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Devastating landslides related to the 2002 Papandayan eruption

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ABSTRACT

Papandayan is an A-type active strato volcano located at some 20 km SW of Garut or about 70 km SE of Bandung the capital city of West Java Province. Geographically, the summit of this volcano lies at the intersection between 07º 19' 42" S and 107º 44" E. The 2002 Papandayan eruption was preceded by two felt earthquakes, 8 times of A-type volcanic earthquakes and 150 times of B-type volcanic earthquake. These events were followed by a phreatic eruption that took place on 11 November at 16.02 local time. Field observation shows that the summit region, mainly around the craters consists of rocks that have hydrothermally altered to yield clay rich material. This clay rich material covers most of the crater floors and the crater rim. Mount Nangklak that forms part of the rim also contains a lava plug from the Old Papandayan volcano. This mountain is covered by fine grained, unconsolidated material, and altered rocks. Much of this altered rocks coincides with solfataric and fumarolic activities of 80 to > 300°C. The summit area also contains high discharge of water either originating from the springs or surface water.

The increase in seismicity, the fine-grained hydrothermal altered rocks, and the existence of some faults that pass through the summit region might have weaken the stability of the summit area. As the result, a landslide occurred on the north flank of Mount Nangklak where the landslide material blocked the upper course of Cibeureum Gede River. This landslide material had formed big mudflows that caused several houses of five villages were partly burried, some bridges were devastated and several hectares of cultivated land were damaged.

Keywords: Papandayan, earthquakes, eruption, hydrothermal, alteration, landslides

SARI

Papandayan adalah gunung api aktif tipe A berstruktur strato yang terletak 20 km sebelah barat daya Garut atau ± 70 km sebelah tenggara Bandung yang merupakan ibu kota Propinsi Jawa Barat. Secara geografis, puncak gunung api ini terletak pada perpotongan antara 07° 19'42" LS dan 107° 44" BT. Erupsi gunung api Papandayan didahului oleh dua gempa terasa, delapan kali gempa vulkanik tipe A (gempa dalam) dan 150 kali gempa vulkanik tipe B (gempa dangkal). Kejadian ini diikuti oleh erupsi freatik yang terjadi pada 11 November pada jam 16.02 WIB. Pengamatan lapangan menunjukkan bahwa daerah puncak Papandayan, terutama sekitar kawah terdiri atas batuan yang terubah secara hidrotermal membentuk mineral lempung. Batuan ubahan tersebut menutup sebagian besar daerah kawah dan pinggiran kawah. Gunung Nangklak yang membentuk dinding dan tersusun oleh sumbat lava dari Gunung Papandayan Tua, tertutup oleh batuan berbutir halus terubah dan tidak terkonsolidasi. Sebagian besar batuan ubahan ini berada di sekitar lobang solfatara dan fumarola yang mempunyai suhu antara 80°- >300°C. Daerah puncak juga mengandung banyak air, baik berasal dari mata air maupun air permukaan.

Peningkatan kegempaan, batuan berbutir halus yang terubah secara hidrotermal dan adanya beberapa struktur sesar yang melalui daerah puncak mungkin telah melemahkan kestabilan daerah puncak. Sebagai akibatnya, terjadi longsor di sebelah utara Gunung Nangklak dimana material

longsoran membendung aliran hulu Sungai Cibeureum Gede, mengakibatkan banjir lumpur yang mengubur sebagian rumah-rumah penduduk di lima desa, beberapa jembatan hancur, dan beberapa hektar tanah pertanian rusak.

***Kata kunci**: Papandayan, gempa bumi, letusan, hidrotermal, alterasi, longsor*

Introduction

Papandayan which is 2.665 m high a.s.l. is one of active volcanoes in West Java. Precisely, this volcano is located about 20 km south of Garut or about 70 km SE of Bandung (Figure 1). Geographically, the summit of Papandayan volcano is situated on 7° 19' 42"S and 107° 44 'E. The Papandayan famous eruption took place in 1772, where 40 villages of about 250 square kilometers in extent were covered by debris avalanche deposits, and 2951 people killed during the event. As the result of this debris avalanche producing eruption, a horseshoe-shaped crater was formed.

Before the 2002 eruption, a small phreatic eruption occurred in 1998 discharging gas and mud that reached a height of 5 m above the crater. The distribution of the eruption products just confined around the horseshoe-shaped crater.

A month before the 2002 eruption, Papandayan volcano had shown some precursors. Seismicity increase and small phreatic eruptions took place in Kawah Mas solfataric field on 1-3 October 2002. The numbers of volcanic B type (shallow earthquakes) increased significantly, followed by a big relatively phreatic eruption in Kawah Baru on 11 November 2002. This event was initiated by felt earthquakes and then followed by volcanic A (deep volcanic earthquakes) and B type earthquakes (Purbawinata and Wirakusumah, 2004).

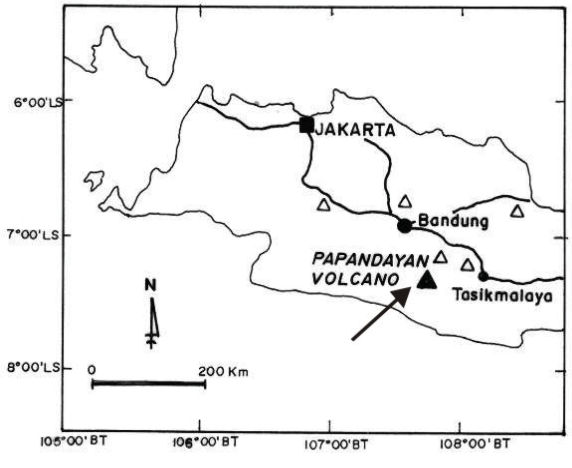

Figure 1. Location map of Papandayan volcano (arrow).

Aim

The aim of this study is to recognize the cause of the susceptibility of an area to slide, and the factors which trigger the movement of the rock mass as what happened prior, during, and post eruption of Papandayan volcano in November 2002.

Problems

The occurrence of landslides in and around a volcanic edifice or other places is a common phenomenon in tropical country like Indonesia. The problems are what factors that influence the occurrence of landslides, why and how landslide occur concomitant with a volcanic activity. The variety of landslide types reflects the diversity of factors which are responsible for their origin. There are several factors which usually contribute to the process of landslide to occur, such as the change of slope gradient, excess of load, shocks, effects of ground water, weathering of rocks, *etc*.

Methods

Field observation was carried out during the eruption of Papandayan in 2002 and during the activity increase in 2004 to find out the cause of devastating and damaging landslides in the studied area. This observation comprises fact finding such as the geology around the summit area, the geometry of the landslides, the products of the 2002 eruption, and the hydrology of the summit area.

Geology

Based on the geological map of Papandayan volcano (Asmoro *et.al.*, 1989) the eruption products of Papandayan consist of lava flows, pyroclastic flow, pyroclastic fall, and lahar deposits. Most of the above deposits are hydrothermally altered mainly around the summit region where fumaroles and solfataric fields are present.

The summit region of Papandayan volcano had at least four large overlapping craters, the youngest of which was breached to the NE by collapse during violent eruption in 1772. The craters of Papandayan contain rocks that have been hydrothermally altered. This material covers most of the crater floors and commonly found in precipitous slopes of the crater rims. Subsequent eruption of these hydrothermally altered craters is locally thick, clayey deposits of explosion rubble and breccia within the horseshoe-shaped crater and on its rim. This clayey hydrothermal alteration was the major way to the destructiveness of historical activity at Papandayan in 1772 (Frank and Lubis, 1987).

Geomorphology

Unlike volcanoes in general, such as Cikurai the nearest neighbouring extinct volcano to the east of this volcano, Papandayan does not show sharp cone on its summit (Figure 2). Previous workers such as Koesoemadinata (1979) and Wahyudin (2004) imply that this phenomena is due to its long activity period and shifting of its eruption centre from one place to another. The collapse of part of its volcanic edifice during devastating eruption in 1772 has left a horseshoe-shaped crater in its summit. Due to sector collapse and shifting of its eruption centres, the morphology of the summit areas of Papandayan has concave and relatively flat surface that can catch more rain water.

Field investigation

Summit Area and NE Slope of Papandayan

The horseshoe-shaped crater of Papandayan volcano has a steep wall that consists of alternating layers of pyroclastic flow and pyroclastic fall deposits, and lava flows. This steep wall is probably

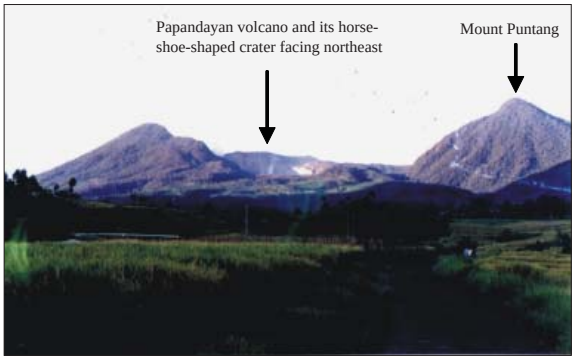

Figure 2. The present morphology of Papandayan Volcano after the collapse during devastating eruption in 1772. Half of its summit portion was thrown and breached to the NE, and covered an area of about 250 square km.

caused by eruptions or faulted. The presence of brecciation, lineament of hills and valleys, hot springs may indicate the process of faulting.

The products of the 2002 eruption consist of wet grey ash fall, altered blocks, magmatic bread crust bombs, blast deposits, and ruble. These products were originating from highly altered lavas of andesitic compositions; some of the rocks show complete silicification. There are some active craters with multiple fumaroles and solfataras (the temperatures of about 300°C) found in the summit region. Some of them filled with hot spring and mud pool (Figure 3). There are two groups of hot springs which can be distinguished in the crater area. The first group of hot springs has outlet temperatures between 40-94ºC, and pH varying from 1.6 to 3.8. Their compositions are typical of acid sulfate-chloride waters. The second group is acid sulfate waters that contain high SO_4 but with low amounts of chlorides. The pH of these springs that range between 1.6 and 2.5 and their temperatures range from 22 to 91ºC. The acid sulfate and steam acid sulfate hot springs are the surface activities of a large hydrothermal system most probably developed since the last magmatic eruption in 1772 (Mazot and Bernard, 2004).

The hot springs which is greenish in color are very acid, the pH varies from 1.6-3.8 and the temperature at the outlet between 40-94ºC. During the 2002 eruption the crater area was covered by eruption material that blocked the flowing of Ciparugpug River.

The concave and relatively flat morphology of the crater area has caused the rain water and other

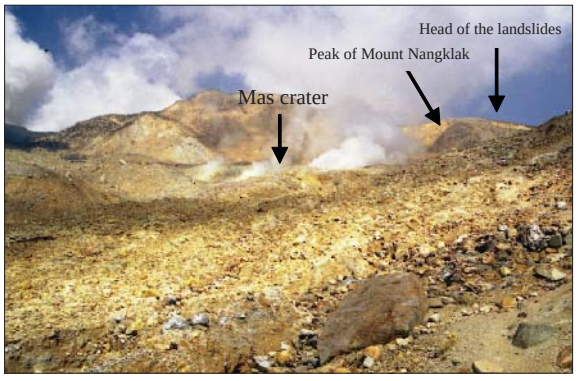

Figure 3. Papandayan crater area, the Mount Nangklak, where the landslides occurred is on the up right corner, as the head of the landslide.

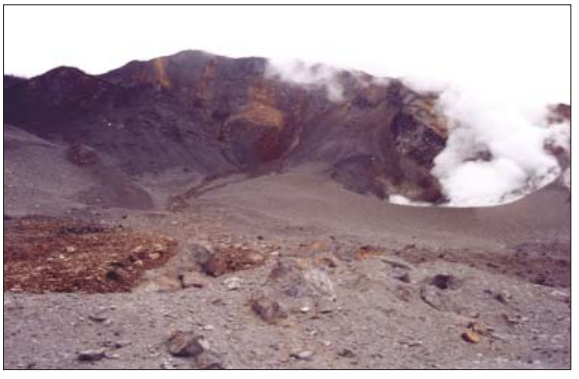

Figure 4. The southern side of Mount Nangklak (smoking) is facing to the crater; directed blast and debris avalanche, part of this hill was thrown away. During this event other new landslides occurred along the inner part of the crater rim, whereas the plain of the first landslides become larger.

surface water to be trapped and it makes a high discharge of ground water. This water comes out at some places in the crater as springs, and this is the head of Ciparugpug and Cibeureum Gede Rivers. The water flowing into the Cibeureum Gede is fresher than to the Ciparugpug, which is present as acid water (Hadisantono and Sumpena, 2002).

Rocks around the craters consist of that have hydrothermally altered rock in-place, as well as altered rocks that have been transported from the original site of alteration. Clay rich rocks produced by in-place alteration cover much of the crater floors and the rim of the craters.

Before the 2002 eruption, Mount Nangklak which is part of the rim also contained a plug from the Old Papandayan volcano, which has been covered by fine grained loose air falls and altered rocks. At present more than half of this mountain has been destroyed by the November 2002 eruption (Figure 4).

Eruptive Events

The eruption of this volcano was preceded by seismicity increase occurred from 1-3 October 2002 and followed by a small phreatic eruption in Kawah Mas. These events were followed by felt earthquakes, volcanic A-type (deep volcanic earthquakes) and volcanic B-type (shallow volcanic earthquakes). The numbers of volcanic B-type earthquake increased significantly from twice to 60 times/day on 10 November 2002 (Purbawinata and Wirakusumah, 2004).

Although the eruption of Papandayan volcano took place for about two months, from October until December 2002, there were only three of them are classified into major eruptions that occurred on 11, 15, and 20 November 2002. Of which, the latest major one produced bread crust bombs, small debris avalanche, and directed blast that went northeastward. The existence of bread crust bombs is believed to indicate a phreato magmatic explosion.

Geologic Structures

There are two general directions of major normal faults which are in SE-NW and NE-SW trends that pass through the summit region of Papandayan volcano (Figure 5). Indications of geological structure that can be recognized in the area are brecciation zone, triangular facet, lineament of valleys and hills, abrupt steep wall, and hot springs.

Landslide Sites

Crater area

Mount Nangklak is part of the Papandayan horseshoe-shaped crater rim located almost in the middle part of the summit area. This mountain is situated in the intersection between the two major faults. It is a steep mountain and there were solfataric and fumarolic fields called the Nangklak crater (now it is covered by erupted product and landslide material). The Mount Nangklak consists of lava plug covered by altered thick fine grained pyroclastic material which is relatively loose material. The shape of the landslide plane that occurred on 11 November 2002,

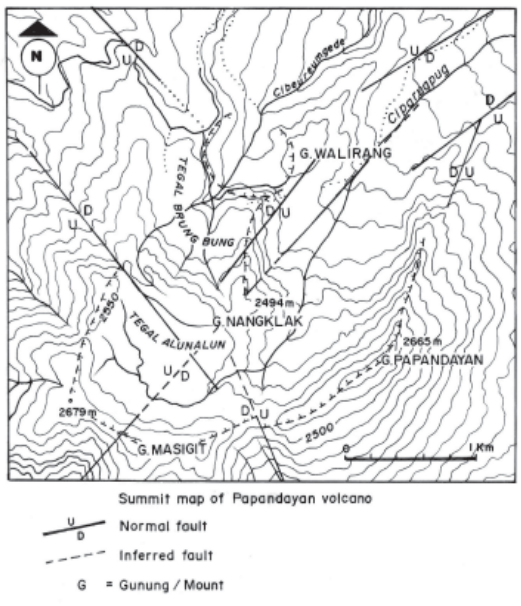

Figure 5. The geological structures (normal faults that oriented in NE-SW and NW-SE trends) and the crater structure of Papandayan. Both general trends of the faults pass through the summit area and intersect to each other around Tegal Alun-Alun as the dead old crater of Papandayan.

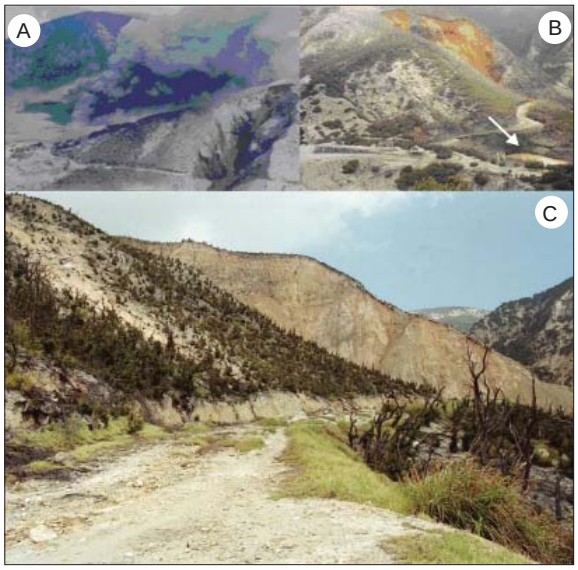

Figure 6. A is the first landslides 11 Nov. prior to eruption, the size was still small; B is the second landslides on 15 Nov the largest eruption, and C is the third large on 20 Nov. The size of the landslide plane became larger & larger. Right corner of figure 6 B (pointed with white arrow) is water pond reflecting the area that contains high discharge water derives from the springs.

is an elongate deep hole about 250 m long x 50 m wide and 50 m deep (Figure 6).

Flank area

Almost the whole of the upper part of the NE flank of Papandayan Volcano consists of hydrothermally altered rocks. The landslide potential areas located near and along the upper course of Ciparugpug River, are controlled by the major fault.

Discussions

Hot spring which is part of the hydrothermal system gradually disturbs the cohesion of rocks resulted in the hydrothermal alteration process. Geologically, the crater and the flank areas of Papandayan volcano have been undergoing strong hydrothermal alteration.

The existence of geological structures such as normal faults have caused fractures around the fault plane and or along fault scarp. Ground water flow exerts pressure on altered fine grained volcanic particles, which impairs the stability of slopes around Mount Nangklak.

Spring water issuing at the base of fractured volcanic rocks, seeps together with the rain water into the altered steep slope of Mount Nangklak, changing its consistency and impairing its physical properties. The change of slope gradient is either caused by faults or volcanic and tectonic processes, provokes a change of stress in the rock mass, the equilibrium is then disturbed. Therefore, the steep slopes of Mount Nangklak that consist of highly altered rocks mainly the fine grained deposits are very susceptible to sliding.

Earthquakes and large volcanic explosions can disturb the equilibrium state of slopes. In loose sand or clastic material such as air fall deposits, shocks can cause a disturbance of intergranular bonds and consequently, a decrease in cohesion. In saturated fine sands and clays, shocks may result in displacement or rotation of grains leading to a sudden liquefaction of the soil (Zaruba, 1967).

The two felt earthquakes, on 11 November 2002 which was accompanied by a big phreatic eruption in Kawah Baru, have shaken the water-saturated and

hidrothermally altered fine grained volcanic sands cover of Mount Nangklak. The unstable slopes and the geological structures found in the area may also have contributed to the occurrence of the landslides of Mount Nangklak resulted in devastating mud flows in Cibeureum Gede River.

The landslides that occurred afterward inside and around the crater region took place during the eruption period mainly around the 15 and 20 November 2002 where phreatomagmatic eruption occurred producing small debris avalanche, bread crust bomb, and directed blast.

Conclusions

The existence of hydrothermal system in the area plays an important role in the process of alteration that weaken the cohesion of the rocks.

The hydrothermally altered volcanic rocks that compose most of the summit area of Papandayan mainly the Mount Nangklak volcano have caused the area to be susceptible to sliding.

The existence of geological structures such as normal faults that cause fractures in rocks allow the ground water exerts pressure on soil particles, which impairs the stability of slopes.

The high discharge water around the summit area has caused the highly altered fine-grained volcanic sands to become saturated. In saturated loose fine sands and clayey rocks, shocks may result in a displacement or rotation of grains leading to a sudden liquefaction.

The felt earthquakes and series of volcanic eruptions that produced shocks had disturbed the equilibrium state of the Nangklak slope which is composed of fine grained hydrothermally altered rocks, resulted in the occurrence of landslides.

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References

Asmoro, P., Wachyudin, D., and Mulyadi, E., 1989. Geological Map of Papandayan volcano, Garut, West Java. *Directorate of Volcanology*, Bandung.

Frank, D., Lubis, H., Casadevall,T.J., Glicken, H., and Suparman, 1987. Influence of hydrothermal alteration on volcanic hazards at Papandayan volcano, West Java, Indonesia. *Hawaii Symposium on How Volcanoes Work*, 1987. Abstract Volume, p.80.

Hadisantono, R.D., Sumpena, A.D., and Abdurachman, E. K., 2002. Banjir lumpur pada letusan Papandayan, Nopember 2002 - Mei 2003. *Internal Report*, Directorate of Volcanology and Geological Hazard Mitigation.

Kusumadinata, 1979. *Data dasar Gunungapi Indonesia*. Direktorat Vulkanologi. Bandung.

Mazot, A. and Bernard, A., 2003. The hydrothermal system of Papandayan volcano and the November 2002 eruption: CO_2 degassing, fluid geochemistry and mineralogy of ejecta. *Journal of Volcanic Activity in Indonesia*, 1, p 129-152; Special Edition. Directorate of Volcanology and Geological Hazard Mitigation.

Purbawinata, M.A., Wirakusumah, A.D., and Pratomo, I., 2004. Directed blast and debris avalanches of 2002 Papandayan eruption, West Java, Indonesia. *Journal of Volcanic Activity in Indonesia*, 1, p.103-114; Special Edition. Directorate of Volcanology and Geological Hazard Mitigation.

Wahyudin, D., 2004. Geologi Gunungapi Papandayan dan Potensi Bahan Galian. *Journal of Volcanic Activity in Indonesia*, 1, p.49-60; Special Edition. Directorate of Volcanologi and Geological Hazards Mitigation.

Zaruba, Q. and Mencl, V., 1967. *Landslides and their control*. Elsevier, Amsterdam-London-New York in co edition with Academia, Publishing House of the Czechoslovak Academy of Sciences. Prague 1969.