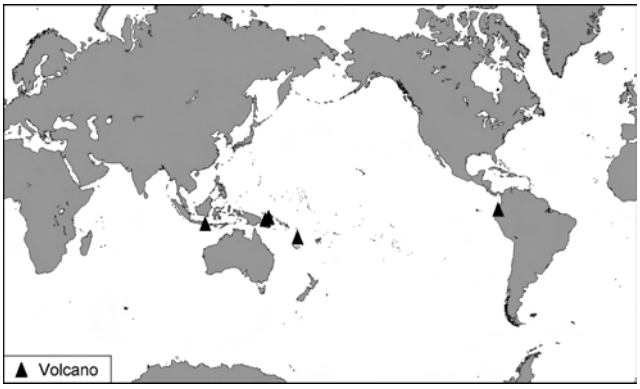
Bulletin of the Global Volcanism Network



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Galeras

SW Colombia
1.22°N, 77.37°W; summit elev. 4,276 m
All times are local (= UTC - 5 hours)

This report covers activity on Galeras volcano after calendar year 2002 (*Bulletin* v. 28, no. 2) and through July 2004. Towards the end of this interval, on 16 July 2004, a new eruptive episode began. In contrast to the 2004 events, the interval from 1994 to June 2004 was characterized by relative quiet, except for a small ash emission from a secondary crater on 7 June 2002. Since 1997 INGEOMINAS has been part of a research project called 'The multiparameter station at Galeras volcano' that was developed with the German group, Bundesanstalt für Geowissenschaften und Rohstoffe (BGR). The station includes the monitoring of fumarolic gas, electromagnetic fields, broadband seismicity, thermal imagery, and other parameters (Seidl and others, 1998). Most instruments were functioning during the recent period of activity.

INGEOMINAS reported that during January-March 2004 Galeras volcanism was at very low levels, with persistent gas emissions from different foci on the active cone, particularly on its W side. There were 60 volcano-tectonic (VT) earthquakes, with many centered ~ 3 km NE of the active cone, several dispersed about the region, and a few epicenters within 2 km of the summit. Magnitudes based on the duration of the signal coda (M_d) varied between 0.1 and 2.8.

Residents felt three earthquakes in Pasto. Two on 27 January occurred at 1511 and 2147 and another on 30 January at 0018. Their respective local magnitudes (M_L) were 2.9, 3.1, and 2.3. All had epicenters 4-5 km NNE of Galeras.

Table 1 compares seismicity for the first quarter of 2004 with the last quarter in 2002 and the first in 2003. The number of VT events clearly dropped, but their energy release varied and was largest in the most recent quarter. The range of depths for the VT earthquakes is roughly comparable, although in the first quarter of 2004 these earthquakes had focal depths only down to 12 km, compared to as deep as 15 and 16 km in the other quarters shown. For the 2004 quarter, six episodes of tremor were recorded. Although fewer episodes occurred than for the other quarters shown in the table, they released an appreciable amount of energy. Spectral analysis generally suggested a fundamental frequency of 4.3 Hz.

In early 2003, LP signals continued to be present in the record, although their classification was made difficult by their atypical signatures. Their frequency spectra showed peaks between 10 and 16 Hz. Sometimes these events were preceded by one or more small-amplitude precursor signals, which appeared to have very similar waveforms. The frequencies were stable over time and from one station to another, indicating processes related to the source rather than to the path or the station site.

The W sector of the active cone continued to show the highest fumarole temperatures. INGEOMINAS measured fumarole temperatures on the active cone in March 2003 and January 2004, and at both times they were cooler than those measured in 2002. Spot measurements in 2002, 2003, and 2004 were reported for two fumarolic areas: Deformes fumaroles (~ 50 m outside the main crater´s SSW rim, 118°C, 85°C, and 86°C, respectively) and Chavas fumarole (344°C, 267°C, and 310°C).

Commencement of 2004 eruptions. The most recent phreatic eruption before 16 July 2004 took place on 7 June 2002 (*Bulletin* v. 28, no. 2). The eruption on 16 July 2004 was preceded by a decrease in the amount of CO_2 released at La Joya fumarole (W side of the cone). The decrease began on 6 June and lasted until the gas sensor stopped working on 26 July 2004. On 27 June the seismic activity picked up. The earthquakes exhibited high frequencies, and they underwent rapid attenuation in both time and space. The VT and LP events were at shallow levels (less than 2 km).

Quarter	Volcano-tectonic Earthquakes			Tremor		Long-period Earthquakes
	Count	Energy (10^{15} ergs)	Depth below summit	Count	Energy (10^{14} ergs)	
Oct-Dec 2002	197	2.9	0.2-16 km	209	27	1,541
Jan-Mar 2003	126	0.49	0.2-15 km	19	0.03	104
Jan-Mar 2004	60	6.7	0.3-12 km	6	12	1

Table 1. Cumulative seismicity in the given three-month intervals (quarter of a year) at Galeras. The second through fourth columns show the number of volcano-tectonic events, a sum of their energy release calculated from their codas, and their focal-depth ranges. The next two columns describe the number of tremor episodes and the associated energy release, and the last column contains the number of long-period events. Courtesy of INGEOMINAS.

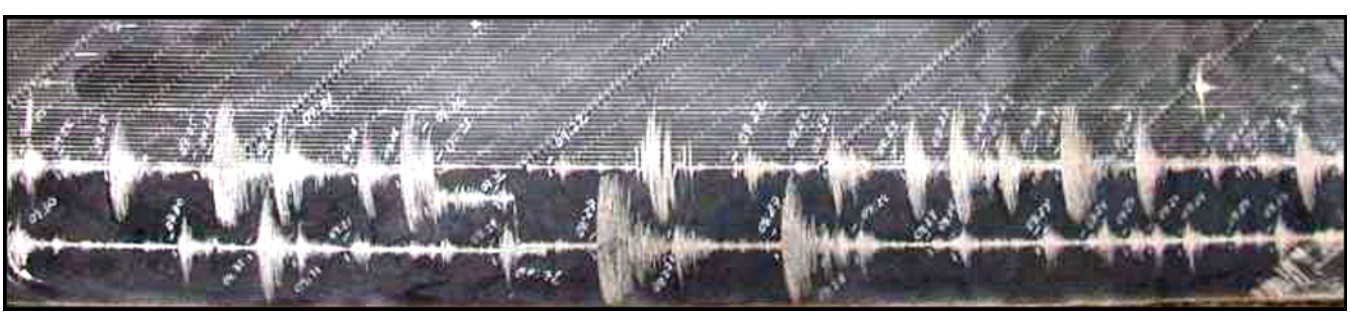

Figure 1. A seismic record of a portion of the Galeras earthquake swarm on 8 July 2004, from the station OLGA on the upper E slope. These were described as fracture earthquakes. During the recording process, the seismologist on duty adjusted the distance between adjacent traces, setting them farther apart than the upper, comparatively quiet portion of the record. The seismologist's notes of earthquake arrival times appear as faint, poorly legible marks on the image. Several earthquakes occurred at such short intervals that they overlapped. Courtesy of INGEOMINAS.

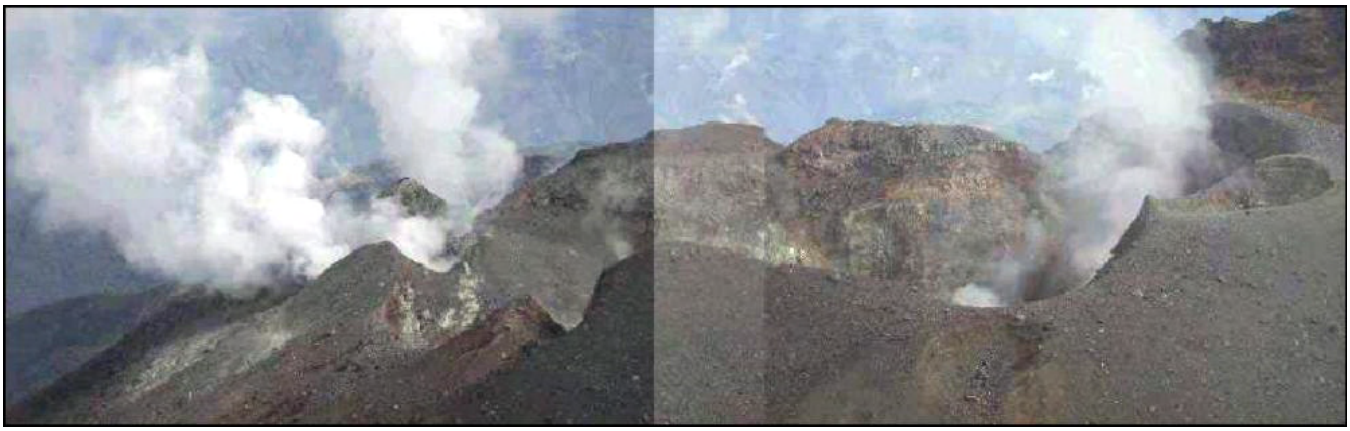

Figure 2. Composite of photos portraying the active cone at Galeras on 9 July 2004. The photos were taken looking NW. At the time these photos were taken the principal focus of emissions was from fumaroles located on the W side of the cone. El Pinta crater on the E edge of the main crater was not emitting any visible products; later, however, this crater became the primary vent. (A map of crater features appeared in *Bulletin* v. 19, no. 7.) Courtesy of INGEOMINAS.

On 8 July 2004 a swarm of VT earthquakes was centered slightly W of the cone at depths of 2-4.5 km. The largest event had M_L 3 (figure 1). The swarm was preceded by intervals with LP events and spasmodic tremor at somewhat lower frequencies.. The seismic episode caused tiltmeters to vary on the E and NE flanks During fieldwork on the S and SW sides of the active cone on 9 July, numerous new points with gas emission were observed. However, the secondary crater "El Pinta" (at the E edge of the main crater) only produced sporadic, weak pulses of gas (figure 2).

On 9 July, only minor, white-colored emissions were observed. They came from the main crater and from sporadic gas venting from the secondary El Pinta crater.

The first episode of ash emissions from El Pinta were noted at 0901 on 16 July and was associated with tremor. It took place under conditions of poor visibility, thwarting clear observations. At the time of ash emission, tremor with very large amplitudes at the upper-flank Olga station had persisted for slightly more than 10 hours (figure 3).

The seismicity and gas venting accompanied signals on the two tiltmeters, as well as variations in the horizontal components of the electric and magnetic fields at an electromagnetic station at the NE base of the active cone. Since the beginning of July, the CO_2 sensor at La Joya fumarole showed a gradual decrease in values, and the temperatures at La Joya and Chavas fumaroles increased gradually just two days before the emission. After 16 July, temperatures at Chavas had risen by 20°C and at La Joya by around 5°C.

According to the personnel of the military outpost at the summit of Galeras, gas emissions had increased by the afternoon of 17 July when compared with those before 9 July. The emissions came from the El Pinta crater and from Deformes fumarolic field, which is located ~ 50 m from the crater on the upper S and SSW flank of the active cone. Gas emissions subsequently decreased until 20 July, when again, small magnitude earthquakes occurred.

Field observations on 19 July disclosed fresh ash on Galeras (figure 4). It had vented from El Pinta crater. The ash thickness ranged from 3 mm at the base of the cone to ~ 20 cm near the point of emission. The right-hand photo on figure 5 shows field workers ascending the steep upper slopes, walking through the thick ash, leaving deep footprints akin to trudging through fresh snow.

On 21 July, an ash emission was seen rising to ~ 500 m above the volcano's rim (figure 5). It was widely visible, including from the largest adjacent city, San Juan de Pasto, which lies just to the E. Seismic signals increased and included a variety of wave forms such as short impulsive events as well as more complex ones. Tremor on 21 July was particularly strong (often dominating the record) and of long duration–extending for ~ 13 hours. Once again the electric- and magnetic-field sensors appeared to respond to the onset of emissions.

Although ash-free, gaseous emissions occurred on 23 July, ash-bearing ones were noted on many days in the following weeks from El Pinta. Specifically, ash

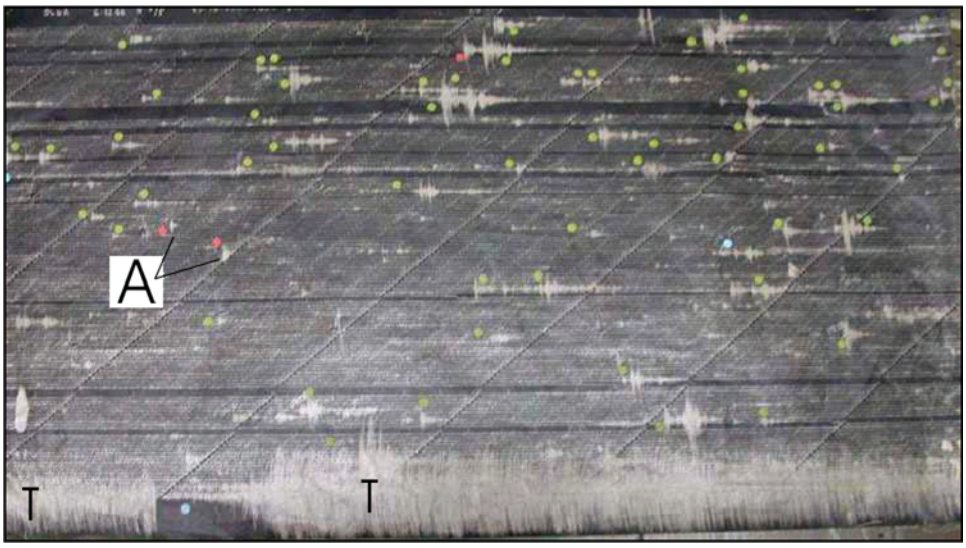

Figure 3. A seismic record from station Olga on 16 July 2004, showing examples of the seismic signals seen as the eruption began. Only a few of the local (or micro) earthquakes were inferred to be associated with classic rock fracture. The bulk of the record contains more complex waveforms, inferred to be related to fluid movement. The bottom of this record is dominated by the kind of high-amplitude tremor often associated with active venting during this eruptive episode. Heavy index lines appear on the seismic record every minute; lighter (faint) intermediate lines are 10 seconds apart. Courtesy of INGEOMINAS.

Figure 4. Galeras reconnaissance investigations undertaken on 19 July (3 days after the ash emission of 16 July). The left-hand photo shows a team in the volcano's E sector where they found thin ash-fall deposits. The right-hand photo shows climbers on the upper part of the cone at El Pinta, in vicinity of the vent, where substantial ash had fallen. Courtesy of INGEOMINAS.

Figure 5. The ash-bearing eruption from Galeras on 21 July 2004, as seen looking W from the town of Pasto. The town sits on the volcano's flank, making it vulnerable to slope instability and other volcanic hazards. Pasto residents have previously undergone considerable tension due to unrest at Galeras in the 1989-2002 eruptive episode. Courtesy of INGEOMINAS.

plumes were every day during 27-31 July accompanied by tremor; LP and VT earthquakes were also recorded. Some of these processes were heard from canyons around the volcano. Several changes at the active cone were noted, which included increases in both venting, exit pressures, and quantities of gases driving the eruptions.

An afternoon overflight on 28 July confirmed a vigorous ash plume coming from El Pinta crater reaching to ~ 1 km altitude and visible for a distance ~ 5 km. A morning overflight on 29 July showed a light, gray to off-white colored plume again emerging from El Pinta and in this case described as blowing NNW, the prevailing direction of strong wind in this season of the year.

On 29 July a low ash plume was visible from Pasto. On that day, scientists took a thermal image of ash clouds; the maximum temperatures were 260°C, seen on the cloud's E side, at a spot above the vent at El Pinta (figure 6). SO_2 measured on 31 July gave a value of 1,366 tons/day.

Two non-technical books discussed the 14 January 1993 Galeras eruptions that killed six scientists and three tourists (Bruce, 2001; Williams and Montaigne, 2001).

Background. Galeras, a stratovolcano with a large breached caldera located immediately W of the city of Pasto, is one of Colombia's most frequently active volcanoes. Major explosive eruptions since the mid-Holocene have produced widespread tephra deposits and pyroclastic flows that swept all but the southern flanks. A central cone slightly lower than the caldera rim has been the site of numerous historical eruptions since the time of the Spanish conquistadors.

References: Bruce, V., 2001, No apparent danger: the true story of volcanic disaster at Galeras and Nevado del Ruiz: Harper Collins, 239 p.

McNutt, S., 2000, Seismic monitoring, *in* Encyclopedia of Volcanoes (H. Sigurdsson, Editor-in-chief): Academic Press, p. 1095-1119.

Seidl, D., Calvache, M., Bannert, D., Buttkus, B., Faber, E., Greinwald, S., Hellweg, M., and Rademacher, H., 1998, The Galeras multiparameter-station: Deutsche Geophys. Ges., Sonderband III / 1998 (Herausg.: J. Zschau, M. Westerhaus), p. 9-11.

Williams, S., and Montaigne, F., 2001, Surviving Galeras: Houghton Mifflin, 270 p.

Information Contacts: *Diego Gomez Martinez*, Observatorio Vulcanológico y Sismológico de Pasto (OVSP), INGEOMINAS, Carrera 31, 1807 Parque Infantil, PO Box 1795, Pasto, Colombia (Email:dgomez@ingeomin.gov.co; URL: http://www.ingeomin.gov.co/pasto/; Email: ovp@ingeomin.gov.co); *Washington Volcanic Ash Advisory Center* (VAAC), Satellite Analysis Branch (SAB), NOAA/NESDIS E/SP23, NOAA Science Center Room 401, 5200 Auth Rd., Camp Springs, MD 20746 USA (URL: http://www.ssd.noaa.gov/).

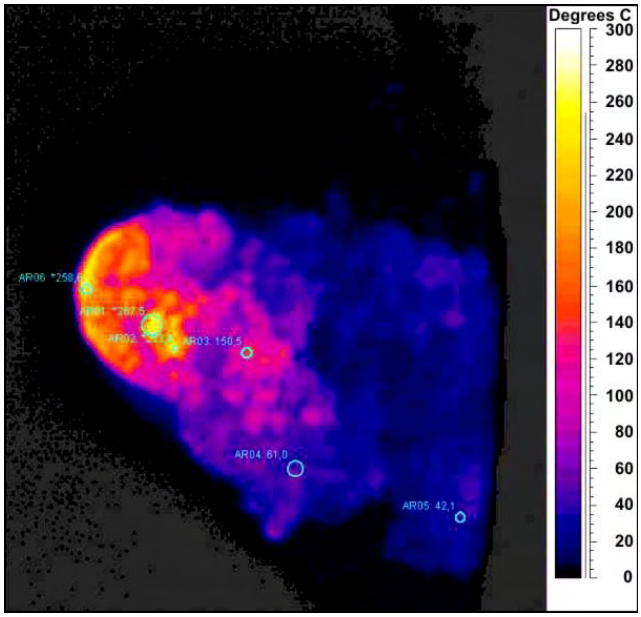

Figure 6. Thermal image of a Galeras eruption cloud on 29 July 2004 coming from El Pinta crater (N is towards the bottom of this image). The image was taken by INGEOMINAS with the support of the Air Force of Colombia, from ~ 500 m over El Pinta crater. The right hand side shows the temperature scale. Courtesy of INGEOMINAS.

Tengger Caldera

east Java, Indonesia
7.94°S, 112.95°E; summit elev. 2,329 m

Mount Bromo's 8 June 2004 eruption killed two visitors and injured five more (*Bulletin* v. 29, no. 5). This report mainly adds a few details for the events of 8 June and a video of the eruption plume. It also summarizes reports through 18 July, an interval characterized by mild ash-bearing eruptions (to 100 m high) without a repeat of the robust eruption seen on 8 June.

A 3-minute-long video clip of the eruption was shot by Kiyoshi Nishi, a volcano seismologist attached to the Indonesian Directorate of Volcanology and Geological Hazard Mitigation (DVGHM). (DVGHM was reorganized from the former Volcanological Survey of Indonesia). Nishi works for the Japan International Cooperation Agency, a Japanese government organization offering technical and grant assistance.

The video begins after a substantial plume had already developed. The plume continued to rise, and the main body of it appeared to ascend with only minor effects of wind, rising in a roughly vertical direction. Identifiable zones of distinct coloration appeared within the plume, in shades of brown, reddish-brown, gray, and white. The white-gray zone, which clearly erupted earlier, moved away from the viewer. Most of the footage shows the brown and red parts of the plume evolving. Subsidiary clouds several times began bulging out of the main plume's margins. The image is valuable because of the need to accurately assess ash plume heights and behavior such as the rise time of the plume top, colored zones, and subsidiary clouds, and the absolute plume heights with respect to time.

Seismicity during 9-14 June was marked by long periods of continuous tremor (maximum peak-to-peak amplitude 6.0 mm), shallow type-A and type-B volcanic earthquakes, intermittent tectonic earthquakes, and a high number of emission earthquakes (see table 2 and *Bulletin* v. 29, no. 5 for details). Reports around this time noted that distance meters (EDM) and global positioning system (GPS) receivers on Bromo recorded deformation that suggested deflation of the edifice. On 14 June, Bromo ejected another ash plume that rose 100 m above the summit.

Nearly two weeks after the 8 June eruption, no similarly substantial event had occurred. On 15 June, DVGHM decreased the Alert Level to II, or 'eruption imminent.' Reports covering 14 June-18 July noted a decrease in seismically detected volcanic emissions (table 2). The number of emission earthquakes decreased by ~ 50% after 20 June and dropped again the week of 12-18 July. Bromo's emissions continued to bear ash, and during 14-27 June a thick ash plume rose 25-100 m above the crater rim. In accord with the decline in seismically detected emissions, observers noted smaller (25-50 m high), thinner plumes during 28 June-18 July.

Other seismicity also decreased (table 2). Seismometers recorded 15 type-A earthquakes during 21-27 June, but this was a peak in the trend for 14 June-18 July, which was generally 1-2 per week. Seismometers recorded no type-B earthquakes at Bromo since the week of its phreatic eruption. Tremor, continuous during 7-13 June, dropped to 2-3 events/week. Local tectonic earthquakes were intermittent.

Background. The 16-km-wide Tengger caldera is located at the northern end of a volcanic massif extending from Semeru volcano. The massive Tengger volcanic complex dates back to about 820,000 years ago and consists of five overlapping stratovolcanoes, each truncated by a caldera. Lava domes, pyroclastic cones, and a maar occupy the flanks of the massif. The Ngadisari caldera at the NE end of the complex formed about 150,000 years ago and is now drained through the Sapikerep valley. The most recent of the Tengger calderas is the 9 x 10 km wide Sandsea caldera at the SW end of the complex, which formed incrementally during the late Pleistocene and early Holocene. An overlapping cluster of post-caldera cones was constructed on the floor of the Sandsea caldera within the past several thousand years. The youngest of these is Bromo, one of Java's most active and most frequently visited volcanoes.

Information Contacts: *Directorate of Volcanology and Geological Hazard Mitigation (DVGHM)*, Jalan Diponegoro No. 57, Bandung 40122, Indonesia (Email: dali@vsi.dpe.go.id; URL: http://www.vsi.dpe.go.id/); *Darwin Volcanic Ash Advisory Centre (VAAC)*, Bureau of Meteorology, Northern Territory Regional Office, PO Box 40050, Casuarina, NT 0811, Australia (URL: http://www.bom.gov.au/info/vaac/); *Kiyoshi Nishi*, Japan International Cooperation Agency (JICA) (URL: http//www.jica.go.jp/).

Date	Volcanic Type A	Volcanic Type B	Tremor	Local Tectonic	Emission
07 Jun-13 Jun	26	15	continuous	0	387
14 Jun-20 Jun	0	0	0	0	376
21 Jun-27 Jun	15	0	3	3	163
28 Jun-04 Jul	1	0	2	0	104
05 Jul-11Jul	2	0	2	3	116
12 Jul-18 Jul	2	0	3	0	79

Table 2. Weekly seismicity at Bromo as measured by the Volcanological Survey of Indonesia (VSI) seismograph. Courtesy of VSI.

Manam

offshore New Guinea, Papua New Guinea
4.10°S, 145.06°E; summit elev. 1,807 m

Activity at Manam's two summit craters remained low during July. The summit area remained mostly cloud-covered during the month; however, when the clouds cleared both craters were releasing white vapor at weak-to-moderate rates. No seismic recording was carried out due to shortage of recording paper. There was no night-time glow observed during the month. Remote sensing scientists working with the MODIS Thermal Alert System noted that no new activity was detected by MODVOLC from 1 January 2003 to 31 May 2004.

Background. The 10-km-wide island of Manam, lying 13 km off the northern coast of Papua New Guinea, is one of the country's most active volca-

noes. Four large radial valleys extend from the unvegetated summit of the conical basaltic-andesitic stratovolcano to its lower flanks. Two summit craters are present; both are active, although most historical eruptions have originated from the southern crater, concentrating eruptive products during the past century into the SE avalanche valley. Frequent historical eruptions have been recorded at Manam since 1616. A major eruption in 1919 produced pyroclastic flows that reached the coast, and in 1957-58 pyroclastic flows descended all four radial valleys. Lava flows reached the sea in 1946-47 and 1958.

Information Contacts: *Ima Itikarai* and *Herman Patia*, Rabaul Volcano Observatory (RVO), P. O. Box 386, Rabaul, Papua New Guinea (Email: hguria@global.net.pg); *Rob Wright*, *Luke Flynn*, and *Eric Pilger*, MODIS Thermal Alert System, Hawaii Institute of Geophysics and Planetology (HIGP), School of Ocean and Earth Science and Technology, University of Hawaii at Manoa (URL: http://modis.hgip.hawaii.edu/; Email: wright@higp.hawaii.edu, flynn@higp.hawaii.edu, and pilger@higp.hawaii.edu); *David A. Rothery* and *Charlotte Saunders*, Department of Earth Sciences, The Open University, Milton Keynes, MK7 6AA, United Kingdom (Email: d.a.rothery@open.ac.uk).

Pago

New Britain, Papua New Guinea
5.58°S, 150.52°E; summit elev. 742 m

Pago was quiet during July. The upper vents released thin white vapor throughout the month. No emission was observed from the lower vents. Seismic activity was at a low level.

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

Information Contact: *Rabaul Volcano Observatory* (see Manam).

Ulawun

New Britain, Papua New Guinea
5.04°S, 151.34°E; summit elev. 2,334 m
All times are local (= UTC + 10 hours)

Ulawun remained quiet during July 2004. Emissions from the main vent consisted of white vapor being released at moderate rates. Wisps of blue vapor were reported on 4-5, 7, and 12-14 July. No noise or night-time glow was reported during the month. Emission of thin white vapor from the two N-valley vents was reported during 4-6 July. Seismic activity was at a low level. Ground deformation continued to show a steady uplift that began late last year.

Air Niugini pilot David Innes noted on 23 August that he had flown past Uluwan early the previous week and noted what appeared to be steam and light 'smoke,' but did not note any ash

The Darwin Volcanic Ash Advisory Center posted two reports on Ulawun. The initial 22 August report noted "thin plume to FL 100 [~ 3 km altitude] extends 60 NM [~ 110 km] to SW on NOAA 15 [image of 2038 UTC on 22 August] . . .. At 0330 UTC on 23 August ash was not identifiable from satellite data."

Andrew Tupper reported that on the morning of 23 August satellite imagery showed a plume ~ 50 km long escaping from Ulawun (figure 7). He went on to comment that the light at that time and the meteorological conditions were perfect for creating and seeing plumes. Discussion with RVO suggested that Ulawun often steams in roughly the same manner, but that atmospheric conditions are only sometime advantageous for seeing the plume. Tupper noted that "In stagnant and/or unstable air, the plume might rise higher above the volcano, but be less visible to satellites (and be obscured by convective clouds); fresh dry-season airflow is by far the best for creating and spotting plumes."

Background. The symmetrical basaltic-to-andesitic Ulawun stratovolcano is the highest volcano of the Bismarck arc, and one of Papua New Guinea's most frequently active. Ulawun volcano, also known as the North Son, rises above the north coast of New Britain opposite Bamus volcano, the South Son. Satellitic cones occupy the NW and eastern flanks. A steep-walled valley cuts the NW side of Ulawun volcano, and a flank lava-flow complex lies to the south of this valley. Historical eruptions date back to the beginning of the 18th century. Twentieth-century eruptions were mildly explosive until 1967, but after 1970 several larger eruptions produced lava flows and basaltic pyroclastic flows, greatly modifying the summit crater.

Information Contact: *Rabaul Volcano Observatory* (see Manam); *David Innes*, Air Niugini, PO Box 7186,

Figure 7. NOAA satellite image of plume from Ulawun taken on 22 August. Arrow points to Ulawun; the plume was ~ 50-60 km long. Courtesy of Andrew Tupper.

Boroko, Port Moresby, National Capital District, Papua New Guinea (Email: deejayinnes@yahoo.com, URL: http://www.airniugini.com.pg/); *Andrew Tupper*, Darwin Volcanic Ash Advisory Centre (VAAC), Commonwealth Bureau of Meteorology, Northern Territory Regional Office, PO Box 40050, Casuarina, NT 0811, Australia (URL: http://www.bom. gov.au/info/vaac/; Email: darwin.vaac@bom.gov.au).

Rabaul

New Britain Island, Papua New Guinea
4.271°S, 152.203°E; summit elev. 688 m

Tavurvur continued to remain quiet during July. Activity consisted of white vapor being released in variable amounts throughout the month. Seismicity was at a low level. Five high-frequency earthquakes occurred each day on 17, 19 and 25 July and two events occurred on 27 July. Only three of these earthquakes were located, two NE of the caldera and the other E of the caldera. Ground deformation continued as slow uplift, which began in October 2003.

Background. The low-lying Rabaul caldera on the tip of the Gazelle Peninsula at the NE end of New Britain forms a broad sheltered harbor utilized by what was the island's largest city prior to a major eruption in 1994. The outer flanks of the asymmetrical pyroclastic shield volcano are formed by thick pyroclastic-flow deposits. The 8 x 14 km caldera is widely breached on the east, where its floor is flooded by Blanche Bay. Three small stratovolcanoes lie outside the northern and NE caldera rims of Rabaul. Post-caldera eruptions built basaltic-to-dacitic pyroclastic cones on the caldera floor near the NE and western caldera walls. Several of these, including Vulcan cone, which was formed during a large eruption in 1878, have produced major explosive activity during historical time. A powerful explosive eruption in 1994 occurred simultaneously from Vulcan and Tavurvur volcanoes and forced the temporary abandonment of Rabaul city.

Information Contact: *Rabaul Volcano Observatory* (see Manam).

Yasur

Vanuatu, South Pacific
19.52°S, 169.43°E; summit elev. 361 m

At the end of June 2004, Yasur volcano started a new cycle of high activity, the fifth since continuous monitoring began in 1993. This cycle is expected to last several months. Having reached a climax in 2002, a lessening of activity had been observed throughout 2003. A return of elevated activity was noted in March 2004, heralding the cycle that began toward the end of June (figure 8). The bulk of the seismic record (over 95%) measured by a station located 2 km from the crated represented vertical ground-movement greater than 60 mm. The increase-decrease cycle is clearly visible. Unfortunately, problems with the power supply of the station's transmitter interrupted the flow of data at the time of onset of high activity.

The new cycle of high activity that began in late June 2004 was accompanied by ash ejection. Ash fall reached several millimeters in thickness at distances up to 4 km from the vents. The cycle was linked to the reopening of the three main channels feeding vents A, B, and C, and the consequent re-emergence of emissions at all three vents.

Fieldwork was conducted on Tanna Island during 10-15 July 2004. Vent A exhibited large ash plumes and low-intensity explosions (figures 9 and 10), with lava bombs ejected toward an area NW of the crater. Strombolian activity was observed at vent B (figure 11). This was the most explosive of the vents, with lava bombs projected vertically more than 300 m above the crater rim. The plume's bluish color was quite visible, confirming the presence of SO_2. A wall of scoria at vent C, present now for several years, separates this vent from vents A and B. Lava ejections from vent C did not extend beyond the lip of the vent. Very dense ash plumes were emitted, but their intensity decreased after 10-11 July. From 11 to 15 July, the scientists measured SO_2 concentration using a Mini Doas spectrometer and calculated a daily output of SO_2 of around 1,000 metric tons per day, twice the amount measured in April 2004.

Background. Yasur, the best-known and most frequently visited of the Vanuatu volcanoes, has been in

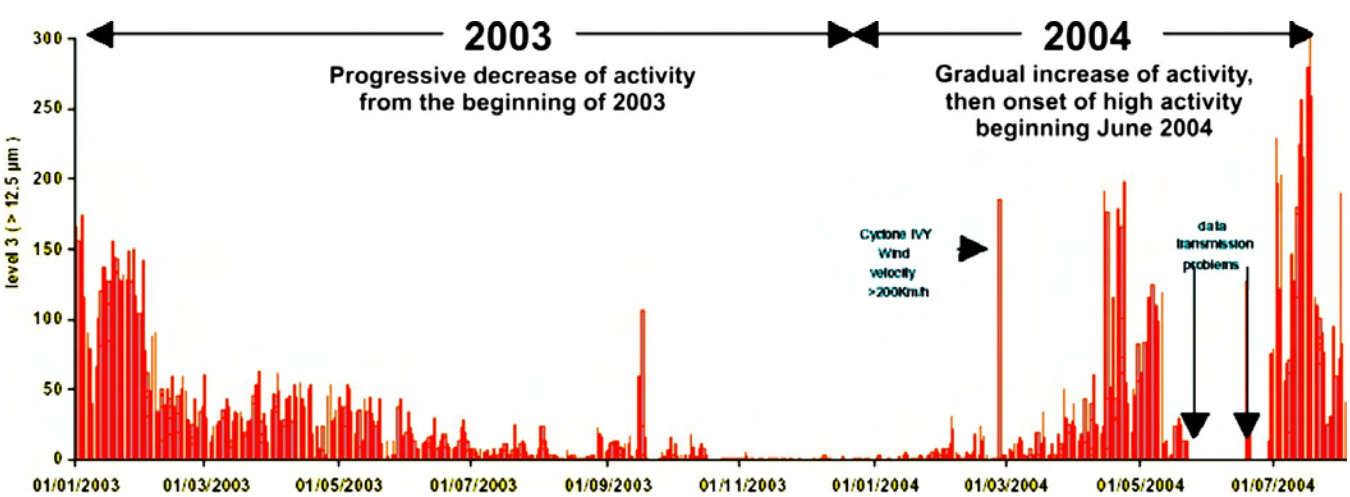

Figure 8. Evolution of activity seen and measured at Yasur volcano from 1 January 2003 to 21 July 2004. The horizontal scale uses the convention of day, month, and year; the vertical scale shows upward increasing 'level 3' seismicity, which is defined as ground displacements of over 12.4 micrometers (μm). The histogram bars were based on seismic measurements recorded by a station located 2 km from the crater and transmitted via the satellites of the Argos system. The text explains various aspects of the data and volcanism. Courtesy of Michel Lardy and Philipson Bani, IRD.

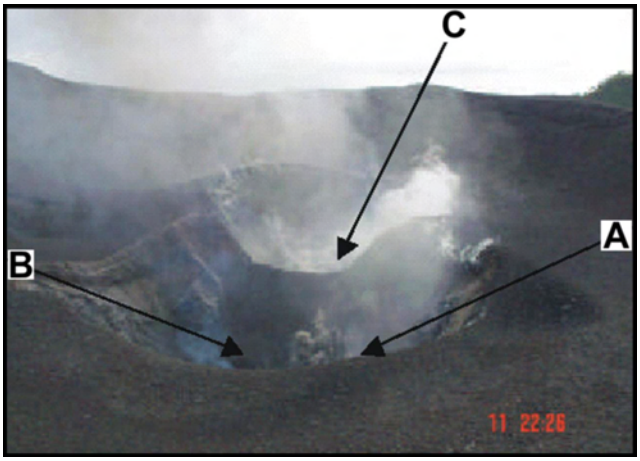

Figure 9. An overview of Yasur's crater on 11 July 2004. Vents are labeled and show typical activity seen during the visit. Copyrighted photo credited to M. Lardy, IRD.

Figure 10. Yasur's vent A in the midst of a dense emission of bombs and ash. A light- colored plume sits over vent C (to the right and in the background). The shot was taken during the fieldwork of 10-15 July 2004. Copyrighted photo credited to M. Lardy, IRD.

more-or-less continuous strombolian and Vulcanian activity since Captain Cook observed ash eruptions in 1774. This style of activity may have continued for the past 800 years. Yasur, located at the SE tip of Tanna Island, is a mostly unvegetated 361-m-high pyroclastic cone with a nearly circular, 400-m-wide summit crater. Yasur is largely

Figure 11. Yasur's vents B (in front), showing blueish emissions, as well as vent C (farthest back), emitting a taller, dense plume. The shot was taken during the fieldwork of 10-15 July 2004. Copyrighted photo credited to P. Bani, IRD.

contained within the small Yenkahe caldera and is the youngest of a group of Holocene volcanic centers constructed over the down-dropped NE flank of the Pleistocene Tukosmeru volcano. Active tectonism along the Yenkahe horst accompanying eruptions of Yasur has raised Port Resolution harbor more than 20 m during the past century.

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