua. Concepción was constructed above a basement of lake sediments, and the modern cone grew above a largely buried caldera, a small remnant of which forms a break in slope about halfway up the N flank. Frequent explosive eruptions during the past half century have increased the height of the summit significantly above that shown on current topographic maps and have kept the upper part of the volcano unvegetated.

Information Contacts: *Instituto Nicaraguense de Estudios Territoriales (INETER)*, Volcanology Department, Apartado 2110, Managua, Nicaragua (URL: http://www.ineter.gob.ni/geofisica/vol/concepcion/concepcion.html).

Figure 14. The yellowish-green acid crater lake of Santa Ana volcano as seen when viewed on 28 June 2007 looking towards the N. Photo taken by Anna Colvin.

Santa Ana

El Salvador
13.853°N, 89.630°W; summit elev. 2,381 m
All times are local (= UTC - 6 hours)

Researchers from Michigan Technological University (MTU) and Servicio Nacional de Estudios Territoriales (SNET) visited the crater of Santa Ana on 28 June and 5 July 2007 to measure crater lake and fumarole temperatures, and to carry out routine water sampling.

Crater lake. The crater lake appeared yellowish-green and had a maximum temperature of 57.5 ºC, measured by a thermocouple at the northern shore. The crater lake was observed to have shifted westward in position since the 1 October 2005 eruption, drowning the main pre-eruption fumarole field to the W and receding from its eastern border (figure 14). A subaqueous hot spring was observed in the center of the lake at the end of a peninsula of exposed sediments (figure 15). The hot spring exhibited episodic pulses of bubbling water about every 5 minutes.

Figure 15. Hot spring emerging in the acid lake at Santa Ana as seen 5 July 2007. Episodic upwelling of whitish fluid radiated out from the base of the large rock in the center of the photo. View is towards the SW; note geologist for scale. Photo taken by Matt Patrick.

Fumaroles. Crater fumaroles were observed to the W and S of the crater lake, and weak fumaroles were also observed on the upper wall above the flat area and below the SW crater rim. The southern crater fumaroles and the upper fumaroles were measured by thermocouple and radiometer (Extech 42545) (figure 16). Fumaroles to the W were not measured due to limited accessibility.

The seven largest southern crater fumaroles were measured along an E-W transect. The lower fumaroles emitted mainly water vapor, though some sulfur crys-

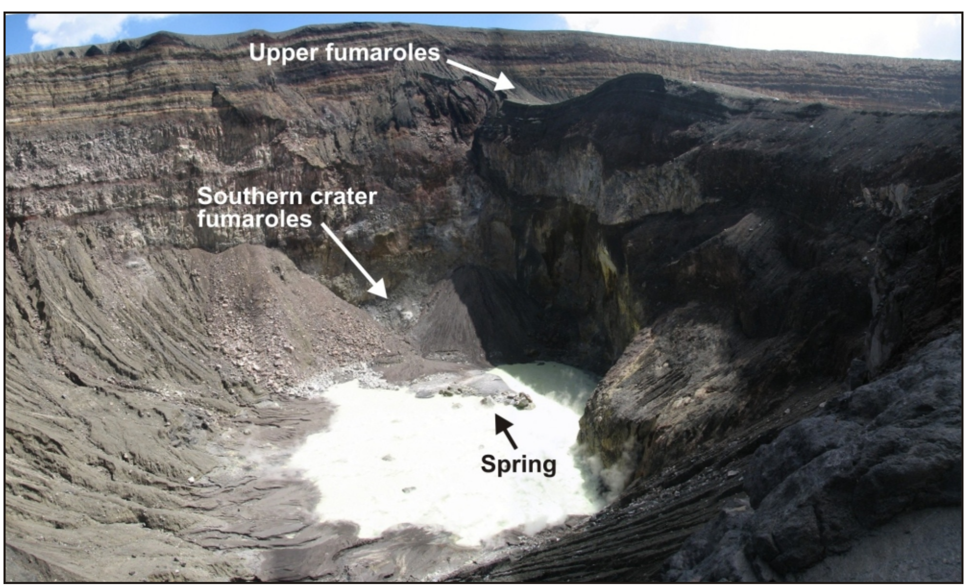

Figure 16. At Santa Ana, the location of fumarole measurements and the hot spring shown in the previous figure. View is towards the SW. Photo mosaic taken 5 July 2007 by Matt Patrick.

tals and a weak sulfurous smell were present. Lower fumaroles temperatures ranged from 92.0 to 95.2 ºC, and thermocouple and radiometer measurements agreed very well (to within 3%). The upper fumaroles were diffuse and relatively weak, occurring in loosely consolidated tephra. The upper fumaroles emitted mainly water vapor and lacked sulfur deposits or sulfurous smell. Upper fumaroles temperatures ranged from 70.0 to 79.0 ºC, and thermocouple and radiometer measurements agreed well (to within 6%).

Geologic Summary. Santa Ana, El Salvador's highest volcano, is a massive, 2,381-m-high andesitic-to-basaltic stratovolcano that rises immediately W of Coatepeque caldera. Collapse of Santa Ana (also known as Ilamatepec) during the late Pleistocene produced a voluminous debris avalanche that swept into the Pacific Ocean, forming the Acajutla Peninsula. Reconstruction of the volcano subsequently filled most of the collapse scarp. The broad summit of the volcano is cut by several crescentic craters, and a series of parasitic vents and cones have formed along a 20-km-long fissure system that extends from near the town of Chalchuapa NNW of the volcano to the San Marcelino and Cerro la Olla cinder cones on the SE flank. Historical activity, largely consisting of small-to-moderate explosive eruptions from both summit and flank vents, has been documented since the 16th century. The San Marcelino cinder cone on the SE flank produced a lava flow in 1722 that traveled 13 km to the E.

Information contacts: *Demetrio Escobar* and *Francisco Montalvo*, Servicio Nacional de Estudios Territoriales, SNET, Km. 5 1/2 carretera a Santa Tecla y Calle las Mercedes, contiguo a Parque de Pelota, Edificio SNET, Apartado Postal #27, Centro de Gobierno, El Salvador 2283-2246 (URL: http://www.snet.gob.sv/); *Matthew Patrick* and *Anna Colvin*, Dept. of Geological and Mining Engineering and Sciences, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931, USA.

Uzon

Kamchatka Peninsula, Russia
54.50°N, 159.97°E; summit elev. 1617 m
All times are local (= UTC +12 hours)

On 3 June 2007 the renowned Valley of Geysers in Kamchatka was seriously damaged by direct burial and subsequent flooding associated with a major landslide. This was communicated in a report from 28 June by the father-and-son team of Vladimir and Andrei Leonov. The Valley of Geysers is a remote geothermal area along a 4-km-long valley near the E margin of Geyzernaya caldera at Uzon-Geyzernaya volcano-tectonic depression ("U"; Leonov and others, 1991) (figure 17).

Although the name Uzon is intrenched in the literature, the shorthand is potentially confusing since it could refer to the caldera on the W side of the complex. Both Uzon and Geyzernaya calderas support hydrothermal systems feeding thermal features. Moreover, a small cone named Uzon resides on the W rim of Uzon caldera. Accordingly, in this report we will refer to the larger complex as Uzon-Geyzernaya. The landslide which entered the Valley of Geysers is refered to as the 2007 Geyzernaya landslide.

The area where the slide occurred was the subject of a recent paper (discussed below) on satellite-detected uplift on the same E side of the caldera where the slide took place (Lundgren and Lu, 2006). "I_c" indicates the approximate center of inflation detected by satellite radar interferometry using data from 2000 to 2003 (Lundgren and Lu, 2006).

According to the Leonovs' report, several beautiful geysers have been lost, including Pervenets, the first geyser discovered by Tatyana Ustinova in 1941, and a group of geysers known as Troynoy group. The main geyser field, Vitrazh, and the largest geyser, Velikan, remained intact (table 2 and figure 18).

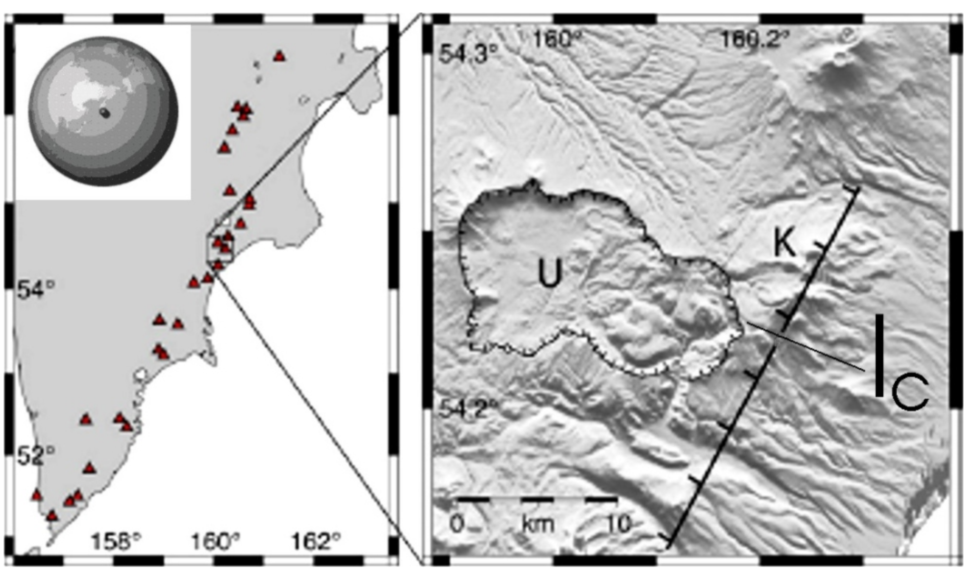

Figure 17. Maps showing Uzon-Geysernaya volcano-tectonic depression on the Kamchatka Peninsula, Russia. (left) Index map of the Kamchatka Peninsula, in the NW Pacific area, showing Holocene volcano locations. (right) Shaded relief map highlighting the topographic margins of the Uzon-Geysernaya volcano-tectonic depression ("U") and the Kikhpinych stratovolcano ("K"), one of the youngest in Kamchatka's eastern volcanic zone; the hachured line indicates the SE side of a regional graben. "I_c" indicates the center of inflation. World inset location map courtesy of NASA Earth Observatory. Main maps are from Lundgren and Lu (2006), but the right map was revised by *Bulletin* editors to add the location and I_c symbol based on interferograms in that paper.

The landslide formed in the upper reaches of Vodopadny creek. The authors suggested that the main cause of the slide appeared to be the common process of gradual erosion. The nearest seismic instrument was ~ 100 km away; on that instrument at the time of the slide's onset, earthquakes were absent.

Correspondence with Vladimir Leonov on 11 September revealed that the slide's computed volume was then considered to be 12-15 million cubic meters. The report also stated that this was clearly the largest historical slide in Kamchatka and possibly one of the largest in all of Russia. Later correspondence clarified this comparison as excluding debris-avalanche deposits such as those associated with lateral blasts closely associated with eruptions in 1980 at St. Helens and in 1956 at Bezymianny.

The landslide of rock and mud went down the Vodopadny creek, reached the Geyzernaya river, and moved along the river to its inflow into the Shumnaya river (figures 18-20). The slide was ~ 2 km in length. A dam was formed on the Geyzernaya river with a height of up to 60 m that caused a rapid backup of water and the formation of a lake. The lake flooded the geysers Bolshoi and Maly located up the river and came close to the main "Vitrazh" geyser field. On 7 June the water level in the lake reached its maximum elevation of 435 m. Later that day the river eroded through the dam and the water level started to decline quickly. During the first four hours the water level subsided to 9 m depth. As of 28 June the main group of geysers appeared safe from flooding.

In the flooding of the Bolshoi and Maly geysers, Bolshoi ended up 2 m under water, and Maly, 15 m under water. In addition, several smaller geysers–Skalisty (Rocky), Konus (Cone), Bolshaya Pechka (Gross Owen)–were also flooded. The pulsating spring Malakhitovy Grot (Malachite Grotto) was half-flooded and sometimes boiled.

On 7 June a new geyser appeared in the Valley but it was active for only several hours. While the water level in the lake increased, a pulsating spring in front of Shchel geyser (perhaps The Little Prince) started to work as a geyser with eruption heights of 4-5 m. After the water level dropped, the geyser returned to a pulsating spring state.

One of the landslide’s tongues came close to tourist-camp buildings in the Geyser Valley (figures 18-22). Although some camp facilities were destroyed, three main houses (a hostel, a scientist’s house, and a ranger’s house) were undamaged. As seen in figures 21 and 22, the edge of the slide reached within about a meter of the hostel and covered parts of the adjacent wood-decked walkway. People occupied buildings when the landslide occurred but the slide halted at a point where no one was injured.

At the time of the slide, a tourist group consisting of over 20 people were in the Valley, but fortunately they were at the thermal field near the river, and only helicopter pilots and some personnel remained at the camp. In addition to stopping near the buildings, the body of the lanslide

Figure 18. An oblique aerial view created on a base map from Google Earth software, depicting the Valley of Geysers looking E (N is to the left). The slide area and direction of flow are clearly marked, the mass having swept down the caldera’s E wall. The topographically flat area in the upper right is the Pacific ocean. Note lodge at small icon in the form of a house. Thermal features indicated by symbol for spring (small circles with tail); many of these are numbered. The image also shows where the slide dammed the Geyzernaya river; the resulting lake submerged the Bolshoi and Maly geysers. Courtesy of Vladimir and Andrei Leonov.

stopped 1 m before the resting helicopter, but trees carried by the slide jutted out and entangled the helicopter.

The 30-m waterfall at the Vodopadny creek junction with Geyzernaya river was fully covered as well as the geyser near the waterfall. The "Thirty-meter rocks" at the entrance to the Geyser Valley were also covered by the landslide. All the small geysers, springs and thermal fields along Vodopadny creek were lost; however, the creek itself established a new course on the slide’s surface.

Overall assessment. Eight large geysers were still functioning at the time of the report, about half of the main geysers that existed before the landslide (table 2). Five of these still working geysers were in the Vitrazh field (Grot, Fontan, Novy Fontan, Dvoynoi, and Nepostoyanny). The three others also still working were Velikan, Zhemchuzhny, and Shchel (the latter, initially submerged but by mid-September was 8 m above the lake level and seemingly returned to normal behavior.

Four large geysers were flooded by the lake (Bolshoi, Maly, Skalisty, Konus). Four were destroyed by the slide (Pervenets, Troynoi, Sakharny, and Sosed).

The Geyzernaya river found a new course on the landslide’s surface. Caves developed on the slide’s surface hosted small lakes. In several places on the river banks observers saw the emergence of earth slumps and new boiling springs (figure 23).

Other information. Igor Shpilenok, a nature photographer, has posted on the web a suite of impressive before-and-after pho-

Number	Status	Name	English translation of name
1	Covered by slide	Pervenets	First born
2	Covered by slide	Troynoi	Triple
3	Covered by slide	Sakharny	Sugar
4	Covered by slide	Sosed	Neighbor
5	Covered by slide	Uvodopada	Near the waterfall
6	Flooded by lake	Skalisty	Rocky
7	Flooded by lake	Konus	Cone
8	Flooded by lake	Bolshaya Pechka	Gross Owen
9	Flooded by lake	Maly	Lesser
10	Flooded by lake	Bolshoi	Greater
11	Active mid-Sep	Shchel	Crack
12-16	Active on 28 Jun	“Vitrazh” geyser field: Grot, Novy Fontan, Fontan, Dvoynoi, Nepostoyanny	“Stained glass” geyser field: Grotto, New Fountain, Fountain, Double, Unstable
17	Active on 28 Jun	Velikan	Giant
18	Active on 28 Jun	Zhemchuzhny	Pearl

Table 2. Summary and key to names and numbers for Valley of Geysers, about half of which were disrupted or destroyed by the 2007 Geyzernaya landslide. The numbers correspond with those on figures 18 and 19. Courtesy of Vladimir and Andrei Leonov.

tos. The photos include shots of the upland area that spawned the landslide prior to the event.

On 20 June, Jesse Allen from NASA published an article about the slide discussing a satellite image of the area captured on 11 June. He noted "The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on NASA's Terra satellite captured this infrared-enhanced image on [11 June] 2007, a week after the slide. The image shows the valley, the landslide, and the new thermal lake. Even in mid-June, just days from the start of summer, the landscape is generally covered in snow, though the geologically heated valley is relatively snow free. The tree-covered hills are red (the color of vegetation in this false-color treatment), providing a strong contrast to the aquamarine water and the gray-brown slide.

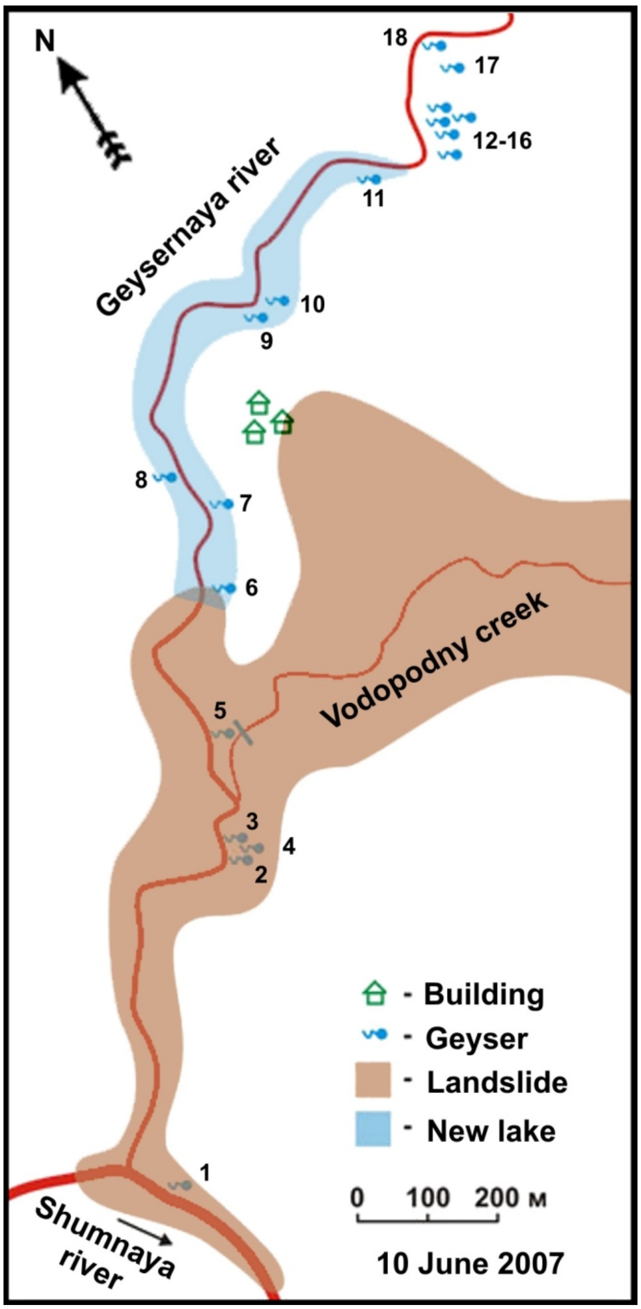

Figure 19. Sketch map on 10 June 2007 showing features after the Geyzernaya landslide. N is to the upper right. The numbers correspond to those on table 2. Courtesy of Vladimir and Andrei Leonov.

Figure 20. A photo looking down at the 2007 landslide from the NE rim of the Valley of Geysers. The lower portion of the landslide dammed the Geyzernaya river and backed up a lake. A surviving cluster of tourist facilities are at the slide's margin. From the Leonov's report; copyrighted photo by I.F. Delemen, Institute of Volcanology and Seismology, Far Eastern Branch of Russian Academy of Sciences (IVaS FEB RAS).

Figure 21. The landslide in the Valley of Geysers left the hostel at the tourist camp just barely outboard of the deposit. The juxtaposition of the deposit and unscathed building reveals the deposit's unsorted character and clast-size distribution, which includes some large blocks several meters in diameter. This photo was shot from ten's of meters away from the hostel. Photo is from the Leonov's report; copyrighted by I.F. Delemen (IVaS FED RAS).

Figure 22. Landslide rubble came to rest near the hostel's side wall. From the Leonov's report; copyrighted photo by I.F. Delemen (IVaS FED RAS).

Figure 23. At Uzon boiling springs and plumes emerged along the banks of the dammed Geyzernaya river after the new lake's water level dropped. Copyrighted photo by Igor Shpilenok; taken from the Leonovs' report.

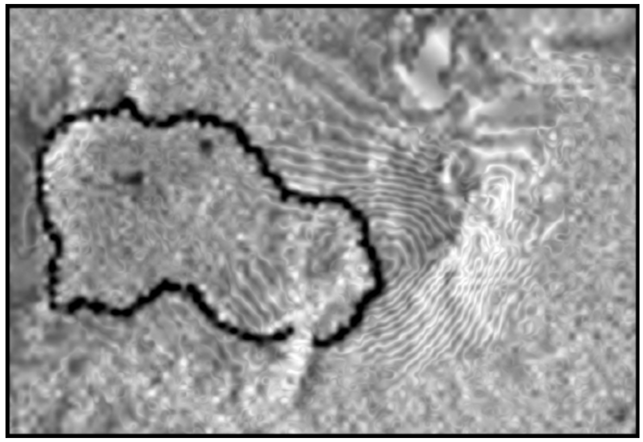

Figure 24. A radar interferogram for Uzon and vicinity showing over 10 cm of uplift centered on the caldera's E rim. The image was also associated with a stated perpendicular baseline Bp=58 and RADARSAT-1 beam and surface-incidence angle from vertical for Beam 4 of 38°. From Lundgren and Lu (2006; their figure 2c).

Lundgren and Lu (2006) noted that their satellite interferometry data showed significant deformation spanning 2000 to 2003. During that interval, they noted ~ 0.15 m of inflation occurred at Geyzernaya caldera. As previously mentioned, the data indicated an area of uplift centered roughly at point I_c on figure 17. In contrast, during1999-2000, and 2003-2004 the radar data failed to indicate significant deformation. Lundgren and Lu (2006) point out that the surface-incidence angles (angles from the vertical) are nearly as sensitive to horizontal as to vertical displacements in the range direction (to the WNW). Based on the maps by Leonovs shown above, the upper portion of the landslide was directed roughly the same way (NW).

For the 2000-2003 interval, modeling by Lundgren and Lu (2006) suggested the main regions of uplift occured beneath central and eastern parts of the Uzon-Geyzernaya volcano-tectonic depression, with extension beyond the caldera to the NE beneath Kikhpinych volcano. Uplift was bounded to the ESE by the graben (the linear feature cutting E of the caldera in figure 17).

Figure 24 shows synthetic-aperture radar (SAR) interferograms, where each shading cycle represents 2.8 cm of line-of-sight displacement at the surface. Hatched lines indicate the caldera rim. This interferogram stems from radar images during the date range 19 September 2000-11 August 2003. This is only one of several interferograms Lundgren and Lu (2006) presented for the interval of significant surface displacement.

References: Leonov, V.L., Grib, E.N., Karpov, G.A., Sugrobov, V.M., Sugrobova, N.G, and Zubin, Z.I., 1991, Uzon caldera and Valley of Geysers, *in* Active Volcanoes of Kamchatka, edited by S.A. Fedotov and Y.P. Masurenkov, Nauka, Moscow, p. 92-141.

Lundgren, P., Lu, Z., 2006, Inflation Model of Uzon Caldera, Kamchatka, Constrained by Satellite Radar Interferometry Observations: Geophys. Res. Ltrs, 16 March 2006 (Vol. 33, No. 6, L06301, Paper No. 10.1029/2005GL025181) (PDF file currently available at http://volcanoes.usgs.gov/insar/public_files/Lundgren_Lu_Uzon_GRL_2006.pdf).

Geologic Summary. The Uzon and Geyzernaya calderas, containing Kamchatka's largest geothermal area, form a 7 x 18 km depression that originated during multiple eruptions during the upper-Pleistocene. Widespread ignimbrite deposits associated with caldera formation have a volume of 20-25 cu km (exclusive of airfall deposits) and cover an area of 1,700 sq km. Post-caldera activity was largely upper Pleistocene to Holocene in age and consisted of the extrusion of small silicic lava domes and flows and maar formation. The Lake Dal'ny maar in the NE part of the 9 x 12 km western caldera, Uzon, is early Holocene in age. The extensive high-temperature hydrothermal system of the Uzon-Geyzernaya volcano-tectonic depression includes the many hot springs, mudpots, and geysers of the Valley of Geysers, a 4-km-long canyon on the E margin of the depression. A phreatic explosion occurred in 1986 in the western part of the Vostochny thermal field, creating a new 14-m-wide crater.

Information Contacts: *Vladimir L. Leonov* and *Ivan F. Delemen*, Institute of Volcanology and Seismology, Far Eastern Branch of Russian Academy of Sciences (IVaS FEB RAS), 9 Piip Boulevard, Petropavlovsk-Kamchatsky, Kamchatka 683006, Russia; Andrei V. Leonov (Email: spanishflyer@gmail.com; URL: http://www.kscnet.ru/ivs/expeditions/2007/Geyser_Valley-06-2007/Geyser_Valley-06.htm); *Igor Shpilenok*, Russian Nature Photography, Chukhrai, Suzemsky raion, Bryansk oblast, 242181, Russia (URL: http://www.shpilenok.com/html/contact.htm); *Jesse Allen*, NASA Earth Observatory (URL: http://earthobservatory.nasa.gov/).