Centennial Eruption at Merapi volcano
–
October / November 2010

P. Jousset, BRGM, 6 December 2010
Updated 17th December

The 2010 eruption at Merapi volcano could have killed many more people. Up to now, “only” about 300 deaths are to be mourned. The large eruption in 1931 killed 1300 people, despite a volume of expelled magma much smaller than during the 2010 eruption and a density of population much higher nowadays. Merapi volcano (7° 32.5’ and 110° 26.5’) is a strato-volcano with an elevation of 2980 m above sea level (before the 2010 eruption). Its flanks covers 4 administrative “kabupaten’ (Sleman, Magelang, Boyolali and Klaten) with a population of more than one million inhabitants. Thanks to the great experience of the Center of Volcanology and Geological Hazard Mitigation (CVGHM) to deal with volcanic eruptions (e.g., Kelut, 2007; Sinabung, 2010) and by gathering observations from modern techniques including those developed within in MIAVITA, the management of Merapi 2010 eruption represents one of the best managed eruptions ever.

The eruption of Merapi in 2010 is really different compared to what we knew from the recent eruptions in 1994, 1997, 2001, and 2006. Those eruptions were associated with a dome growth and collapse, with sometimes one or two explosions (VEI~4). A dome is a piling of rocks resulting from slow emission of hot viscous magma at the ground surface. At Merapi, when the dome reaches 2 to 4 millions cubic meters, it becomes unstable and collapses, producing “nuées ardentes”. Predicting the exact time of collapse is difficult, as no precursor exists. Eruptions of this type happened every 4 to 6 years and lasted rarely longer than 15 days. Associated pyroclastic flows and evacuated areas, for these recent eruptions, never exceeded 6 and 10 km respectively. Those eruptions were studied in details by CVGHM in collaboration with scientific teams from Europe, USA, Japan, New-Zealand …

In the framework of the MIAVITA project, Dr. Surono (Head of CVGHM and partner of MIAVITA) invited BRGM and the University of Cambridge to join the team in charge of the monitoring of the activity during this eruption. Dr. Marie Boichu (University of Cambridge) and Dr. Philippe Jousset (BRGM) joined CVGHM team at Yogyakarta at the beginning of November and contributed to follow the main part of the eruption, in the heart of the Indonesian team.

The 2010 eruption affected all directions around Mount Merapi. Nuées ardentes reached 4 km to the North, 11.5 km to the West, 7 km to the East and about 15 km to the South. Explosive bombs reached 4 km from the summit in all directions, with large emissions of ash and gas into the atmosphere. Ash dispersed by the wind affected mostly the western part of the volcano, and disturbed air traffic up to Jakarta. The airport of Yogyakarta closed for more than

The MIAVITA project is financed by the European Commission
under the 7th Framework Programme for Research and Technological Development, Area “Environment”,
Activity 6.1 “Climate Change, Pollution and Risks"

15 days. As the rainy season has recently started, the large ash deposits are already being transformed in mud flows (lahars) flooding valleys close to Mount Merapi. In order to protect population, the Indonesian government decided, with the help of USGS to set-up a system of more than 20 geophones along the valleys and transmits data in real time to the Center of Volcanology. With such a real-time system set-up for the first time at Merapi volcano, the BPPTK will be able to alert security teams as soon as a lahar starts in any valley, by sending messages to the right place at the right time.

Preliminary analysis of observed records and eruptive sequence at Merapi allows drawing 4 main phases, quite classical for a volcanic eruption.

The first phase involved phenomena associated with magma intrusion below the volcano. First signs of reactivation of Mt. Merapi were detected at the beginning of 2009. Those signs were an increased number of earthquakes, and slight inflation of the volcano. Pak Surono proposed at the kick-off meeting held in Yogyakarta on July 1-4, 2009 to change the Indonesian target volcano from Kelut (which did not show any sign of further activity after the 2007 eruption) to Merapi volcano. The MIAVITA consortium agreed… Later signs of reactivation became slowly more evident; CVGHM expressed concern about Mt. Merapi activity at the mid-term meeting of MIAVITA on 16-17 September 2010 in Rome. Mt. Merapi was expected to start a new eruption within the next 3 months. On 20 September, the alert level was raised from “Aktif Normal” (= normal activity) to “Waspada” (= be careful), on the basis of an increase in the number of volcanic earthquakes and in the dome deformation measured by Electronic Distance Measurements (EDM). Aware that the volcano was reactivating, MIAVITA’s monitoring team accelerated the preparation of equipment in Indonesia and in Europe. On 21 October, because the seismic activity still increased and because summit deformation rate dramatically increased (more than 20-30 cm/day) as observed by EDM, the status was raised to the 3rd alert level “Siaga” (= be ready). During the following 4 days, the number of volcanic earthquakes increased again to more than 250 earthquake/day and deformation rate at the summit exceeded 50 cm/day; on 25th October 2010 at 06:00 local time, the status was raised to the 4th level “Awas” (= danger), 35 hours before the first eruption, which meant that population was evacuated within a radius of 10 km. More than 800 volcanic earthquakes were recorded by the permanent network and the MIAVITA broadband seismological network. The first eruption occurred on 26 October at 17:02 Local Time. The seismic energy released over this period is equivalent to the cumulated energy of the 1994, 1997, 2001, 2006 eruptions together. The eruption on 26 October destroyed former domes, and “nuées ardentes” reached ~ 6 to 7 km to the South. More than 30 lives were claimed in Kinarejo village, including Mbah Marijan, the gate keeper of the volcano, after traditional belief. All victims refused to follow authority recommendations. Many people thought that the eruption was finished after this episode.

The second phase started after a short time of relative calm, when fresh magma appeared in the new crater forming a new lava dome with quite strong lava emission rate. For about 2 days, the eruption produced a 8 km height column, partly corresponding to the evaporation of water of the hydrothermal system at the summit and from magma intruded from SO_2 analysis.

The MIAVITA project is financed by the European Commission
under the 7th Framework Programme for Research and Technological Development, Area “Environment”,
Activity 6.1 “Climate Change, Pollution and Risks"

During the third phase (starting on 3rd November), a series of magmatic explosions with increasing frequency and intensity occurred, some of them heard at more than 30 km from the summit, for about 3 days. The excluding zone was enlarged to 15 km during these powerful eruptions of beginning of November. The peak of activity occurred on 5 November 2010 at 00:05 Local Time (4 November, 17:05 GMT), with a powerful explosion (VEI~4) which led to pyroclastic flows up to 15 km long in Gendol. The seismic MIAVITA station located at 50 km South of the volcano (Imogiri) was the only one capable to monitor the volcano at the time (others seismic stations were either destroyed, either saturated): the amplitude of the seismic signal doubled compared to the explosion on the 3rd November amplitude, also recorded Imogiri. The excluding zone had just been extended to 20 km at the time of the large explosion, on the basis of this observation., saving many lives. The plume rose to more than 15 km height. This explosion liberated a large quantity of SO_2 and ash, which disturbed air traffic for several days up to Jakarta. A lot of scientific equipment (including MIAVITA BB seismometers) was destroyed at the summit and on the flank of the volcano up to a distance of 4 km. At the paroxysm, the MIAVITA station located at 50 km South of the volcano, was the only one non-saturated seismometer able to follow the timing and magnitude of the explosions.

The fourth phase consisted in intense degassing and continuous eruption of nuées ardentes. This activity was accompanied by a strong tremor (saturation of the station at 6 km distance) with peak frequencies between 1 to 8 Hz. The tremor intensity decreased slowly with time and was sometimes punctuated by strong explosions, heard in Yogyakarta (~ 30 km far from the summit), until 15 November. On 19 November, when the activity lowered, the excluding zone was reduced with a radius ranging in 5-15 km depending on the direction On 3 December, the alert level was decreased from “Awas” (Danger) to ”Siaga” (Be Ready)

These different stages could be described and analysed in great detail in real time, thanks to the large number of modern techniques deployed for the occasion, especially within the European project MIAVITA: broadband seismology (BRGM), deformation surveyed by InSAR interferometry (INGV), SO_2 gas flux from ground measurements using UV-DOAS spectroscopy (Cambridge University) and SO_2 satellite images (NILU). Those observations were processed as quickly as possible and sent to Dr. Jousset and Dr. Boichu in Yogyakarta. The integration of theses observations with ground deformation measurements from USGS and visual ground observations performed by CVGHM, and benefiting from of the great experience of Indonesian volcanic management, Dr. Surono and the local team could establish diagnosis on the eruption status and the phenomena and issue efficient and timely recommendations to the local authorities to manage evacuations.

The summit of Mount Merapi has dramatically changed. The present crater (~ 500 m large and > 200 m deep) contains a small dome, which hosted some explosions until November 15th when gas could not escape freely. The total released energy (estimated from the RSAM = Real-time Seismic-Amplitude Measurement) is greater than 100 times the one associated to the commonly encountered type of eruptions like in 2001 or 2006. However, eruptions of this magnitude have been recorded many times on Merapi.in geological time.

The MIAVITA project is financed by the European Commission
under the 7th Framework Programme for Research and Technological Development, Area “Environment”,
Activity 6.1 “Climate Change, Pollution and Risks"

Due to this exceptional situation, the President of the Republic of Indonesia, Bapak Susilo Bambang Yudoyono, requested Dr. Surono to enlarge the collaboration. An American team from USGS came to set up a seismic network for monitoring lahars; a Japanese team from the Disaster Prevention Research Institute set up infrasonic equipments to track explosions; a French team from the Institut de Recherche pour le Développement installed one additional broadband seismometer. Prof. Franck Lavigne (MIAVITA member), also joined the team in charge of lahar monitoring, together with his Ph.D student Adrien Picquout, who is semi-permanently present in Yogyakarta. All these observations represent a very valuable scientific data set never gathered up to now on Merapi, and will contribute greatly to the understanding of this eruption.

With only 300 deads, but more than 380 000 refugees, this eruption is the one which implied the largest number of moved people for this kind of event. Vulnerability studies by the MIAVITA's team (Prof. Franck Lavigne, CNRS, Dr. Susanna Jenkins, CAR and Jochen Berger, University of Hohenheim carried out in December 2010 will help to estimate the socio-economic cost and the number of saved lives thanks to the extraordinary good management of the crisis by CVGHM.

Dr. Surono obtained his Ph.D. in France and is at the head of CVGHM, in charge of 129 active volcanoes. Every year, at least 1 volcano on average starts an eruption (Kelut: 2007; Sinabung: 2010; Merapi: 2010; Bromo: 2010; ...). Dr. Surono has a long experience of managing volcanic eruptions and has become in the last weeks very famous in Indonesia. Since the death of Mbah Marijan on 26 October, he is now referred as the new gate keeper of Merapi, armed with modern techniques of volcano monitoring, hazard and risk assessment as well as communication.

The MIAVITA project is financed by the European Commission
under the 7th Framework Programme for Research and Technological Development, Area "Environment",
Activity 6.1 "Climate Change, Pollution and Risks"