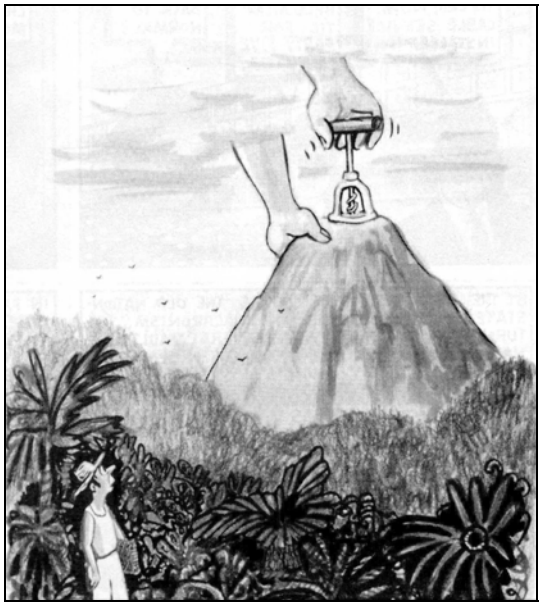
ASH FALL
Newsletter of the Volcanology and Igneous Petrology Division
Geological Association of Canada

#50

March, 2000



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Geological Association of Canada

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our Annual Meeting is scheduled for Thursday, June 1, 1200-1400 p.m.

Processes in physical volcanology and volcaniclastic sedimentation: modern and ancient, edited by W.U. Mueller, E.H. Chown and P.C. Thurston will be published this spring in Precambrian Research.

Contents:

White, J.D.L.: Subaqueous eruption-fed density currents and their deposits

Cousineau, P. A. and Bédard, J.H.: Sedimentation in a subaqueous arc/back-arc setting: the Bobby Cove Formation, Snooks Arms Group, Newfoundland.

Kessler, L.G. II and Bédard, J.H.: Epiclastic volcanic debrites - evidence of flow transformations between avalanche and debris flow processes, Middle Ordovician, Baie Verte Peninsula, Newfoundland.

Mueller, W.U., Garde, A., and Stendal, H.: Shallow-water, eruption-fed, mafic pyroclastic deposits along a Paleoproterozoic coastline: Kangerluluk volcano-sedimentary sequence, southeast Greenland.

Oberholzer, J.D and Eriksson, P.G.: Subaerial volcanism in the Paleoproterozoic Hekpoort Formation (Transvaal Supergroup), Kaapvaal craton.

Ayres, L.D. and Peloquin, S.: Subaqueous, Paleoproterozoic, metarhyolite dome-flow cone complex, Flin Flon greenstone belt, Manitoba.
Corcoran, P.L.: Recognizing Distinct Portions of Seamounts using Volcanic Facies Analysis: examples from the Archean Slave Province, Northwest Territories, Canada.
Chown, E.H., N'Dah, E., and Mueller W.U.: The relation between iron formation and low temperature hydrothermal alteration in an Archean volcanic environment.
Lafrance, B., Mueller, W.U., and Daigneault, R.: Evolution of a submerged arc island: the Normetal volcanic complex, Abitibi greenstone belt, Québec ,Canada.
Thurston, P.C. and Kozhevnikov, V.N.: An Archean quartzite-andesite association in the Baltic Shield: Implications for assemblage types and shield history.
van der Westhuizen, W and de Bruiyn, H.: High temperature ash flow - wet sediment interaction in the Makawassie Formation, Ventersdorp Supergroup, South Africa.

ANNUAL FINANCIAL REPORT VOLCANOLOGY AND IGNEOUS PETROLOGY DIVISION G.A.C.

Balance Dec 31 1998	893.67		
		Revenue	**Expenses**
Ashfall 47 Postage			80.25
Ashfall 47 Xeroxing			93.09
Postage, MSc theses			9.84
Xerox ann mtg			3.97
Presentation boxes			22.80
Engraving Career Achievement			32.96
Engraving Gelinas Gold & Silver			65.91
Engraving Gelinas Bronze			29.96
Dues		6.00	
Ashfall 48 postage			119.86
Ashfall 48 xeroxing			81.36
Stationery			25.29
Dues July 16		684.00	
Canadian Geoscience Council		940.00	
Dues		6.00	
Stationery			16.09
Ashfall 49 postage			114.58
Ashfall 49 xeroxing			67.62
Dues Dec 3		66.00	
Bank Charges 99			33.30
Balance Dec 31 1999	1798.79	1702.00	796.88

ASSETS

Career Achievement medals	3
Gelinas Gold and Silver medals	21
Gelinas Bronze medals	8

Comment:
The 1999 financial statement, shown below, shows that the Division has followed previous years with a slight deficit, if we take into account that the reimbursement from the Canadian Geoscience Council was for expenses incurred in the previous year. A breakdown of our costs is fairly simple, Ashfall, three times a year, about the

minimum necessary, engraving and presentation charges for medals, the cost of munchies for the annual meeting, and bank charges. Revenue is very simple $6, from each Fellow, Associate and Corporate member. The student members, 45 out of a membership of 202 last year, do not pay dues. The treasurer could put a large part of the bank balance out in a GIC, which might offset the bank charges, at least, but the only other economy measure is to reduce the cost of Ashfall. Electronic delivery of Ashfall has been proposed at a number of Annual Meetings. The Structural Division operates this way, I know, but is it ideal? Firstly, 45 members have not submitted an e-mail address, for reasons of privacy, or in some cases because they simply do not have one. Secondly, a paper copy may sit on someone's desk and get read, perhaps over a coffee break, and I assume the corporate members expect a newsletter for their staff. So it is clear there has to be a paper copy for at least some of the members. If there is an electronic issue, it seems it must necessarily be somewhat different. No-one wants to download a huge message, so photographs, cartoons and the like cannot be included. Furthermore the Volcano watch part of electronic Ashfall could just be a series of recommended web sites. This is something to consider at the annual meeting, or to forward to a member of the executive if you cannot be present. If we continue to erode our surplus, dues must be increased, as some of the medals will have to be renewed in a year or two.

Fieldwork '99

It was suggested at our annual meeting that we survey the attending members, to find out where they were doing field work in the coming field season. It should have been reported in an earlier Ashfall, but the reality of the situation is that our highly disorganised secretary mislaid the sheet of paper!

Georgia Pe-Piper; Greece: Brian Cousens; Mt. Shasta, Long Valley Caldera, Yellowknife: Cathie Hickson; Wells Gray Clearwater B.C., La Paz, Bolivia: Tony Fowler; Montserrat, Abitibi, Ontario: David Piper; Greece, Cobequid Highlands: Pierre-Simon Roy; Abitibi: Patricia Corcoran; Slave Province: Wulf Mueller; Slave Province, Abitibi-Val-d'Or: Michael Higgins; Iceland, Sept-Iles: Don Francis; Ungava, Central Yukon, Northern B.C. Sorry for the delay.

Field Trips

The Division has sponsored field trips beyond the scope of regular Annual Meetings in the past,- Hawaii, Mexico, Italy and Greece if memory serves me well. This branch of our operations has fallen by the wayside over the years, although a number of members have indicated an interest in further trips. The chief problem lies in the need for a guide and an organiser. Les Coleman did yeoman service as organiser in the past, but found it time consuming. Is there a possible solution,- someone out there with a part of the world he or she would care to show off? Or could we band together as a group and go along with a commercial venture? Volcano Tours <www. volcanotours.com> has a number of tours scheduled every year, for example. Is there any interest among the membership in going together on one of these tours?

MESSAGE FROM THE CHAIR

The obstacle of distance in Canada means that much of the activity of the Volcanology and Igneous Petrology Division is concentrated into a few days at the annual meeting of the GAC. I hope as many members as possible will manage to attend "GeoCanada 2000" in Calgary at the end of May. The Division is sponsoring a Special Session on "How do magmas solidify?" organised by Michael Higgins and Tony Fowler. Other sessions of interest to VIP members include "The Future in Petrology", "Granites and granulites: making the lower crust", "Volcanogenic massive sulfide deposits of Latin America", together with rock displays of mantle xenoliths (by past-President Kelly Russell) and the Muskox Intrusive.

Please plan to attend our annual business meeting and free lunch at noon on Thursday June 2nd, when we will honour this year's winner of the Career Achievement Award and the student winners of the Gelinas medals. Make sure that good theses at the B.Sc., M.Sc. and Ph.D. levels are submitted for these awards, details of which will be found elsewhere in this newsletter and on our web site. The business meeting is also an opportunity for you, the members, to tell the Executive what you would like to see happen in the Division in the coming year.

I look forward to seeing you in Calgary

Georgia Pe-Piper

Etna

The Southeast Crater at the summit of Etna continues to produce violent paroxysmal eruptive episodes at intervals ranging from 6 hours to more than 24 hours, and the number of such events since 26 January has risen to 26. The latest occurred on the morning of 16 February after a repose interval of 13 hours.

While each paroxysm is of very short duration - the phase of strongest activity does not exceed 10 minutes - the paroxysms appear to become more violent with time. Some of the paroxysmal episodes begin with lava fountains from vents on the lower northern flank of the SE Crater cone and then activity extends upslope towards the summit

vent of the cone, culminating in vigorous lava fountaining from several vents aligned along a N-S trending fissure cutting the summit. Others apparently begin in the summit area or high on the S flank and then extend northwards.
Lava flows are commonly emitted on both sides of the cone, but those from the northern vents are more voluminous. Fountain heights during the most recent episodes have been 500-600 m, and eruption columns (which in their lower parts contain much ash and lapilli) rise several kilometres above the summit, causing lapilli and ash falls in various directions, depending on prevailing wind. The sectors most affected in the past few days have been the southwestern, southern and eastern flanks of Etna, with fine-grained lapilli and ash falls up to 30 km away.
During the more recent eruptive episodes, the area around the Torre del Filosofo mountain hut (which lies approximately 1 km S of the SE Crater) has received heavy fallout of large scoria clasts (up to 30 cm in diameter) and occasional dense bombs. Observation of these events at close range is therefore extremely dangerous, and no one should approach closer than to within 3 km of the SE Crater, especially in downwind direction.

More information, photos and links to other web sites about Etna are available on the Etna News Page of "Italy's Volcanoes: The Cradle of Volcanology":
http://www.geo.mtu.edu/~boris/ETNA_news.html
Boris Behncke Dipartimento di Scienze Geologiche, Sezione di Geologia e Geofisica Università di Catania

Shishaldin volcano
54°45.33'N 163°58.00'W (CAVW #1101-36)
Summit Elevation 9,373 ft (2,857 m)
Low-level seismic activity continued over the last week at Shishaldin volcano. Vigorous steaming was reported, buy no thermal anomaly has been observed in satellite imagery. AVO will continue to monitor the situation closely with real-time satellite and seismic data and will issue further updates as the situation warrants.
Shishaldin volcano is one of the most active volcanoes in the Aleutian arc, erupting at least 29 times since 1775. The most recent eruptive period occurred in April-May 1999. The April 19th eruption sent an ash plume to over 45,000 ft (13,900 m) ASL. Shishaldin volcano is located near the centre of Unimak Island in the eastern Aleutians. The cone has a base diameter of approximately 10 miles (16 km) and a small summit crater that typically emits a steam plume with occasional small amounts of ash.

Alaska volcanoes
Seismic activity is monitored in real time at 21 volcanoes in Alaska. Some of these volcanoes may currently display anomalous seismicity, but they are not considered to be at a dangerous level of unrest. Spurr, Redoubt, Iliamna, Augustine, Snowy, Griggs, Katmai, Novarupta, Trident, Mageik, Martin, Aniakchak, Pavlof, Dutton, Isanotski, Fisher, Westdahl, Akutan, Makushin, and Great Sitkin volcanoes are all at or near normal levels of background seismicity.
Volcano information on the internet: http://www.avo.alaska.edu

Kamchatkan volcanic activity
The following Release was received by e-mail from KVERT (Kamchatkan Volcanic Eruptions Response Team). All times are Kamchatkan Standard Time (KST), 21 hours ahead of AST.
Klyuchevskoy volcano
56°03' N, 160°39' E; Elevation 4,750 m
During the past week (March 17-23), seismicity at the volcano was at background levels. Mainly shallow earthquakes were registered. On March 17, 20-21, a steam-gas plume rose 1000-1,500 m above the volcano extending 5-10 km to the northeast and southeast. On March 22-23, a plume rose 50-100 m above the volcano. On March 18, the volcano was obscured by clouds.
Bezymianny volcano
55° 58'N, 160°36'E; Elevation 2,895 m
Seismic activity has been at background activity since March 19 but indicates rock avalanches continue at the volcano although no volcanic tremor has been recorded. Visual reports from the village of Kozirevsk, on March 18 at 21:06 KST (0906 UTC) indicated a dense dark plume rose 5000 m ASL and extended >150 km as a cloud to the southwest. The base of the cloud was not distinct and ash fall may have been occurring. On March 19-22, a steam-gas plume rose 1000-2000 m above the volcano, extending up to 10 km to the northeast and east. On March 23, the plume rose 200 m above the volcano. Satellite images provided by AVO continued to show a thermal anomaly but of decreased intensity.
Sheveluch volcano

56°38' N, 161°19' E; Elevation 2,447 m
Seismicity under the volcano was above background levels. On March 17-23, a steam-gas plume rose 500-1000m above the volcano, extending up to 10 km to the northeast and east. On March 24, the volcano was obscured by clouds. Visual reports from Klyuchi on March 17 at 17:52 KST (0532 UTC)show a short-lived explosive eruption that sent an ash-poor plume to about 1000 m above the dome (~3,500 m ASL); an accompanying increase in seismic activity also occurred. The plume extended 7 km to the west. At 13:45 KST (0145 UTC) on March 18, seismic data indicated another short-lived weak explosive eruption. At 02:49 KST (1449 UTC) on March 24, seismic data indicated a short-lived but vigorous explosive eruption occurred. Shallow seismic events continue to be recorded.

Karymsky volcano
54o03'N, 159o27'E; Elevation 1,486 m
The low-level strombolian eruptive activity that has characterized the volcano for much of the past four years continues. During the past week, the number of gas and ash explosions decreased from 300 to 110 per day.
Avachinskaya group of volcanoes
53°15'N, 158°51'E;
Seismicity at Avachinsky and Koryaksky volcanoes is at normal levels.

Mutnovskaya group of volcanoes
Gorely volcano, 52°33'n, 158°02' e, elevation 1,828m and Mutnovsky volcano,
52°27'n, 158°12'e, elevation 2324 M.
After more precise analysis of the visual reports from Petropavlovsk-Kamchatsky and comparison of seismic signals from several seismic stations, KVERT determined the following: on March 17, at 7:00 KST(1900 UTC), a short-lived explosive eruption sent a gas-steam plume to heights of ~1,000 m (~3,000 m ASL) above Mutnovsky volcano; the plume disappeared within half an hour. A corresponding shallow seismic event was registered at 18:56 KST (00656 UTC) followed by low-frequency (1 cps) volcanic tremor. At 13:00 KST (0100 UTC) on March 17, a gas-steam plume rose 3,000 m ASL and extended to the southeast; the activity ended by 17:00 KST. On March 18-19, the volcano was obscured by clouds and on March 20-23, the volcano was quiet. The episodes of low-level low-frequency volcanic tremor continue.
Olga Chubarova Kamchatka Volcanic Eruptions Response Team, IVGG, Piip Blvd, 9 Petropavlovsk-Kamchatsky,683006,RUSSIA. E-mail: ivgg@svyaz.kamchatka.su

Manam
Mild eruptive activity occurred at Manam's two summit craters during the first week of November. Main Crater released occasional pale gray ash clouds accompanied by weak roaring noises during 2-4 November; no glow was visible at night. The summit was covered on the 5th and 6th. When it became clear on the 7th, it was seen emitting only weak-to-moderate volumes of white vapor. This level of emissions continued until the end of the month and throughout December.
Southern Crater released thin white vapor during the first few days of November. However, activity shifted from Main Crater on the 7th and Southern Crater released pale gray ash emissions at irregular intervals. An explosion at 1140 produced an ash cloud that rose several hundred meters above the summit, resulting in fine ashfall on the NW part of the island. Although both craters were covered by atmospheric clouds on 9th, weak roaring noises were evident. Southern Crater released small-to-moderate volumes of white vapor after 10 November through December.
Seismic activity was low during November. However, there was a slight increase in seismic amplitudes during the first week of the month. This increase coincided with the mild increase in activity observed from the two summit craters. Seismic amplitudes dropped for a while after mid-November 1999. It reached a trough in the second week of December, then began to increase again. The level was still rising at the end of the December. These observations took place within the range of normal background level.
The steady fluctuating inflation measured by the water-tube tiltmeter since July levelled off in late October. No changes were observed in November or December. There was an accumulated inflationary tilt of about 20 µrad between July and late October.
The 10-km-wide island of Manam is of one of Papua New Guinea's most active volcanoes. Four large radial valleys extend from the unvegetated summit of the conical 1807-m-high stratovolcano to its lower flanks. These "avalanche valleys," regularly spaced 90 degrees apart, channel lava flows and pyroclastic avalanches that have sometimes reached the coast. Five satellitic centres are located near the island's shoreline. 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 since 1616.
Itikarai, H.Patia, and F. Taranu, Rabaul Volcano Observatory (RVO), P.O. Box 386, Rabaul, Papua New Guinea

(Email: rvo@datec.com.pg).

Guagua Pichincha

This report covers 22 November through 24 December 1999, an interval when long-period earthquakes increased precipitously. The dome in the caldera's western sector continued to produce explosions, lava extrusions, and rockfalls. November 1999 marked the 32nd month since the unrest began; occasional ashfalls and associated disruptions (minor ashfall, airport closures, hundreds of evacuated refugees) have had a significant impact on Quito residents.

Seismicity. Earthquake hypocenter maps appearing on the Geophysical Institute's website showed the vast majority of earthquakes clustering beneath the crater area; in some cases these clusters also spread W with gradually decreasing density. The website also included a diagrammatic cross section through the crater (figure 6) illustrating the inferred plumbing system, including some typical depths for various kinds of earthquakes. On the inset, the diagram shows an inferred shallow aquifer within the edifice that intersects the active conduit and presumably contributes to the repeated phreatic eruptions.

During November 1999 phreatic explosions took place 41 times. Many months during the crisis had fewer than 20 explosions per month, and the November 1999 value was the second highest of the crisis. The highest monthly total occurred during October 1999, a count of 53 explosions.

Seismicity had been escalating rapidly during September-October 1999 (see plot, Bulletin v. 24, no. 10). A precipitous climb in long-period (LP) earthquakes continued during November, reaching dramatic levels (table 2); in September long-period earthquakes occurred ~12,000 times, in October ~15,000 times, and in November ~44,000 times. For another comparison, LP counts earlier in the crisis (July 1998-August 1999) generally remained below 200 earthquakes per month. Thus, compared to this broader interval, the November 1999 count of LP events reflected more than a 200-fold increase. In addition, November's LP earthquakes exceeded the sum for LP events during the previous 16 months.

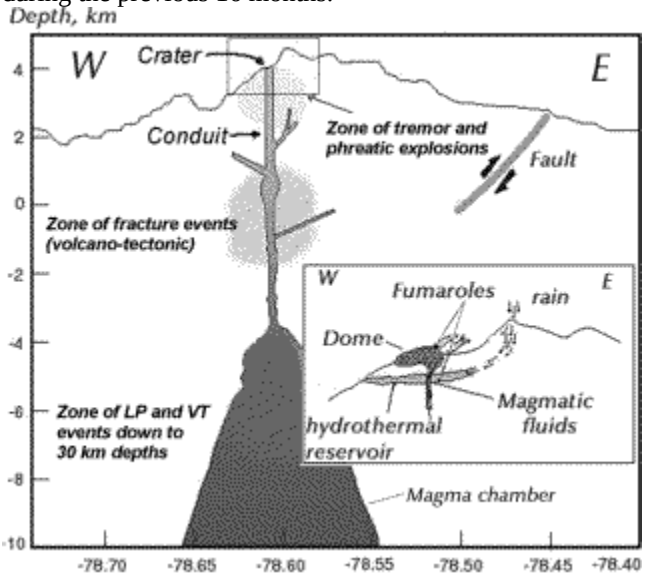

Figure 6. A diagrammatic E-W cross-section through the crater at Guagua Pichincha. The cross-section is intended to show the overall internal structure and the zones where the main kinds of earthquakes seen during the crisis have typically originated. The scale across the bottom of the main diagram corresponds to a local co-ordinate system; the one along the left side of the main diagram indicates depth with respect to sea level (0 km). The inset contains an enlarged view of the crater area. Courtesy of the Geophysical Institute.

Mayon

The beautifully symmetrical Mayon volcano, which rises to 2,462 m above the Albay Gulf, is the Philippines' most active volcano. The structurally simple volcano has steep upper slopes with average inclines of 35-40 degrees and its summit is capped by a small summit crater. The historical eruptions of this basaltic-andesitic volcano date back to 1616 and range from Strombolian to basaltic Plinian. Eruptions occur predominately from the central conduit and have also produced lava flows that travel far down the flanks. Pyroclastic flows and mudflows have swept down many of the approximately 40 ravines that radiate from the summit and have often devastated populated lowland

areas.
Mayon stratovolcano, in SE Luzon, entered a period of increasing unrest in May 1999. This has led to significant ash eruptions, lava flows, and pyroclastic flows–and associated rises in the hazard status. On 22 June 1999 an eruption sent an ash plume 10 km above the summit and the volcano continued to exhibit activity that could signify additional eruptions (Bulletin v. 24, no. 6). After this event the hazard status was raised from Alert Level 1 (slight unrest) to Alert Level 2 (moderate unrest, no eruption imminent). Another ash explosion on 5 January 2000 produced a 5-km-high ash column.
A lava dome was spotted growing in the summit crater on 12 February. Accordingly, on the 15th the hazard status was raised to Alert Level 3 (intensifying unrest, magma close to the crater, eruption within weeks). Dome theodolite measurements showed continuing growth and, as of 23 February, the dome was ~74 m wide by ~24 m high. On 19 February, portions of the dome began to glow, presumably as magma forced cracks to open. At the time of this report, the dome already overlapped the SE side of the crater, which was unconfined and open. On 20 February some lava fragments detached from the dome and incandescent rockfalls descended the SE flank, traveling within a large channel called the Bonga Gully.
As of 23 February, PHIVOLCS had recommended evacuation to at least 7 km from the summit in the SE and to at least 6 km elsewhere. The former is a permanent danger zone. Activity continued to increase during the night of 23-24 February, with minor explosions and lava fountaining, prompting a change in the hazard status to Alert Level 4 (hazardous eruption imminent, possible within days) at 0300 on 24 February. No additional evacuation was recommended, but people residing within 8 km of the summit were advised to prepare for evacuation. Later that morning, at 0829, a pyroclastic flow descended the SE flank towards the Bonga Gully. This caused the hazard status to rise to Alert Level 5 (hazardous eruption in progress). Eruptive and seismic activity continued into early March.

At 1658 on 22 June Mayon emitted an ash column that rose 7-10 km above the vent (figure 1). The emission was recorded by the seismic network of the Philippines Institute of Volcanology and Seismology (PHIVOLCS) as an explosion that lasted for 10 minutes. No volcanic earthquakes nor other visible signs of abnormal activity were observed before the explosion. During May, however, low-frequency volcanic earthquakes had been recorded intermittently, accompanied by faint crater glow.
The explosion represented an isolated event as activity immediately declined to typical incidents of weak steaming without measurable seismicity. Faint glow was seen the next day at the summit crater. An aerial survey noted a new explosion pit at the summit; the small diameter pit was later described as a deep hole lined with sulphur deposits (figure 2). The presence of sulphur suggested that lava had not yet ascended to the surface.
Beginning at 0700 on 25 June there was a slight increase in seismicity and SO2 emission. The COSPEC measured an SO2 flux of 4,800 tons/day, compared with 4,200 tons/day the previous day. SO2 fluxes normally average 500 tons/day. A short interval of high-frequency tremor was also recorded.
Tremor, light steaming, low-frequency volcanic earthquakes, and elevated SO2 fluxes continued for several days. Also, deformation surveys conducted with laser-ranging EDM equipment indicated sustained inflation on the SE slope.
PHIVOLCS maintained an alert status of "Level 1," advising the public not to venture within 6 km of the summit area (figure 3). In particular, residents were advised to avoid the Bonga pyroclastic fan, an area on the SE side of the volcano that contains a deep canyon and lies directly below the crater rim notch. This fan was the site of most of the fatalities in the 1993 eruption and is considered the area most vulnerable to future pyroclastic flows.

Figure 1. A column of steam and ash rising from Mayon's crater and a pyroclastic flow descending its SE flank during its sudden isolated explosion on 22 June. Photograph courtesy of PHILVOCS.

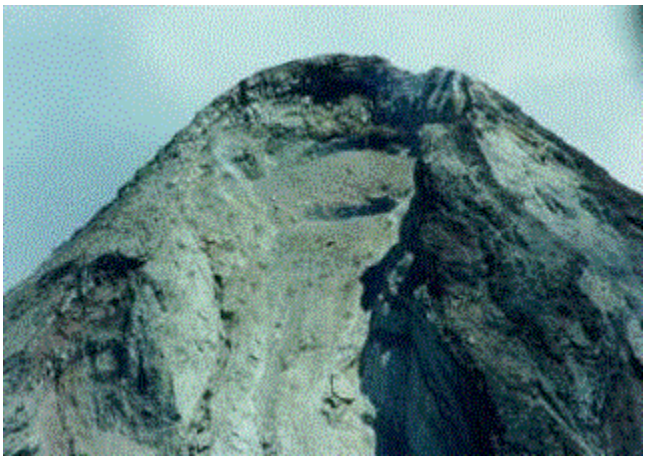

Figure 2. The crater of Mayon as it appeared after the 22 June explosion. A new, circular explosion pit developed on the crater floor; the shadow formed along the rim of this pit can be seen in this NW-looking photo shot through the breech. Courtesy of PHILVOCS.

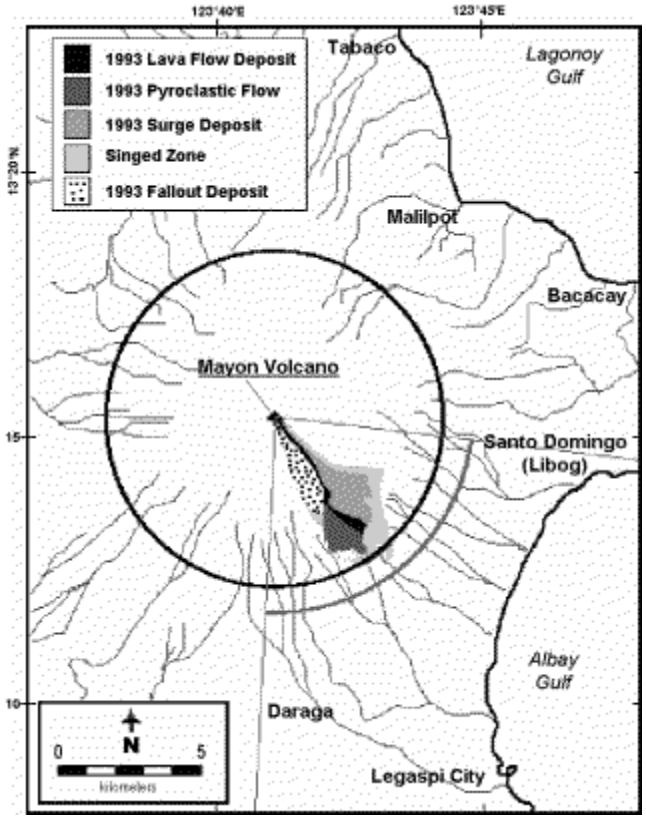

Figure 3. Details on Mayon and vicinity taken from a volcanic hazards map (PHILVOCS, 1999). The legend describes some effects of the 1993 eruption. The solid black circle represents the 6-km-radius safety zone currently in effect. An additional 1-km-wide precautionary zone lies to the SE of the volcano below the Bonga Pyroclastic Fan. Some local cities and river drainage are also shown. Courtesy of PHILVOCS.

Information Contacts: Raymundo S. Punongbayan and Ernesto Corpuz, Philippine Institute of Volcanology and Seismology (PHIVOLCS), C.P. Garcia St. Diliman, Quezon City Philippines (URL: http://www.phivolcs.dost.gov.ph/).

Piton de la Fournaise, Réunion Island, Indian Ocean
21.23°S, 55.71°E; summit elev. 2,631 m

A basaltic shield volcano, Piton de la Fournaise, forms the SE half of Réunion Island, 700 km E of Madagascar. It has been one of the most active oceanic volcanoes, with more than 100 eruptions in the last 300 years. Three calderas formed at around 250,000, 65,000, and <5,000 years ago by progressive eastward slumping of the volcano. Most historical eruptions originated from the summit and flanks of a 400-m-high lava shield that grew within the youngest caldera.

The massive Piton de la Fournaise shield volcano on the island of Reunion is one of the world's most active volcanoes. Much of its more than 530,000 year history overlapped with eruptions of the deeply dissected Piton des Neiges shield volcano to the NW. Three calderas formed at about 250,000, 65,000, and less than 5,000 years ago by progressive eastward slumping of the volcano. Numerous pyroclastic cones dot the floor of the calderas and their outer flanks. Most historical eruptions have originated from the summit and flanks of a 400-m-high lava shield that has grown within the youngest caldera (Enclos Fouqué), which is 8 km wide and breached to below sea level on the

eastern side. More than 150 eruptions, most of which have produced fluid basaltic lava flows, have occurred since the 17th century. Only six eruptions, in 1708, 1774, 1776, 1800, 1977, and 1986, have originated from fissures on the outer flanks of the caldera. Monitoring is done from the Observatoire Volcanologique du Piton de la Fournaise (OVPDLF).

Less than 2 months after the end of the eruption of July (Bulletin v. 24, no. 9), a new seismic crisis started at 1037 on 28 September. Most of the observed 189 seismic events had magnitudes of less than 1. All were situated above sea level. Only two of them had significantly larger magnitudes of 1.8 and 2.2, at 1042 and 1053, respectively.

An eruption started at 1158 in the W part of Dolomieu crater with a strong whistling noise. Seconds later, a 10-m-diameter, ~50-m-high lava fountain rose from the SW corner of Dolomieu crater. Immediately after that, a fissure formed going NW, followed by the development of small lava fountains and a lava flow. Less than 5 minutes later the fissure measured ~200 m long and was terminated by another lava fountain 20-30 m high. At 1210, the fissure opened on the S flank "en echelon," ~100 m below the crater rim. The two upper fissures measured ~50 m long, followed by a third one ~250 m. The lava flow down the steep S flank extended ~1 km in less than 15 minutes. It continued to the SE on a more gentle slope and reached "Château Fort" crater, 2 km away, within two hours.

Less than 8 hours after the eruption started, activity was limited to some individual points on the upper S flank, while the main lava flow had stagnated. No further activity was observed in the Dolomieu crater. In the night, small fissures on the S flank at 2,150 m elevation produced some small pahoehoe lava flows.

On 8 October, after a significant increase of tremor, steam release was observed in the south "enclos," at 1,900 m altitude, ~4 km away from Dolomieu crater and on the morning of 11 October a new 600-m-long lava flow was observed 500 m to the SE, on the base of crater "Villèlle," close to southern border of the caldera. On 18 October this lava flow measured ~1.5 km. No further activity was observed at this site on 21 October. As of 22 October tremor was still visible, mainly in form of small "gas piston events," centered on the upper fissures on the S flank of Fournaise, where a small cone was formed. The eruption ended following small "gas piston events" on at about 1800 on 23 October. Residual fumarolic plumes, consisting primarily of water vapor, were visible the following week.

Mapping of the lava flow was performed in the first days by use of small hand-held GPS. Early lava flows, in Dolomieu crater and on the S flank are mainly aa lava flows. In the Dolomieu crater, it represents a surface of ~40,000 m2 (?) and a volume of <100,000 m3. It partly covered the July lava flow. On the border of the lava flow we could observe fissuring of the ground, up to 3 m deep, due to the weight of the new up to 3-m-high lava flow.

The main lava flow on the S flank represents about 300,000 m2 and <1 x 106 m3. Taking into account an emplacement within less than 5 hours, the eruption rate was estimated to be >50 m3/s. The small pahoehoe flow from the fissures at 2,150 m altitude covered less than 5,000 m2.

The southern-most lava flow starting at crater Villèlle also was mainly pahoehoe. There were no projections at its point of emission, indicating a highly degassed magma. On 11 October a ~1 m lava flow emerged from a small "well" on the SW base of "Villèlle." The volume of this lava flow is estimated to be under 50,000 m3. All recovered samples were aphyric basalt.

A new eruption occurred at Piton de la Fournaise in February 2000. The previous eruption, in September and October 1999 (Bulletin v. 24, no. 9), included a ~50-m-high lava fountain rising from the SW corner of Dolomieu crater and a main lava flow covering ~300,000 m2 on the S flank in a deposit with a volume of 1 x 106 m3.

Following a significant increase of seismicity during January 2000, a seismic crisis started at 2335 on 13 February and the eruption began at 0018 on 14 February. At least five vents opened "en echelon" on the N flank. These vents formed two N-flowing lava fields. One, consisting of aa lavas, formed on the E side of crater "Puy Mi-Cote", and the second issued from a large fissure above "Piton Kapor" (Bulletin v. 23, no. 3). Both flows joined close to the border of the caldera and followed the slope eastward to "La Plaine des Osmondes." At about1100 on 14 February, lava fountains on the main fissure were 5 m high. Further observations were hampered by very heavy rainfall and winds from a tropical storm centered 250 km N of Réunion Island.

A basaltic shield volcano, Piton de la Fournaise forms the SE half of Réunion Island, 700 km E of Madagascar. It has been one of the most active oceanic volcanoes, with more than 100 eruptions in the last 300 years. Three calderas formed from events at around 250,000, 65,000, and 5,000 years ago by progressive eastward slumping of the volcano. Most historical eruptions originated from the summit and flanks of a 400-m-high lava shield within the youngest caldera.

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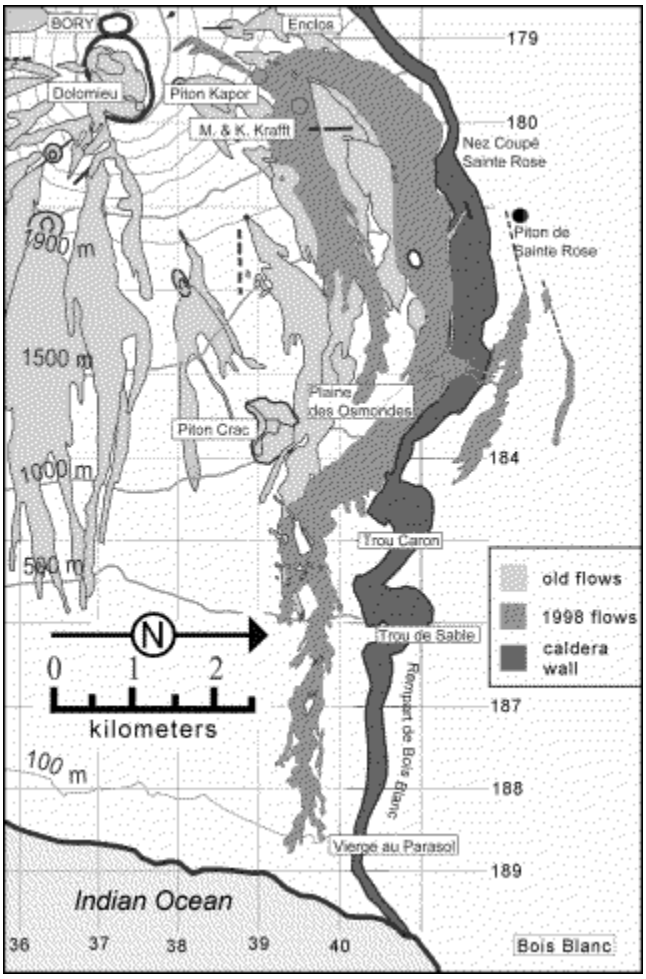

Map of the NE quadrant of Piton de la Fournaise showing important craters and other features. The dark tone represents the caldera wall, the light-gray areas indicate the extent of lava flows dating from 1972. The medium-gray shows flows since March 1998. Courtesy of OVPF.

Pacaya

A vigorous new phase of explosive and effusive activity began at Pacaya in late 1999 (Bulletin v. 24, no. 12). The eruption began with Strombolian activity on 23 December 1999 and, by 16 January 2000, built a ~50-m-high cinder cone within the summit crater. On 4 January the lava had started to flow beyond the summit crater and, by 10 January, the lava extended 1 km down the SW flank. Subsequently, the summit crater fed a second lava flow that descended the 30-40° slopes along the N flank of Pacaya's central cone (figure). At the base of the cone, the lava channel bifurcated and the outer crater wall deflected the flows NW. Along its medial section, the southernmost channel was 5-7 m deep and 7-10 m wide. By 2130 on 14 January this portion of the flow had formed a tube. After exiting the channel and tube system, the lava formed a pond in the basin between the base of the cone and outer crater wall building a 200-m wide compound aa lava field ~1 km long. This field overlaid most of the lava field formed by the September 1998 eruption.

At 1615 on 16 January the eruption increased in intensity and changed from Strombolian to fountaining. These fountains fed ash plumes, which were observed on GOES images, and the cinder cone built earlier was destroyed during the first 5 minutes of the high intensity activity. Fountaining initially reached heights of 800 m but diminished to 300 m by 1830. Fallout from the fountains fed near-constant nuées ardentes and a lava flow that extended 600-700 m to the SW (figure 3). Within the summit crater lava fountaining appeared from about four vents, or possibly a fissure, with the highest and most vigorous fountains issuing from the southernmost sources. Fountains from these southernmost sources projected obliquely to the S. Strombolian activity returned around 2030.

The 16 January episode was one of the most spectacular at Pacaya in all of its current 35-year-long history of eruption. While the population of Guatemala City watched the fountaining, the fall of over 30 cm of tephra in the area S of the vent forced over 1,000 people to leave that area and closed the Aurora Airport that evening.

Activity in the morning of 19 January was characterized by low-level degassing but at 1325 an ash plume rose ~5 km above summit level. Ballistic block fall occurred during the first minute and a maximum temperatures of 97°C was measured at the base of the column a few minutes later. The plume spread mainly to the S, but wind shear caused spreading of the plume to the N and W. The intensity of ash emission began to wane and by 1415 the plume height had declined to 200-300 m and the ash plume temperature decreased to 24-35°C. Persistent ash emission continued from at least two sources within the summit crater throughout the afternoon with frequent larger pulses causing the plume to increase in height and temperature. Persistent ash emission continued to heights of ~50 m, with occasional puffs pushing the plume to ~100 m, causing higher temperatures and ash drifting 3-6 km to the S. Seismic records show that the high intensity portion of this eruption lasted 8 minutes followed by a 30-minute-long hiatus and then 7 to 8 pulses each lasting between 45 seconds and 4 minutes.

Seismic records indicated a renewal of activity in the late afternoon of 22 January. GOES hot spot monitoring tool (http://volcano1.pgd.hawaii.edu/goes/) indicated hot-spot activity beginning between 1725 and 1745 and relating to intracrater activity. A Landsat-7 Enhanced Thematic Mapper (ETM+) scene acquired at ~1030 on 23 January shows an intense thermal anomaly within the summit crater, a point source 180-240 m in diameter. The absence of an elongated anomaly extending from this source indicates that flow activity had not begun at that time.

By 24 January, Strombolian eruptions fed a persistent, diffuse plume of fine ash that rose ~1.5 km above the summit. Later observations on the same day showed vigorous, near-continuous Strombolian activity with explosions occurring at a rate of 19-28 events per minute and throwing incandescent bombs as large as 1-2 m in diameter and occasional ribbon spatter to heights of about 300 m. At nightfall observers from Guatemala City could see a continuous glow from the crater. Bombs from at least two vents landed within a few hundred meters from the vents on the N, S and W flanks; the ejecta on the S causing incandescent avalanches within 200-300 m of the crater as bombs tumbled down the steep slopes of the summit cone. Lava flow extended southward for 400-500 m, and turned SSE to SE at the base of the cone. For the first 400-500 m, the flow was mainly contained in a 5- to 10-m-wide channel with two heavily crusted sections, but at the break of slope of the cone an incandescent aa flow widened to ~200 m. The flow front contained three lobes, each 30-70 m wide and the longest of which advanced ~ 1 km from the vent (figure).

Although a persistent ash plume was observed from Guatemala City the following day (25 January), the plume had disappeared by 0900. A rapid decline in GOES-recorded hot spot radiance between 2143 on 24 January and 0056 on 25 January indicated that lava had ceased to flow.

At 1815 on the evening of 29 February, a second major eruption began. An ash column rose 2 km into the sky and then, at 2140, a column of erupting lava rose to ~700 m above the summit. Wind blew the ashes to the SSW, falling on the towns of Escuintla and Siquinala. The National Disaster network declared a red alert and surrounding communities were evacuated. A hot spot appeared on the GOES image around 2045 and a peak of activity was reached around 2200 which diminished sharply thereafter. However, by 1030 on 1 March, the hot spot intensity was still fairly high, albeit lower than the peak the previous evening.

On 1 March Andy Harris and co-workers in the HIGP/SOEST group noted a "big flash" in the GOES data depicting Pacaya. This appeared to develop from a hot spot that began around 2045 on 29 February (0245 on 1 March GMT), possibly as early as 2015. Peak hot spot activity (and the flash) was reached around 2202, and an ash cloud tracking NE (which extended seven to nine GOES pixels during 15 minutes) was apparent in imagery at that time. After 2202, the hot spot intensity fell sharply but as of 1032 on 1 March it still remained.

Harris also noted that their system issued an automated email notice for this event at 0424 GMT, just 22 minutes after acquiring the image. Since their system alerted them to the hot spot a few hours prior to the main flash and ash emission, this enabled them to watch as activity escalated.

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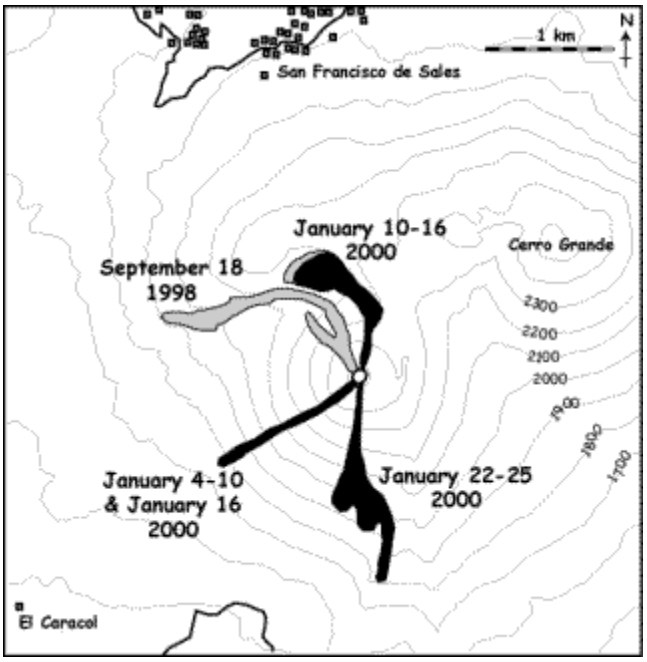

. Sketch map of Pacaya showing flow fields active during September 1998 and January 2000. Courtesy of Otoniel Matías, Andy Harris, Bill Rose, Luke Flynn, and James Vallance.

Nyamuragira

As 27 January eruption began, witnesses assumed they heard artillery fire.

This report covers the period 27 January-early February 2000 at Nyamuragira, ~50 km NW of the town of Goma. The following report was prepared by Akumbi Mbiligi with additional notes and explanations provided by Hiroyuki Hamaguchi, who has collaborated on Virungan volcano research for over 20 years.

Mbiligi learned that an eruption began at 0800 (GMT) on 27 January. During that night the volcano expelled incandescent material and rocks. The area where the venting took place was SE of the summit, near Kagano (29.217°E, 1.433°S), a centre active during 1989-98 (see map in Bulletin v. 14, no. 5). Investigations were attempted during 28-29 January. The eruption site could not be reached from Rumangabo, the settlement containing Virunga National Park's main office and the observatory's seismic station, because of security problems in the Park. More specifically, the forest surrounding Nyamuragira has been partly occupied by rebel groups since 1994, a situation that has thwarted geological observations. Mbiligi also visited Kakomero, a small village at the park entrance supporting guides and serving as a past base camp for climbers.

Press reports indicated that the eruptive activity spread panic among people near the eastern Congolese rebel stronghold at Goma. The refugees thought they were under attack. According to press reports seen in the early phases of the eruption, the westerly advancing lava flows had not presented Goma with any immediate threat of encroachment. In addition to the lava flow, the eruption was characterized by ejection of bombs, cinders, and ash from the crater and a strong rumbling. According to Mbiligi and his sources, as of 31 January the volcano's activity had decreased notably.

NOAA infrared satellite imagery illustrated the extent of the lava flow as it appeared beginning around the time of the eruption. One image from 2 February showed a distinct thermal signature interpreted as a hot spot (several pixels in extent) and a possible ash plume trailing off towards the W (see, for example, multichannel color-composite image, number D03304: NOAA-14 POES AVHRR GAC; Channels 3,2,1 at 4-km resolution; acquired at 0456 GMT). As of 10 February satellite imagery continued to indicate high thermal fluxes from fresh lava flows. Around the time of the eruption at least one Earth Probe TOMS image indicated elevated sulfur dioxide concentrations (with a few scattered pixels reaching over 15 milliAtm-cm).

Background. Africa's most active volcano, Nyamuragira is a massive basaltic shield volcano north of Lake Kivu and NW of Nyiragongo volcano, along the border between Rwanda and the Democratic Republic of Congo (formerly Zaire). Lava flows from Nyamuragira cover 1,500 km2 of the East African Rift. The summit is truncated by a small 2 x 2.3 km summit caldera that has walls up to about 100 m high. Some historical eruptions have occurred within the summit caldera, modifying the morphology of the caldera floor. Other eruptions have issued from the numerous fissures and cinder cones on the volcano's flanks. Flank radial fissure activity has been common in the 30 eruptions known since 1882. A lava lake in the summit crater, active since at least 1921, drained in 1938. Twentieth-century

flank lava flows extend more than 30 km from the summit, reaching as far as Lake Kivu.

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