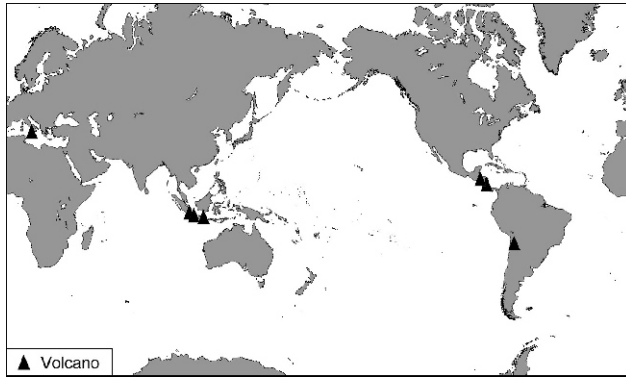


Bulletin of the Global Volcanism Network

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National Museum of Natural History

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Etna

Italy

37.734°N, 15.004°E; summit elev. 3,330 m

All times are local (= UTC + 2 hours)

Although *BGVN* 32:08 discussed the eruption of 4-5 September 2007, this report goes on to more fully describe Etna's lava fountaining at the Southeast Crater (SEC) observed during that eruption, and also adds other details such as a map of the resulting lava flow. The fountain associated with the eruption was spectacular, though by far not the tallest seen on Etna (that was 8 years earlier, on 4 September 1999, at the Voragine, when a fountain rose over 2 km high). The fountaining lasted a full 10 hours, whereas most other recent fountains on Etna only lasted 15-20 minutes.

As background, Etna became active on 15 August 2007 following four eruptive episodes on these dates: 29 March 2007, 11 April, 29 April, and 6-7 May 2007. At the end of August, ash emissions were nearly entirely replaced by Strombolian activity.

The header at the top of this report contains a new summit elevation corrected to the latest LIDAR (light detection and ranging) data, which was acquired in the Spring of 2007. It revises an older estimate of 3,350 m to 3,330 m.

A significant increase in tremor amplitude took place at ~1600 on 4 September. After that, a sustained lava fountain rose from the SEC's August-September vent, jetting to 400-600 m above the vent for the next ~10 hours (figure 1). A dense tephra plume blew E toward the Ionian Sea. Lava flowed over the vent's E and SE rims, initially forming three branches that coalesced at a short distance from the SEC and descended as a single flow toward the Valle del Bove, to a distance of 4.6 km (figure 2).

Heavy showering of tephra occurred on the E flank in the areas between the towns of Fornazzo, Milo, and Giarre. As a precaution, the International Airport of Catania was closed for a few hours early on 5 September.

Renewed activity at Etna in late September and early October was similar to that seen in mid-August; incandescence was noted in some of the emissions in early-mid October. Observations were frequently hampered by bad weather, but as of 22 October, sporadic emissions continued without significant variations in their intensity.

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 of Etna is the Valle del Bove, a 5 x 10 km horseshoe-shaped caldera open to the east. 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.

References: Behncke, B., and Neri, M., 2007, L'eruzione del 4-5 settembre 2007 al Cratere di Sud-Est (Etna): osservazioni di terreno in prossimità della bocca



Figure 1. Lava fountain and flow emitted at the SEC on 4 September 2007. The photo was taken from the Acireale in Catania, ~20 km SE of Etna. Courtesy of INGV-CT and Alfio Amantia (credit on the photo).

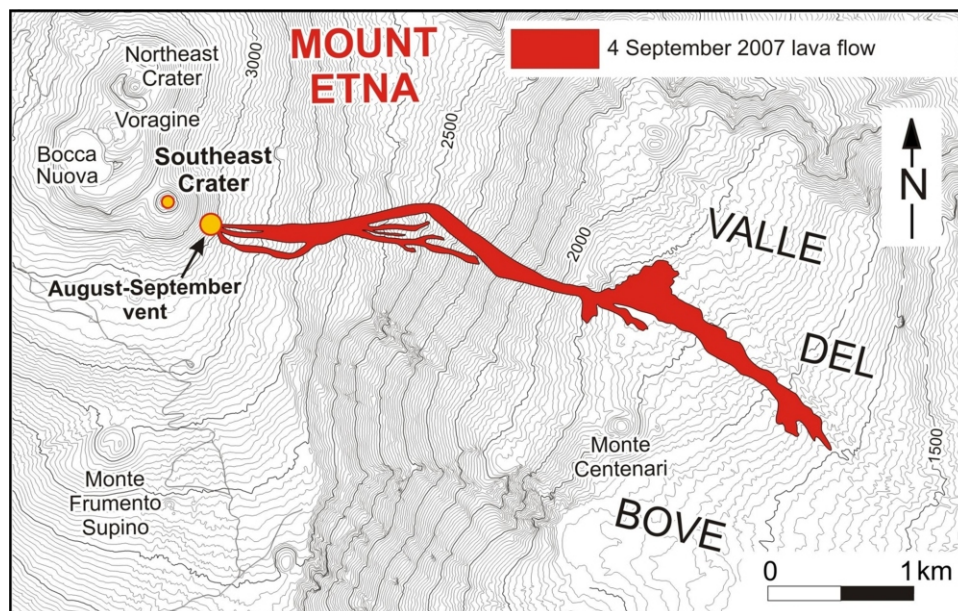


Figure 2. Preliminary map of Etna's lava flow emitted during the 4-5 September 2007 lava fountain of the Southeast Crater. The eruptive August-September vent is indicated on the eastern slope of the Southeast Crater cone. Courtesy of Boris Behncke and Marco Neri (INGV).

eruttiva. Report published on-line at: <http://www.ct.ingv.it/Report/RPTVGSTR20070906.pdf>.

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Information Contacts: Boris Behncke and Marco Neri, Istituto Nazionale di Geofisica e Vulcanologia (INGV), Sezione di Catania, Piazza Roma 2, 95123 Catania, Italy.

San Miguel

El Salvador

13.434°N, 88.269°W; summit elev. 2,130 m

All times are local (= UTC - 6 hours)

A sudden increase in seismicity occurred on 9 October 2006 but no landslides or rock falls were associated with the event and it was attributed to gas emissions in the crater (BGVN 31:10). This report carries on from 9 October 2006.

During the morning of 10 October 2006, seismic activity declined to a continuous vibration with an amplitude that oscillated between 50 and 75 RSAM (real-time seismic amplitude measurement) units. This condition continued until 0600 on 11 October, when the seismicity increased to 125 continuous RSAM units.

The responsible authorities issued an alert that encompassed an area within 4 km from the center of the crater. Because of the elevated energy level of seismicity relative to the previous activity, the National Service of Territorial Studies elected to monitor the volcano and report developments to the National System of Civil Defense.

As of 15 October 2006, the level of activity at San Miguel was considered to be moderate, implying the possibility of an eruption sometime in the next several months. The civil defense authorities established a Yellow alert level (phase 3) for the area within 4 km of the crater center but later reduced it to Green. Around 15 October the RSAM continued to vary from 8 units to 45 units. During the preceding 24 hours, 55 earthquakes were registered; however, none were noticed by the local population. Sulfur dioxide



Figure 3. View of the crater at San Miguel, looking S on 4 July 2007. The whitish area in the bottom right of the photo reflects steaming from the main fumarole field. Courtesy of Servicio Nacional de Estudios Territoriales (SNET) and Michigan Technological University.



Figure 4. View of the W side of San Miguel's crater, taken from the N rim. Fumaroles 1 (F1) and 2 (F2) are in the right central portion of the image. Courtesy of Servicio Nacional de Estudios Territoriales (SNET) and Michigan Tech University.

(SO₂) fluxes reached 150-250 metric tons per day, which was considered a low level. On 16 October, tremor fluctuated between 45 and 50 units, and 25 earthquakes were recorded but not felt by residents.

The period from the October 2006 activity through July 2007 was essentially devoid of any abnormal variations in seismicity, volcanism, or elevated gas emissions.

On 4 July 2007, volcanologists from Servicio Nacional de Estudios Territoriales (SNET) and Michigan Technological University climbed San Miguel to make observations and take fumarole temperatures. The volcano remained at a low level of activity. The crater morphology and the intensity and location of fumaroles within the crater remained similar to that observed in recent visits (e.g., October 2006 BGVN 31:10). The main fumarolic area was near the bottom of the crater on the S wall (figure 3). Other sparse fumaroles were present, with most clustered near the crater bottom and on the crater's W wall.

Fumarole measurements: Temperatures were measured at two fumarolic areas on the upper W crater wall (figure 4). These are visited by SNET on a regular basis and comprise the only fumaroles safely accessible from the rim. Temperatures at fumaroles 1 and 2 were 67°C and 57°C, respectively. The gas lacked any sulfurous smell, suggesting water vapor only. These fumarole temperatures are similar to those measured in recent visits.

Geologic Summary. The symmetrical cone of San Miguel volcano, one of the most active in El Salvador, rises from near sea level to form one of the country's most prominent landmarks. The unvegetated summit of the 2,130-m-high volcano rises above slopes draped with coffee plantations. A broad, deep crater complex that has been frequently modified by historical eruptions (recorded since the early 16th century) caps the truncated summit of the towering volcano, which is also known locally as Chaparrastique. Radial fissures on the flanks of the basaltic-andesitic volcano have fed a series of historical lava flows, including several erupted during the 17th-19th centuries that reached beyond the base of the volcano on the N, NE, and SE sides. The SE flank lava flows are the largest and form broad, sparsely vegetated lava fields crossed by highways and a railroad skirting the base of the volcano.

The locations of successive flank vents have progressed during historical time, shifting to higher elevation.

Information Contacts: *Eduardo Gutierrez*, *Demetrio Escobar*, and *Francisco Montalvo*, Servicio Nacional de Estudios Territoriales (SNET), Km. 5 ½ carretera a Santa Tecla y Calle las Mercedes, contiguo a Parque de Pelota, Edificio SNET, Apartado Postal #27, Centro de Gobierno, El Salvador (URL: <http://www.snet.gob.sv/>, Email: egutierrez@snet.gob.sv, descobar@snet.gob.sv, fmontalvo@snet.gob.sv); *Matthew Patrick* and *Anna Colvin*, Dept. of Geological and Mining Engineering and Sciences, Michigan Tech University, 1400 Townsend Drive, Houghton, MI 49931, USA (Email: mpatrick@mtu.edu, ascalvin@mtu.edu).

References: Chesner, C.A., Pullinger, C., Escobar, C.D., 2003, Physical and chemical evolution of San Miguel Volcano, El Salvador. GSA Special Paper 375.

Escobar, C.D., 2003, San Miguel Volcano and its Volcanic Hazards: MS thesis, Michigan Technological University, December 2003, 163 p.

Major, J.J., Schilling, S.P., Pullinger, C.R., Escobar, C.D., Chesner, C.A., and Howell, M.M., 2001, Lahar-Hazard Zonation for San Miguel Volcano, El Salvador: U.S. Geological Survey Open-File Report 01-395 (Available on-line).

Arenal

Costa Rica

10.463°N, 84.703°W; summit elev. 1,670 m

All times are local (= UTC - 6 hours)

Since our last report on Arenal in 2005 (*BGVN* 31:10), silicic lava emissions were continuous with some occasional more intense periods, including events in May 2006 and September 2007. The agency OVSICORI-UNA noted that from October 2005 through September 2007 the generally low level of activity at the main vent area at Crater C was characterized by continuous emissions of lava, gases, and periodic strombolian eruptions. Pyroclastic flows were occasionally produced, the result of collapse of an active lava flow front. The volcanism was accompanied by characteristic seismic activity, which is indicated in table 1 for the interval September 2005 - December 2006. During this period, Crater D displayed fumarolic activity only; accordingly, the discussion below focuses on activity at Crater C and the Arenal edifice. Note that during the reporting interval, the directions of materials descending the flanks has shifted from time to time.

During October and November 2005, lava flows of comparatively low volume occurred on the cones's SW, W, and NW flanks. In early November, an incandescent pyroclastic flow descended the cone's W flank. Lava continued to descend the SW flank during December and into January 2006 and new flows also took paths down the W and NW flanks. Blocks of lava on the SW and NW flanks tumbled down the slopes, shifting primarily to the N and NE flanks in February. Wherever these viscous blocks of lava detached and tumbled down the flanks of the cone, they started small fires in areas of vegetation.

Mild activity continued through March, April, and the beginning of May 2006, with a few sporadic localized in-

creases. In April, the W lava flow temporarily increased in volume for a short while, then ceased. A new flow developed on the N slope.

10 May 2006 pyroclastic flow. On 10 May a significant pyroclastic flow traveled down Arenal's N flank. Tumbling incandescent blocks of lava, with temperatures up to 1,000°C, collided with each other and the slope of the volcano and broke apart, producing great amounts of ash. An ash-and-gas cloud drifted SW. Although the pyroclastic flow was not coupled with any clearly distinguishable recorded seismic event, it descended the slope in an incandescent torrent, burning and devastating everything in its path. On 20 November 2006, the Arenal Mountain Lodge observatory reported suspected tumbling blocks on the S flank.

Small lava flows on the N slope continued through at least February 2007. Sporadically, small avalanches of lava detached from the flow fronts (these events also occurred on the NE and NW slopes), producing small ash columns that seldom exceeded 500 m above the crater rim.

Eliecer Duarte reported a new lava flow moving SW based on his visit of 28 March 2007, when he found Arenal "as energetic as usual" (figure 5). He wrote that the new SW-directed flow was producing a significant amount of debris that rolled down a wide area. Some of the biggest pieces arrived intact at distal vegetated areas, including ~ 2 km maximum from the source vent at crater C. A lava tongue was visible from the tourist and residential areas. Small pyroclastic flows, derived from dome fragments, broke off and produced small clouds of ash that blew W.

OVSICORI-UNA reports noted generally low-level activity at Arenal continued through August and September 2007, with little variation, except for infrequent, more active events (such as the one noted below). Ash emissions and their dispersal were generally nominal. The lava fronts continued to tumble down in small avalanches and slides, sometimes reaching the upper part of the forest on the N side, starting small fires. Eruptions produced ash plumes

Month	Eruption earthquakes	Daily average	LP events	Hours of tremor
Sep 2005	548	18	16	576
Oct 2005	631	20	34	468
Nov 2005	877	29	17	561
Dec 2005	—	—	—	—
Jan 2006	—	—	—	—
Feb 2006	867	31	24	536
Mar 2006	969	39	24	399
Apr 2006	804	28	33	436
May 2006	—	—	—	—
Jun 2006	987	33	14	424
Jul 2006	754	24	37	342
Aug 2006	—	—	—	—
Sep 2006	—	—	—	—
Oct 2006	244	8	2	597
Nov 2006	204	7	—	626
Dec 2006	221	7	—	644

Table 1. Seismic activity registered at Arenal's station VACR, located 2.7 km NE of the active crater, during September 2005-December 2006. Months with "—" indicate that data were not reported for that month. Data were normalized from mean values for months when the station had incomplete data (25 days in March 2006 and 27 days in April 2006). Courtesy of OVSICORI-UNA.



Figure 5. Advancing lava flows (masked by low-hanging dusty plumes) on the SW flanks of Arenal, 28 March 2007. The lava flows generated occasional avalanches, small pyroclastic flows, and block-and-ash flows. The inset photo shows the summit area in clear conditions revealing a spire-encrusted lava dome clinging to the upper flanks. Courtesy of E. Duarte, OVSICORI-UNA.

that rose up to 2.2 km altitude. During September 2007, lava domes, lava flows, and hornitos continued to develop.

18 September 2007 pyroclastic flows. According to Jorge Barquero, at about 1000 on 18 September, eyewitnesses at the Arenal Mountain Lodge observatory saw rocks loosening at the base of the dome, first sending small avalanches S and SW and ultimately dropping sufficient quantities of the dome to form somewhat larger pyroclastic flows. The event was recorded by a local seismograph.

Multiple pyroclastic flows traveled S to a runout distance of ~ 1 km (figure 6). During the night, small avalanches continued sporadically; some resulting explosions contained ash. Explosions occurred that occasionally produced airborne ash. Although mainly small avalanches



Figure 6. A photo of looking straight along the path (and resulting deposits) of the 18 September pyroclastic flow, which traveled directly down Arenal's S flank. The flow had a runout distance of ~ 1 km. Note areas of relatively intact vegetation adjacent the lower portions of the deposit. Courtesy of Jorge Barquero H., Instituto Costarricense de Electricidad (ICE).

were noted, one larger glowing one descended the S flank and at 1930 that evening a large part of the S flank glowed red. By dawn on 19 September observers saw a new lava flow had emerged from Crater C, the front of which soon became the source of rock avalanches.

Geologic Summary. Conical Volcán Arenal is the youngest stratovolcano in Costa Rica and one of its most active. The 1,670-m-high andesitic volcano towers above the eastern 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 Peridos 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 western flank.

Information Contacts: E. Fernández, E. Duarte, W. Sáenz, V. Barboza, M. Martínez, E. Malavassi, and R. Sáenz, Observatorio Vulcanológico Sismológica de Costa Rica-Universidad Nacional (OVSICORI-UNA), Apartado 86-3000, Heredia, Costa Rica (URL: <http://www.ovsicori.una.ac.cr/>; Email: efernan@una.ac.cr, eduarte@una.ac.cr); Jorge Barquero Hernandez, Instituto Costarricense de Electricidad (ICE), Apartado 5 -2400, Desamparados, San José, Costa Rica (Email: jabarque@ice.co.cr).

Poás

Costa Rica

10.20°N, 84.233°W; summit elev. 2,708 m

All times are local (= UTC - 6 hours)

The last *Bulletin* report on Poás provided information on the phreatic eruption on 25-26 September 2006 (BGVN 32:07). This report discusses continuing hydrothermal variations and one minor phreatic eruption (to 30 m above the crater lake) during October 2006 through September 2007. The pyroclastic cone continued fumarolic activity issuing columns of gases that reached 300 to 400 m above the crater. Information for this report were provided by the

Observatorio Vulcanológico y Sismológico de Costa Rica-Universidad Nacional (OVSICORI-UNA).

Crater lake. During the period October 2006 through September 2007, Laguna Caliente the active crater lake of Poás volcano, displayed a greenish-gray color with convection cells in the center and temperatures ranging from 41 to 58 °C. As depicted in table 2, between 5 and 12 October 2006, the temperature and level of the lake increased suddenly suggesting a greater heat flow into the lake. By late October, the temperature decreased slightly and the level of the lake began to fall. Overall, the lake level fell 6.45 m from September 2006 through August 2007, and then stabilized. Often gases originating from the bottom of the lake produced a ring of dark gray material 80 m in diameter floating at the center of the lake. In the NE wall at the lake level, fumaroles produced yellowish particles that floated on the lake.

Small phreatic eruption. According to reports of a park ranger, a phreatic eruption occurred at 1230 on 16 December 2006. The eruption reached a height of 30 m and the erupted material fell back into the lake.

Date	Lake temperature	Relative elevation change in lake surface (meters)
Sep 2006	41°C	—
05 Oct 2006	46°C	—
12 Oct 2006	55°C	+ 0.43 m
27 Oct 2006	53°C	- 0.46 m
Nov 2006	48°C	- 0.33.m
Dec 2006	48°C	—
Jan 2007	—	—
Feb 2007	48°C	- 0.70 m
Mar 2007	49°C	- 1.11 m
Apr 2007	51°C	- 1.18 m
May 2007	27°C	- 1.45 m
Jun 2007	58°C	- 1.58 m
Jul 2007	57°C	- 0.15 m
Aug 2007	58°C	- 0.59 m
Sep 2007	56°C	+ 0.08 m

Table 2. For Poás, the temperature of Laguna Caliente and changes in lake level from September 2006 through September 2007. Courtesy OVSICORI-UNA.

Date	Temperature (°C)
Oct 2006	144°C
Nov 2006	143°C
Dec 2006	—
Jan 2007	—
Feb 2007	124°C
Mar 2007	118°C
Apr 2007	116°C
May 2007	110°C
Jun 2007	117°C
Jul 2007	108°C
Aug 2007	108°C
Sep 2007	67°C

Table 3. Temperature of N terrace fumarole at Poás depositing sulfur during October 2006 through September 2007. Courtesy OVSICORI-UNA.



Figure 7. Fumarolic activity at Poás formed a sulfur cone during late 2006 and into 2007. This shot shows the upper part of the sulfur cone in the left foreground. Parts of the steaming pyroclastic cone and adjacent crater lake appear in the background. Courtesy of OVSICORI-UNA.

Fumaroles. In October 2006 the fumaroles of the N terrace emitted columns of gases and deposits of sulfur forming a small dome. One fumarole produced a whistling noise and had temperature of 144°C. By February 2007, the fumarole cooled to 124°C but continued building a small sulfur cone (figure 7). Sulfur depositions continued through September 2007 when the fumarole closed. Table 3 depicts fumarole temperatures through September 2007.

On the SE and NW walls, hot springs with gas temperatures between 89°C and 94°C also deposited sulfur. By March 2007, the hot springs had largely dried and only two gave off very low volume emissions with a temperature of ~ 55°C. Throughout the reporting period, cracks on the intermediate terrace and on the NE edge of the crater widened with new points of gases appearing and deposition of sulfurous material. By February 2007, emission levels began to diminish, and they continued diminishing through September. Fumarole gas temperatures in this area remained steady at near 94° C.

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 2,708-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 7,500 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: E. Fernández, E. Duarte, W. Sáenz, V. Barboza, M. Martinez, E. Malavassi, and R. Sáenz, Observatorio Vulcanológico Sismológica de Costa Rica-Universidad Nacional (OVSICORI-UNA), Apartado 86-3000, Heredia, Costa Rica (URL: <http://www.ovsicori.una.ac.cr/>; Email: efernan@una.ac.cr, eduarte@una.ac.cr).

Láscar

Northern Chile

23.37°S, 67.73°W; summit elev. 5,592 m

All times are local (= UTC - 4 hours)

Our last *Bulletin* report on Láscar (*BGVN* 31:11) discussed minor explosions and ash plumes during September-October 2006, morphological changes in the central active crater since the May 2005 eruption, and an ongoing investigation on fumarolic gases venting in the active crater.

Reports since November 2006 and into late 2007 indicated that Láscar continued to emit ash plumes. On 22 January 2007, based on satellite imagery, the Buenos Aires Volcanic Ash Advisory Center (VAAC) reported continuous emissions from the volcano that drifted NNE. Then, according to the VAAC, on 11 March 2007 an ash cloud from Láscar rose to 5.5-6.7 km altitude and drifted E. The VAAC's next report on Láscar indicated that on 23 May, an ash plume from Láscar rose to an altitude of 9.1 km and drifted SSE, based upon a Significant Meteorological Information (SIGMET) advisory and satellite image observations. Finally, the VAAC reported that, based on pilot reports and satellite image observations, on 18 July 2007 an ash plume rose to altitudes of 7.6-9.1 km and drifted NE. We have not seen any activity reports on Láscar between this July report and 23 October 2007, perhaps suggesting an absence of unusually vigorous activity during that interval.

Geologic Summary. Láscar is the most active volcano of the northern Chilean Andes. The andesitic-to-dacitic stratovolcano contains six overlapping summit craters. Prominent lava flows descend its NW flanks. An older, higher stratovolcano 5 km to the east, Volcán Aguas Calientes, displays a well-developed summit crater and a probable Holocene lava flow near its summit (de Silva and Francis, 1991). Láscar consists of two major edifices; activ-

ity began at the eastern volcano and then shifted to the western cone. The largest eruption of Láscar took place about 26,500 years ago, and following the eruption of the Tumbres scoria flow about 9000 years ago, activity shifted back to the eastern edifice, where three overlapping craters were formed. Frequent small-to-moderate explosive eruptions have been recorded from Láscar in historical time since the mid-19th century, along with periodic larger eruptions that produced ashfall hundreds of kilometers away from the volcano. The largest historical eruption of Láscar took place in 1993, producing pyroclastic flows to 8.5 km NW of the summit and ashfall in Buenos Aires.

Information Contacts: Buenos Aires Volcanic Ash Advisory Center (VAAC), Servicio Meteorológico Nacional-Fuerza Aérea Argentina, 25 de mayo 658, Buenos Aires, Argentina (URL: <http://www.meteofa.mil.ar/vaac/vaac.htm>).

Ijen

Java, Indonesia

8.058°S, 114.242°E; summit elev. 2,799 m

All times are local (= UTC + 7 hours)

Researchers from Simon Fraser University, McGill University, and the Institut Teknologi Bandung (ITB) conducted fieldwork at Ijen from 6 July to 2 August 2007. During this period, volcanic activity was restricted to persistent degassing of the solfatara (sulfurous fumarole) located on a small dome in the SE part of the crater (figure 8). However, local sulfur miners reported a decrease in the amount of mineable sulfur, a change presumably linked to increasing exit temperatures of the fumarole gases. Visual observation revealed no change in the crater lake level or fumarole activity compared to observations (*BGVN* 32:02) at roughly the same time last year (dry season).

During the visit, exit temperatures measured at the pipes ranged from 115 to 270°C (table 4), similar to those measured in 2006. Fumaroles on top of the dome had substantially higher temperatures, ranging up to 600°C, with the hottest emitting orange flames. By comparison, fumarole temperatures reported for the top of the dome in 1999, the last year for which there are published data (*BGVN* 24:09), were less than 250°C.

Fumarolic sampling techniques included condensate bottles, and sublimates collected in silica tubes. In addition, they also used a Giggenbach bottle, a technique in which the escaping gases are bubbled through a caustic solution of NaOH in an evacuated flask. Reactions, such as those between the caustic solution and CO₂ in the sampled gas, both remove some species from the gas

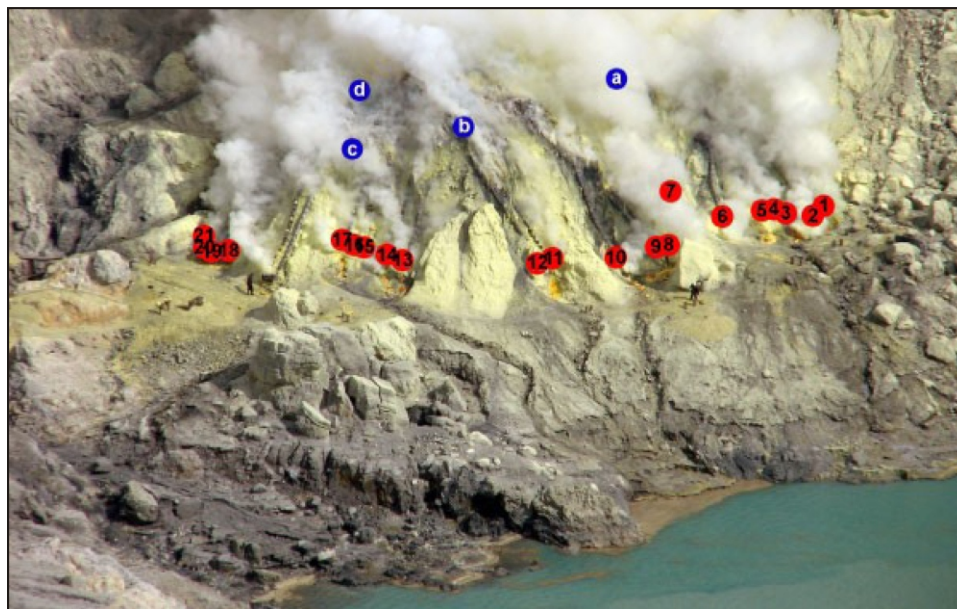


Figure 8. Overview of the N flank of the dome-like fumarole field (solfatara) as viewed from the crater rim of Ijen. Miners have installed pipes leading down from the dome. The pipes are used to condense sulphur, which is subsequently mined. Temperatures were measured in the pipes (numbered 1-21) and in fumaroles (lettered a-d) (see table 4). Fumarole temperatures were measured near the top of the dome. For scale, note sulphur miners near pipes 18 and 8/9. Courtesy of V. van Hinsberg.

Location	Temperature	Location	Temperature
Pipe 1	—	Pipe 14	199°C
Pipe 2	235°C	Pipe 15	205°C
Pipe 3	—	Pipe 16	155°C
Pipe 4	255°C	Pipe 17	194°C
Pipe 5	215°C	Pipe 18	178°C
Pipe 6	210°C	Pipe 19	—
Pipe 7	267°C	Pipe 20	187°C
Pipe 8	216°C	Pipe 21	194°C
Pipe 9	230°C		
Pipe 10	210°C	Fumarole A	>495°C
Pipe 11	175°C	Fumarole B	331°C
Pipe 12	116°C	Fumarole C	335°C
Pipe 13	168°C	Fumarole D	601°C

Table 4. Temperature (°C) of gases measured at ~ 50 cm depth in pipes and fumaroles using a K-type thermocouple. Courtesy of Glyn Williams-Jones.

and result in residual gases collected at the top of the flask. The samples obtained with the various techniques are typically studied and analyzed later in the lab.

Distinct variations in fumarole temperature observed during the course of the field campaign linked closely to weather conditions. On clear, wind-free days, fumarole temperatures were highest. The escaping fumes were generally white in color, and miners were forced to pour water on the pipes to induce sulfur condensation. On windy, clouded days, fumes were much denser and yellow in color, covering all surfaces in a veneer of sulfur. At Fumarole d, this change in weather conditions from clear and wind free to windy and cloudy corresponded to a drop in fumarole temperature from 600 to 450°C. The changes in fumarole conditions were observed to occur rapidly (i.e., within 15 minutes of a cold front moving in), suggesting to the researchers the likelihood of extensive interaction between magmatic and atmospheric gases immediately below the dome's surface.

Crater lake and Banyu Pahit river. The temperature of the crater lake was monitored daily on the S shore below the dome from 8 to 21 July 2007; it varied between 36.1 and 37.4°C. These variations also corresponded to changes in the weather. A transect along the Banyu Pahit river (see map, below) from the dam to the bridge at Watu Capil, revealed that the water was a few degrees above ambient where it emerged, but was close to the air temperature from 500 m downstream. A strong, persistent increase in discharge was observed on 21 July 2007, returning flow to the levels of 1999.

Elemental fluxes. A survey of sulfur dioxide (SO₂) fluxes was made using a portable UV spectrometer (FLYSPEC) on 11, 12, and 27 July 2007 along the SE rim of the crater (~ 2,350 m elevation) and involved, respectively, eight, sixteen, and seven walking traverses under the plume with the instrument pointed upwards.

The gas plume produced directly from the active solfatara (~ 2,150 m elevation) rose buoyantly before flowing over the crater rim. On 11 July, the maximum concentration path length of the gas in the plume fluctuated between 1,800 and 2,600 ppm-m over the eight scans made during a period of 3.5 hours. The wind speed (measured with a handheld anemometer at plume height) during this

time averaged 2.9 m/s and the resultant SO₂ flux was therefore calculated to average 219 metric tons per day (t/d), with a standard deviation of 99 t/d. On 12 July, the average gas concentration was similar, ranging between 1,600 and 3,000 ppm-m. The average wind speed during this survey period (3 hours) fluctuated between 2.0 and 4.5 m/s and the resultant SO₂ flux averaged 185 t/d, with a standard deviation of 60 t/d.

On 27 July average gas concentrations were considerably higher, ranging from 2,200 to 13,000 ppm-m over two hours. The higher concentrations were a result of the plume being less dispersed. The average wind speed during this period ranged from 2.6 to 4 m/s and the resultant SO₂ flux averaged 215 t/d, with a standard deviation of 68 t/d. Based on this very limited three-day survey, the average daily flux of SO₂ was estimated to be 206 t/d and was lower than that measured during a two day survey last year by ~ 130 t/d (BGVN 32:02).

The amount of native sulfur precipitating at the solfatara can be roughly estimated from that mined, given that the bulk of this sulfur is recovered. Approximately 100 miners extract sulfur, removing it from the crater in two trips each day, and carrying on average 60-80 kg of sulfur per trip. This corresponds to the deposition of 14 t/d.

Fumarole gas samples collected using Giggenbach flasks complemented the FLYSPEC measurements and determine the flux of elements other than SO₂, CO₂, and H₂O. Rock samples and water samples taken from the lake and acid springs will allow further quantification of the output of volatiles and metals.

Self-potential surveys. These are surveys that involve measurement at the ground surface of the local, static, direct-current potentials between electrodes inserted to shallow depth at known separation distances. The method is sometimes also called spontaneous potential and abbreviated as SP. These potentials develop from numerous sources, including fluid flow, diffusion, and oxidation and reduction reactions between minerals in contact with water.

As in 2006 (BGVN 32:02), SP surveys were conducted on the summit rim and also down the S flank to the intersection of the Banyupuhit river (dashed line, figure 9) and the main road. The survey was complemented by ground temperature measurements, which found the only thermal anomaly was located in the immediate vicinity of the dome. In comparison to 2006, only the N rim of the crater showed a significant SP variation, with a decrease of SP of ~ 100mV. This variation may indicate a slight decrease of the hydrothermal activity. While the SP values are minima, the SP/elevation gradient is still slightly positive (+0.03 mV/m) suggesting that the hydrothermal system on the N rim is strong enough to compensate for the influence of the hydrological zone, characterized on the E and NE by negative SP (with a minimum at -120 mV) and an inverse SP/elevation gradient of -1.07 mV/m. This almost certainly represents the inflow of meteoric water and groundwater.

The 2006 SP survey suggested that the S and W flanks of the crater were characterized by a hydrothermal system; however, this year's SP and temperature study shows greater complexity. The main SP/elevation gradient is between -0.31 and -0.56 mV/m with a higher SP average than on the E rim (-4 mV in the S versus -70 mV in the E). This suggests that the S part of the crater is controlled mainly by the hydrological and underlying hydrothermal systems of the acid lake. Although some other small hydrothermal

anomalies were found along the S and SW slopes (1 and 2 on figure 9), the area was principally characterized by hydrological systems.

Thus, while the presence of strong hydrothermal activity within the crater is unequivocal, the temperature and self-potential surveys to date show no evidence of it extending beyond the crater rim.

Unrest at nearby Raung volcano and potential significance for Ijen. As noted in the Raung report later in this issue of the *Bulletin*, the Darwin VAAC reported a pilot observation of a possible ash emission from Raung between 25-31 July 2007, not visible on satellite imagery. The researchers at Ijen saw no evidence of this event nor did they hear any mention of it from local coffee plantation workers. However, subsequent detection by satellites of an ash eruption from Raung between 26-27 August adds credence to a 25-31 July event. The close proximity of Raung to Ijen and the apparent increase in temperature of Ijen's dome could possibly auger the onset of a new phase of explosive activity at Ijen.

Geologic Summary. The Ijen volcano complex at the eastern end of Java consists of a group of small stratovolcanoes constructed within the large 20-km-wide Ijen (Kendeng) caldera. The N caldera wall forms a prominent arcuate ridge, but elsewhere the caldera rim is buried by post-caldera volcanoes, including Gunung Merapi stratovolcano, which forms the 2,799 m high point of the

Ijen complex. Immediately W of Gunung Merapi is the renowned historically active Kawah Ijen volcano, which contains a nearly 1-km-wide, turquoise-colored, acid crater lake. Picturesque Kawah Ijen is the world's largest highly acidic lake and is the site of a labor-intensive sulfur mining operation in which sulfur-laden baskets are hand-carried from the crater floor. Many other post-caldera cones and craters are located within the caldera or along its rim. The largest concentration of post-caldera cones forms an E-W-trending zone across the southern side of the caldera. Coffee plantations cover much of the Ijen caldera floor, and tourists are drawn to its waterfalls, hot springs, and dramatic volcanic scenery.

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Raung

Java, Indonesia

8.125°S, 114.042°E; summit elev. 3,332 m

All times are local (= UTC + 7 hours)

Nine anomalous Moderate Resolution Imaging Spectroradiometer (MODIS) observations of volcanic hot spots were reported during 3 June-8 October 2004 (BGVN 30:01). No other activity was reported from Raung until 26 July 2007. That day the Darwin Volcanic Ash Advisory Center (VAAC) indicated that a pilot had observed an ash plume, possibly from Raung, which their ash advisory reported as follows: "AIREP [an aircraft observation] reported ash cloud observed over volcano on eastern tip of Java. Plume up to 5000 feet [~ 1.2 km] above summit. Volcano assumed to be Raung. Ash not seen on latest satellite pass due to cloud."

Darwin VAAC produced five reports in reference to a Raung ash plume emitted on 26 August 2007. Visible wavelength imagery on MT SAT disclosed a plume at FL 150 (15,000 feet, or 4.6 km altitude) drifting E at ~ 10 km/hr (at 0430 UTC on 26 August). The last view of the cloud was reported at 0833 UTC, still at the same altitude and moving at the same velocity. That plume rose to an altitude of 1.5 km. Ash was not visible on satellite imagery. The Darwin VAAC reported that satellite imagery had detected an ash plume from Raung during 26-27 August that rose to an altitude of 4.6 km and drifted E.

Geologic Summary. Raung, one of Java's most active volcanoes, is a massive stratovolcano in easternmost Java that was constructed SW of the rim of Ijen caldera. The 3332-m-high, unvegetated summit of Gunung Raung is truncated by a dramatic steep-walled, 2-km-wide caldera that has been the site of frequent historical eruptions. A pre-historic collapse of Gunung Gadung on the west flank produced a large debris avalanche that traveled 79 km from the

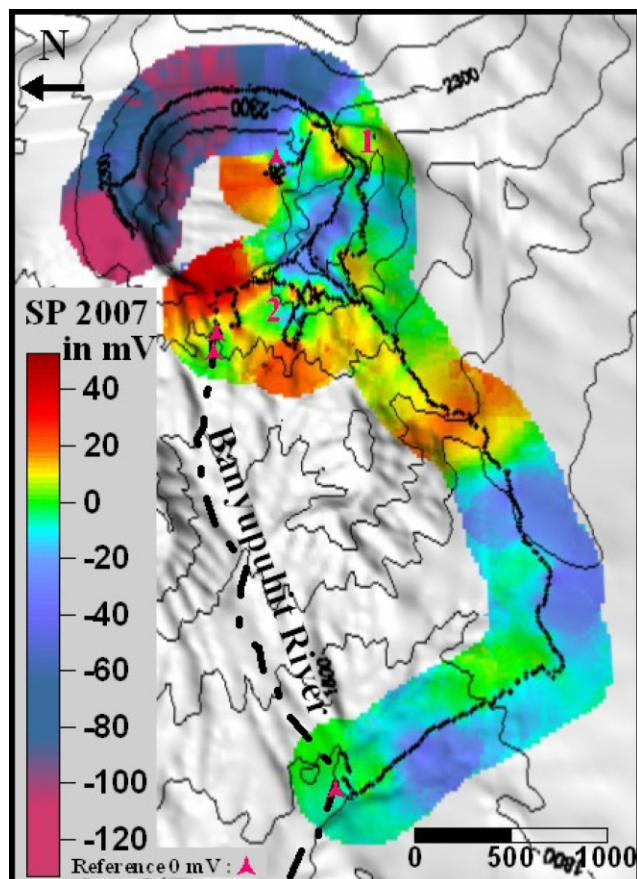


Figure 9. Self-potential (SP) survey results overlain on a digital elevation model (DEM) of the active crater of Kawah Ijen. All the SP data were referenced to the upper Banyuwuh river and to a spring on the inner E slope of the crater (triangles). Contour intervals are 100 m. Courtesy of G. Mauri and V. van Hinsberg.

volcano, reaching nearly to the Indian Ocean. Raung contains several centers constructed along a NE-SW line, with Gunung Suket and Gunung Gadung stratovolcanoes being located to the NE and west, respectively.

Information Contacts: *Darwin Volcanic Ash Advisory Center*, Bureau of Meteorology, Northern Territory Regional Office, PO Box 40050, Casuarina, Northern Territory 0811, Australia (Email: darwin.vaac@bom.gov.au; URL: <http://www.bom.gov.au/info/vaac/>).

Salak

Java, Indonesia
6.72°S, 106.73°E; summit elev. 2,211 m
All times are local (= UTC + 7 hours)

This is the first *Bulletin* report on Salak (a stratovolcano near the W end of Java, figure 10). Historical records indicate the last eruption occurred in 1938, and the volcano remains in repose—this report discusses gas-related fatalities. The last section of this report reviews gas exposure limits, gas-mask filters, and monitoring devices to enhance understanding of two sulfurous volcanic gases (SO_2 and H_2S).

According to news articles, sulfur-gas poisoning from one of Salak's fume-filled craters was suspected in the deaths of six teenagers on 7 July 2007. The victims, who were between the ages of 14 and 16, were part of a group of about 50 students camping on the volcano for the weekend.

The bodies were found with blood and foam on their mouths and noses. According to a Reuters report of 9 July 2007, police officer Thomas Alexander reported that "one of the students was found dead with foam on his mouth, a strong indicator of sulfur poisoning." Several more poisoned students were taken to a nearby hospital for treatment.

Deadly gases. A data sheet on SO_2 , a common and potentially hazardous sulfurous gas found at volcanoes appears on the Center for Disease Control website (NIOSH, 2007). The gas's density is 2.26 times heavier than air of the same temperature. (In other words, when near the ambient air temperature, SO_2 gas will generally tend to descend into low-lying places such as closed craters, lava tubes, etc.) The NIOSH recommended exposure limit for a 40 hour work-week composed of up to 10-hour days is 2 ppm. Their stated recommended exposure limit for short-term (15-minute) exposure is 13 ppm.

These guidelines apply only to healthy adults, and exclude the effects of multiple gases, strong physical exertion, etc. Another

hazardous sulfurous gas emitted by volcanoes is H_2S . It has a density of 1.2 times that of air and a recommended exposure limit that is a more stringent (NIOSH ceiling) value that should not be exceeded: 10 ppm for 10 minutes. But, this gas is thought to quickly react to form SO_2 in many circumstances. The NIOSH website also discusses appropriate filters for gas masks. Small, portable, digital monitors now exist for many gases; some will operate as remote sensors with dedicated telemetry.

Geologic Summary. Salak volcano was constructed at the NE end of an eroded volcanic range. Satellitic cones occur on the SW flank and at the northern foot of the forested volcano. Two large breached craters truncate the summit of Gunung Salak. One crater is breached to the NE and the westernmost crater was the source of a debris-avalanche deposit that extends 10 km WNW of the summit. Historical eruptions from Gunung Salak have been restricted to phreatic explosions from craters in a prominent solfataric area at 1,400 m elevation on the western flank. Salak volcano has been the site of extensive geothermal exploration.

Reference: NIOSH, 2007, NIOSH Pocket Guide to Chemical Hazards, Sulfur dioxide: US Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health (URL: <http://www.cdc.gov/niosh/npg/npgd0575.html>).

Information Contacts: *Reuters* (URL: <http://www.reuters.com/>); *Asia-Pacific News* (URL: <http://www.asiapacificnews.com/>); *Associated Press* (URL: <http://www.ap.org/>); *Deutsche-Press Agentur* (URL: <http://www.dpa.de/>).



Figure 10. Satellite imagery from Google Earth showing Salak (center, ~ 60 km SSW of Jakarta) and other volcanoes of western Java. Courtesy of Google Earth.

Krakatau

Indonesia

6.102°S, 105.423°E; summit elev. 813 m

All times are local (= UTC + 7 hours)

Eruptive activity in recent years was low at Krakatau. The Indonesian volcanological monitoring agency, now called the Center of Volcanology and Geological Hazard Mitigation (CVGHM), did not report any eruptive activity between June 2005 and September 2007. Seismic data collected during this period (figures 11 and 13), although intermittent and variable, suggests mainly low-level activity (discussed in more detail below).

Starting on 23 October 2007 reports noted multiple gray plumes from eruptions lasting 3-6 minutes; these vented from a crater near the summit of Anak Krakatau (figure 12). The eruptions and associated increased seismicity during 23-26 October 2007 prompted CVGHM to raise the Alert Level to 3. Poor weather conditions allowed only intermittent observations, but plumes rose to an altitude of ~ 1 km during 23-26 and 30 October. Similar eruptions were continuing in early November (figure 12).

Activity during April 2005-September 2007. On 13 April 2005 increased seismicity prompted authorities to raise the Alert Level to 2 (on a scale of 1-4). Seismic activity decreased over the next four days to a normal level. Visitors were banned from the summit and crater of Anak Krakatau due to toxic gas emission. Another increase in seismic activity was reported around 16 May. Elevated seismicity was also recorded on 24 September 2005, 8 December 2005, and 18-19 June 2006 (figure 11).

On figure 11, a conspicuous, longer period of high seismicity occurred during most of December 2006, when tremor and low-frequency events also increased. That peak on figure 11 ended prior to the end of the month. No eruptions were noted in available reports by CVGHM for these episodes of elevated seismicity in 2005 or 2006. For the intervals where data were available during the first eight months of 2007, seismicity was generally moderate to low.

Monitoring. The monitoring system (KRAKMON) consists of a number of geophysical, gas-geochemical, and environmental measuring sites on the Krakatau island complex. All data are acquired continuously and are transmitted



Figure 12. Photograph of an ash plume from Anak Krakatau, 1 November 2007. View is to the SE from a monitoring station on Sertung island. Rakata island is in the background. Courtesy of CVGHM.

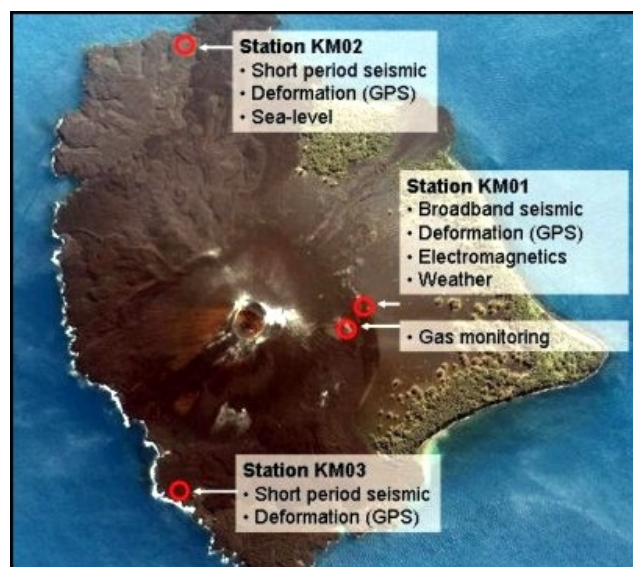


Figure 13. Satellite image of Anak Krakatau showing part of the monitoring network. Stations KM01, KM02, and KM03 are equipped with seismometers (broad-band at KM01) and GPS systems for deformation monitoring. A weather station is installed at KM01, a sea-level sensor at KM02. An electro-magnetic station (KM05) is located near station KM01. Gases are monitored at a nearby fumarole. Courtesy of CVGHM.

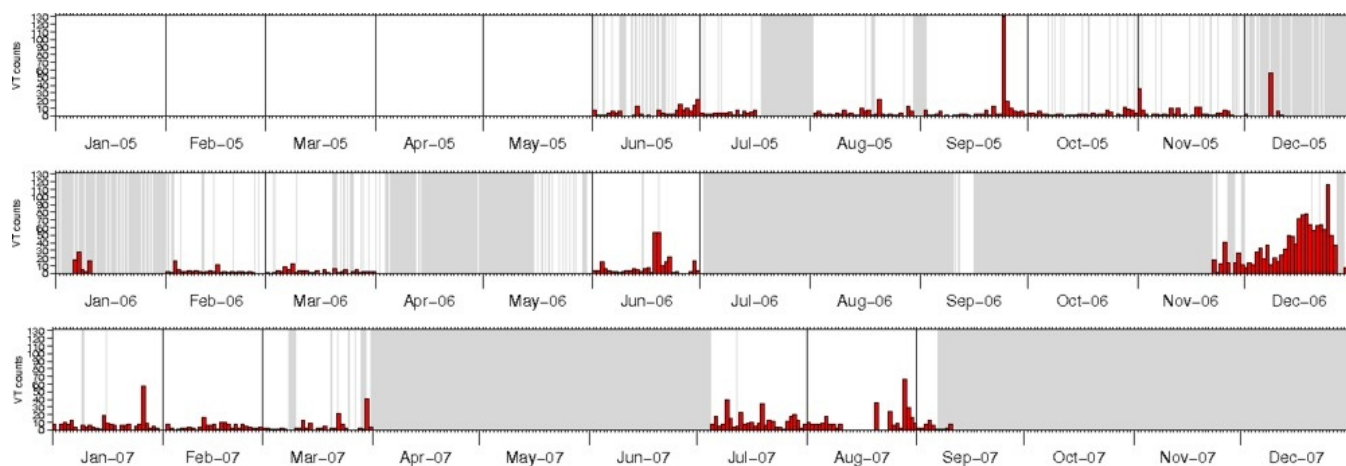


Figure 11. Volcano-tectonic earthquakes recorded at Anak Krakatau, June 2005-early September 2007. Grayed-out areas represent periods when seismic data were not available. Courtesy of CVGHM.

to the Pasauran Observatory (western Java) via digital radio telemetry. In Pasauran, the data are collected and transmitted to a server in Jakarta. From there, the data were accessible through internet (<http://krakmon.vsi.esdm.go.id/>). Three stations are located on Anak Krakatau (figure 13). A fourth station on Sertung island consists of a short-period seismometer and a digital camera with a view of Anak Krakatau.

Geologic Summary. The renowned volcano Krakatau (frequently misstated as Krakatoa) lies in the Sunda Strait between Java and Sumatra. Collapse of the ancestral Krakatau edifice, perhaps in 416 AD, formed a 7-km-wide caldera. Remnants of this ancestral volcano are preserved in Verlaten and Lang Islands; subsequently Rakata, Danan and Perbuwatan volcanoes were formed, coalescing to create the pre-1883 Krakatau Island. Caldera collapse during

the catastrophic 1883 eruption destroyed Danan and Perbuwatan volcanoes, and left only a remnant of Rakata volcano. This eruption, the 2nd largest in Indonesia during historical time, caused more than 36,000 fatalities, most as a result of devastating tsunamis that swept the adjacent coastlines of Sumatra and Java. Pyroclastic surges traveled 40 km across the Sunda Strait and reached the Sumatra coast. After a quiescence of less than a half century, the post-collapse cone of Anak Krakatau (Child of Krakatau) was constructed within the 1883 caldera at a point between the former cones of Danan and Perbuwatan. Anak Krakatau has been the site of frequent eruptions since 1927.

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