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The characteristic of eruption of Indonesian active volcanoes in the last four decades

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ABSTRACT

Indonesia has 129 active volcanoes those are scattered in Sumatra, Java, Bali, Nusa Tenggara, Maluku, and Sulawesi islands. Approximately 13% of the world's active volcanoes are located in Indonesia. Active volcano in Indonesia is divided into three categories, namely type A, B, and C. A type are those volcanoes recorded eruption since 1600. B type volcanoes are those in solfataric and or fumarolic activity, there is crater since the year 1600 there is no evidence of increasing activity nor eruption. Type C are volcanoes those are in solfataric stage and or occasionally the volcanic edifice is not clear. There are 79 active volcanoes that consist of type A, 29 volcanoes type B, and 21 volcanic type C."A type volcano" is the first priority for our institution to monitor their activities. Each year approximately 10 to 12 active volcanoes in Indonesia increase their activity, and two to four volcanoes erupted with different characters. At least there are five characters of volcanic eruption of Indonesian active volcanoes that can be recognized in the last four decades. The first character are volcanoes with lava domes; the second are those with crater lakes; the third are those with open vent system; the fourth with gas eruption, and the fifth are cones inside a caldera.

Keywords: character of volcanic eruption, solfataric, fumarolic

SARI

Indonesia mempunyai 129 gunung api aktif yang tersebar mulai Sumatera, Jawa, Bali, Nusa Tenggara, Sulawesi dan Maluku. Jumlah tersebut sama dengan 13% gunung api aktif di dunia. Gunung api aktif Indonesia dibedakan dalam 3 kategori berdasarkan sejarah letusannya, yaitu gunung api tipe A, tipe B, dan tipe C. Gunung api tipe A tercatat pernah meletus sejak 1600, jumlahnya 79. Tipe B adalah gunung api yang mempunyai kawah dan lapangan solfatara/fumarola tapi tidak ada sejarah letusan sejak tahun 1600, jumlahnya 29. Gunung api tipe C hanya berupa lapangan solfatara/fumarola, jumlahnya 21. Gunung api tipe A yang diprioritaskan untuk diamati. Setiap tahun antara 10 sampai 12 gunung api yang meningkat aktivitasnya, yang mencapai tahap letusan sebanyak 2 sampai 4 dengan karakter yang berbeda. Paling sedikit ada 5 karakter letusan gunung api di Indonesia yang diamati dalam empat dekade terakhir, yaitu letusan yang menghasilkan kubah lava, letusan dari danau kawah, ketiga letusan dengan

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pipa (kepundan) yang terbuka, keempat adalah letusan gas, dan yang ke lima adalah letusan yang menghasilkan bukit baru di dalam kaldera.

***Kata kunci**: karakter letusan gunung api, solfatara, fumarola*

INTRODUCTION

Indonesia has 129 active volcanoes those are scattered throughout the archipelago except the island of Kalimantan. Approximately 13% of the world's volcanoes found in Indonesia. The Indonesian archipelago is one of a classic region that shows a relationship between active volcanism and tectonic which is influenced by the interaction of three tectonic plates, the Eurasian Plate moving to the south, the Indian-Australian plate moving towards the north, and the Pacific Plate is moving towards the west.

The Cenozoic Volcanoes in Java mostly appeared over Neogene marine sediments in the upper complex than the Pre-Tertiary (Hamilton, 1979). The dominant rock type of lava on the island of Java is basaltic andesites with silica content of approximately 55% (Nicholls and Whitford, 1976). There is a positive correlation between the depth of Benioff Zone and K2O contents, trace elements and Sr isotope ratios, which indicates that the magma originating from the mantle is related to subduction. The thickness of the crust under the volcanic arc in Java ranges from 20-25 km with a Benioff Zone dipping of 55 ^{0} to the north.

The distribution of the Quaternary volcanoes in Indonesia is shown on figure 3. The young mountain system in Indonesia consist of two parallel island arcs, namely: volcanic inner arc and non volcanic outer arc trench. Sumatra and Java are good examples. Hirokawa (1980) stated that most volcanoes in the volcanic inner arc are stratovolcanoes, are composed of andesite, many of which are active. Some of them have cinder cones and or lava domes, as central and parasitic volcanoes.

Based on their activities and eruptions, Indonesian active volcanoes are divided into three types, namely: type A, type B and type C (Kusumadinata, 1979). Type A are volcanoes that show magmatic eruption at least once since the year 1600, experienced activity increase, or even just phreatic eruption. At this time, some of them frequently erupt, such as Semeru, Dukono, Marapi, Ibu and Raung. The other volcanoes of this group erupt periodically 1-5 years the longest. Due to this reason, therefore, the type A volcanoes are included as the first priority to be monitored by the Centre for Volcanology and Geological Hazard Mitigation. The volcanoes are monitored by using continuous and periodic seismic methods, assisted by other methods such as electronic distance measurement (EDM), tilting, global positioning system (GPS), and gas and water geochemistry. When the activity in-

creases mobile seismometers are immediately installed.

There are 79 A type volcanoes those are scattered in different areas and they are shown in figure 1, whereas the distribution of each area is shown on Table 1. B type volcanoes are those in solfataric and or fumarolic activity,since the year 1600 there is no evidence of increasing activity nor eruption. Type C are volcanoes those are in solfataric and or occasionally the volcanic edifice is not clear. There are about 21 volcanoes observed through out the country those are in the form of solfataric and fumarolic field, and they are known as geothermal areas.

Table 1: Distribution of Indonesian Active Volcanoes

Area	Active Volcanoes			Sum
	A Type	B Type	C Type	
Sumatera	12	12	6	30
Java	21	9	5	35
Bali	2	-	-	2
Lombok	1	-	-	1
Sumbawa	2	-	-	2
Flores	17	3	5	25
Laut Banda	8	1	-	9
Sulawesi	6	2	5	13
Kepulauan Sangihe	5	-	-	5
Halmahera	5	2	-	7
Sum	79	29	21	129

Definition Of Active Volcanoes Indonesia:

A - Type: Volcano since the year 1600 shows an increased activity, magmatic or even only phreatic eruption.

B - Type: Volcano in solfataric and/or fumarolic activity, since the year 1600 there is neither evidence of increasing of its activity nor eruption.

C -Type: Solfatara and/or fumarole field, some times the volcanic edifice is not clear.

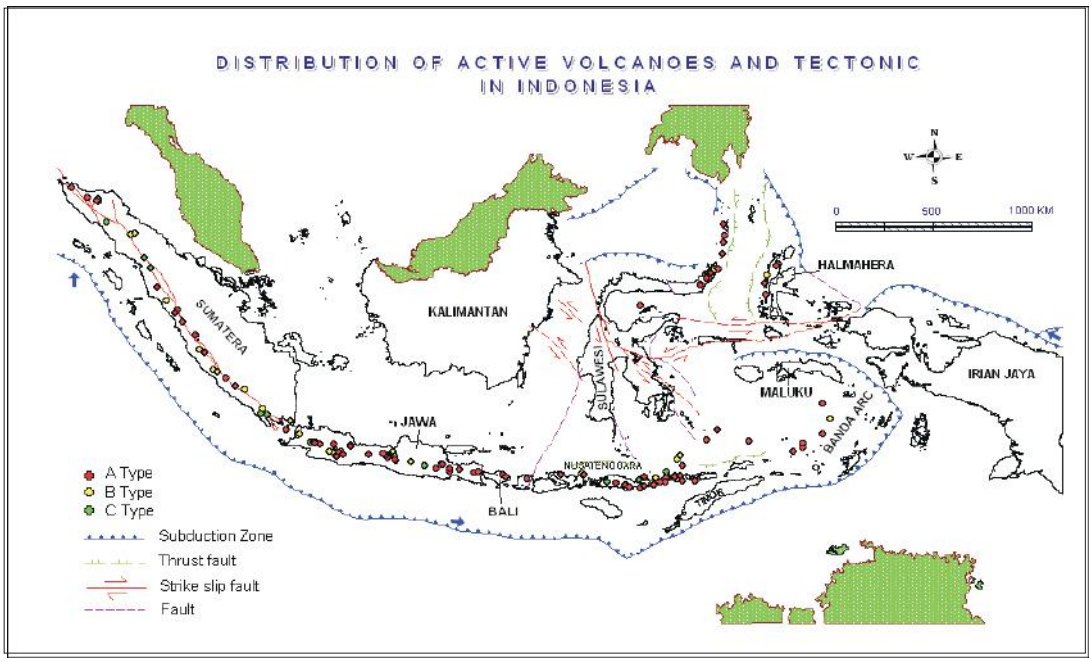

Figure 1. Distribution map of active volcanoes of Indonesia.

METHOD

The review of eruption characteristics of Indonesian active volcanoes is based on the records of volcanic eruptions and activity increase during the last four decades. Based on the activities history, a volcano is not a sudden change of eruption characters, but it takes a long time to change. Mt. Kelud for example, is a volcano with a crater lake that has turned into a volcano with lava dome.

During its activities history, Mt. Kelud has produced 7 lava domes. So Kelud activity has returned to its previous eruption characters. By knowing the eruption characteristics of a volcano is expected to be useful in forecasting and mitigation efforts when its activity increases. But this will be a void for a dormant volcano when becomes active again. Within two decades, there were two volcanoes erupted after 400 years dormant. Based on these facts, the classification of the active volcanoes of Indonesia must be rethought.

ERUPTION CHARACTERISTICS

Each year the activity of approximately 10-12 Indonesian active volcanoes increased, and two to five of them erupted. There are 78 volcano observatories across the country to monitor the type A volcanoes continuously. Each Observatory has at least one component seismometer, but some others have more.

In the last five decades the eruption characteristics of Indonesian active volcanoes can be divided into five categories namely: vol-

canoes with lava domes, crater lakes, open vents, gasses and cones within calderas.

1. Volcanoes with lava domes

Morphologically these volcanoes are conical in shaped with lava domes on their summits. This type is belong to Merapi (Yogyakarta); Soputan (North Sulawesi); and Karangetang (Sangihe Islands) and Kelud that erupted in 2007. These are the most active volcanoes in Indonesia, almost every year at least one of them erupts producing lava dome or the previous dome grows bigger and higher.

Lava dome forming is often followed by lava flows and or pyroclastic flows generated by dome collapse or lava avalanche. Thin ash fall deposits are generally related to pyroclastic flows which is distributed locally depends on the prevailing wind during the emplacement of the pyroclastic flows. Pyroclastic flow deposits are usually found in valleys close to the lava dome or lava flows up to 5 km away (Fig. 2). Pyroclastic flows are rich in dense lithic and juvenile rock fragments of andesite to basaltic andesite composition set up in ash – sandy matrix.

Merapi is a famous volcano in the world. It has a special character called Merapi type. Within five decades this volcano had built new lava dome and producing several events of dome collapsed pyroclastic flows (Fig. 3). When a new lava dome formed, it shifts to different points around the crater that implies the hazard area that will be affected by eruption.

Volcano monitoring especially the summit area, ground deformation, seismic, and visual methods are very important to predict the next eruption and mitigation efforts. Volcanic terrain is a good area for agriculture due to fertile soil and nice scenery for tourism, so this area becomes more attractive for many people. Population in the hazard zone becomes denser. This is another issue which is more complex for Local Government to manage land use.

Figure 2: Merapi type eruption with pyroclastic flows, May 15, 2006. (CVGHM collection)

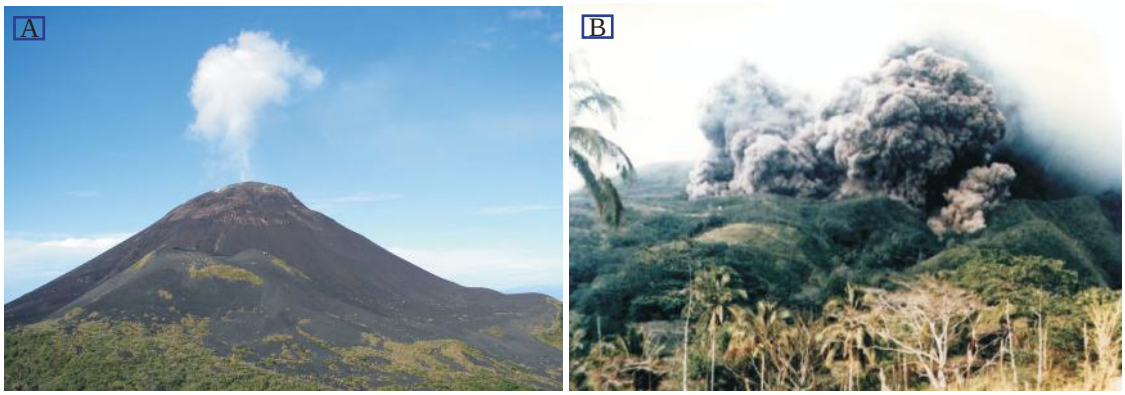

Figure 3: Conical shaped of Soputan (A), and Karangetang pyroclastic (B) flows generated by lava flow collapsed (Photograph: A. Solihin and Suratman).

2. Volcanoes with Crater Lake

Indonesia with its tropical climate is very potential to have rain fall the whole year. In that, crater area is a potential area to get big accumulation of rain water. Ijen, Galunggung, Awu, Kelimutu, Dieng, Sorik Marapi, and Papandayan volcanoes are examples where water accumulated abundantly on the crater areas (Figure 4). Several calderas are also mostly filled with large volume of water such as: Lake Rinjani, Batur, and Toba.

Figure 4: The crater lake of Dempo (A), Ijen (B), Awu (C), Sorik Marapi (D) volcanoes, Sinila (E) and Sileri (F) in Dieng volcanic complex. Photograph: Zaennudin, Sri Sumarti, Agus Budianto, and SR. Wittiri.

For volcanoes those have crater lakes, in case of eruption usually begins with phreatic eruption, then followed with lake water pouring into the surrounding valleys. It would be very dangerous if the volume of the crater lake is very large, because it may cause many casualties, such as Kelud eruption in 1586, where 10,000 people have been killed by the eruption lahars.The most victims caused by the last major eruption was due to Kelud eruption in 1919, where 5.160 people were killed by the hot eruption lahars that reached 37.5 km from the crater. To reduce the volume of crater lake water, in 1920 a tunnel with a length of 980 m and diameter of 2 m was built, and the tunnel was completed in 1924. This tunnel reduces the volume of the crater lake's water from 40 million m^3 to 1.8 million m^3.

The next major eruption occurred in 1951 after the tunnels completed that had caused 7 people killed including three officers of Kelud Volcano Observation Post. They were not affected by hot eruption lahars as it was. The eruption lahars reached a distance of only 12 km from the eruption center. This is very different from the eruption in 1919 that reached a distance of 37.5 km.

The 1951 eruption had caused the bottom of the crater lake became deeper 79 m, and the volume increased up to 21.6 m^3 prior to 1966 eruption. As the result, when Kelud erupted in 1966, about 210 people killed by the eruption lahars. The later eruption took place in 1990 at 11:41 am, initiated by high phreatomagmatic eruptions column that rose ± 5.000 m above the summit. Although 32 people were dead, 500 houses and 50 schools were destroyed and collapsed,but there were no direct victims affected by the eruption.

Most of the Kelud eruptions initiated by phreatic eruptions and followed by pyroclastic flows and pyroclastic falls producing eruptions. It implies that most of the victims affected by Kelud eruption were related to the water volume of the Crater Lake during the event. In the last five decades the eruptions of Kelud volcano took place in a short time, commonly in several days – a week eruption periods. But, since November, 2007 the characters of eruptions had changed. Instead of eruption lahars there has been a lava dome appeared inside the crater; and the lake was gradually disappeared (Figure 5).

Eruptions of volcanoes that have crater lakes are initiated by a phreatic eruption and often followed by several pyroclastic falls, such as: Awu and Sorik Marapi volcanoes. These eruptions are not as big as Kelud eruption. The phreatic and air fall deposits were not widely distributed, they just covered the area near the crater.

Ijen is one of the famous volcanoes that has the deepest crater and the most acid crater lake water in the world. It is about 900 x 600 m in size and its deepest part is about 200 m with pH < 0.2 (Fig. 6). Phreatic eruptions were the only activities shown during the last five decades. The farthest deposits were found only 500 m away from the crater. A detail study should be carried out in the future due to its big volume and high acidity of its crater water. When a major magmatic erup-

tion and it is followed by sector failure occur, it can cause serious pollution and damage to the surrounding environment.The northern and western parts of the crater rims are generally composed of pyroclastic fall deposits intercalated by lava flows (Fig. 6A) and phreatic deposits only cover the surface part that were deposited in historic time. The phreatic deposits were originating from the present crater which were deposited around the crater up to 2 km away (Fig. 6B). In the last five decades all phreatic eruptions were deposited just confined inside the crater up to a distance of 500 m at most.

Ijen volcano is one of the 22 cones of the post Ijen caldera forming eruption. This volcano began to build its edifice at least 7.000 years ago, most of its eruption products are pyroclastic deposits (Zaennudin, et al., 2006). The last pyroclastic magmatic producing eruption occurred about 700 years ago. At present about 10 – 12 tons of sulfur a day are produced from the solfataric field that employed about 100 -150 people who bring the sulfur on their shoulder down to the nearest town everyday. (Fig. 6C). This area has become sulfur mining that operates during the day time but this volcano also as interesting tourists attration in East Java. The existence of the sulfur miners and tourist activity in the area, it is important issue for the local Government to anticipate the volcanic hazard when this volcano erupts in the future.

The acid water of the Crater Lake is flowing to Banyupait River forms natural gypsum (Fig. 6D). At least there are five points of leaking a long the river. The water of Banyupait River that flowing to lower areas has become a problem for the people who live in the surrounding areas. The high acidity water had influenced plantation and people health.

Figure 5. Lava dome of Kelud eruption 2007.

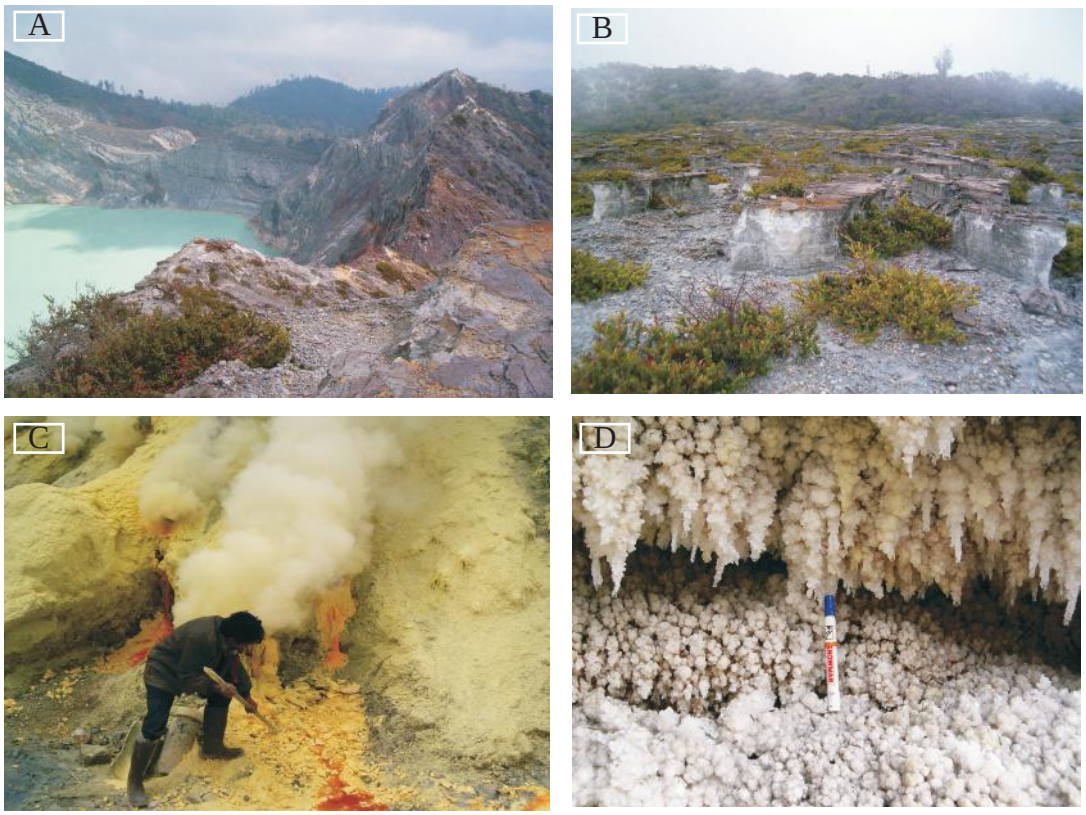

Figure 6. The thin Crater Lake rim of Ijen volcano (A). Phreatic eruption deposits of Ijen (B), potential sulfur from Ijen solfataric field produces at least 10 – 12 tons sulfur everyday (C), and natural gypsum derived from the acid Crater Lake water that flows into the upstream of Banyupait River (D). Photograph: Sri Sumarti.

Volcanoes With Open Vent System

The eruption characteristics of volcanoes with open vent system are shown by a small eruptions with eruption column height ranges from several meters up to several hundreds of meters above the crater, such as: Semeru, Raung, Dukono, Marapi (West Sumatra), and Kerinci. These volcanoes erupt very often; several times a day. Semeru and Dukono volcanoes erupt every 20 - 30 minutes (Fig. 7). These volcanoes are not so dangerous for people who live around the volcano, for those who stay at distance of more than 700 m will not affected by bomb and lapilli, and fragments. The eruption sometimes become an interesting object for tourism to know the real volcanic eruption. By understanding of eruption characteristics of a volcano, future eruption of a volcano can be predicted more accurately. The characteristic of eruption of these volcanoes generally produced pyroclastic fall deposits which are only distributed around the summit area at a distance of up to 700 m. Continuous pyroclastic falls producing eruption will cause accumulation of loose material around the summit. As the result, when heavy

rain falls on the summit area lahars may occur through the river valleys originating from the summit. Semeru volcano has a different character open vent system. It sometimes produces pyroclastic flow of collapsed lava flows. It is commonly derived from a lava tongue (Fig. 8), which flows in a sectorally area to the south-southeastern valley up to 9 km away from the source.

Figure 7. An ash cloud of Semeru eruption is sometimes becomes tourist attraction

Figure 8. Lava tongue collapsed pyroclastic flows of Semeru volcano.

Lethal Volcanic Gasses Eruption

This characteristics of eruption is belong to Dieng volcanic complex in Bondowoso – Banjarnegara Districts, Central Java Province. This area is a plateau Which is located about 2000 above sea level, consists of several cones and craters. Based on the geological feature the Dieng complex can be divided into two areas: East Dieng and West Dieng. The East Dieng is younger volcanic complex than the West Dieng area. Both areas are bounded by Mt. Nagasari occupies the middle part.

Dieng volcanic complex was formed in Late Quarternary to Recent. The last magmatic activity occurred about in a century ago. The recent activities are only phreatic and lethal gasses eruptions (Sukhyar, 1994). The later phreatic eruption occurred in July, 2004. This area is controlled by west-east faults trend as the first order generation of faulting, and was followed by southeast – northwest trend as the second order of faulting processes. There are many craters were formed and the distribution of volcanic gasses emission were related to the faults in this area (Fig.9). West Dieng is the most dangerous area of volcanic gasses emission; this area is also called Batur depression (Sukhyar, 1994).

A big lethal volcanic gasses eruption was ever occurred on February 20, 1979 and killed 149 villagers. The event is occur after a tectonic earthquake shocked Dieng area and then followed by a phreatic eruption from the Sinila crater. The villagers panicked due to the sound of the eruption and a phreatic eruption deposit that was flowing in a valley close to their village. They run to the different directions from the area of phreatic deposit. The lethal volcanic gasses that originated from magma passed trough of a weaker zone of faulting and they are trapped by clayed layer of an altered ash pyroclastic fall deposit. In West Dieng several buried faults are found which are very difficult to recognize in the field, because they were already covered by younger pyroclastic deposits. Old small craters spread around this area. Supriyati et al., (2006) studied faults in this area with mercury content method in soil. Also Humaida et al (2005) mapped concentration of CO_2 in soil which indicated that the distribution of CO_2 formed pattern that are followed faults.

During rainy season the ash fall layers become wet and more dense. This condition has caused the toxic gasses more difficult to induce. The weak fluxes of dominantly CO2 gasses emission, has caused the volcanic gasses trapped and accumulated under the altered ash fall deposit. The accumulated toxic gasses will appear onto the surface through fault zone when the trapper layers are disturbed by earthquakes, phreatic eruption or cracking during dry season. Dieng area has fertile soil of ash fall deposits, that causes vegetable grows well in this area. Potato is the best agricultural product of this area, but it has provoked a new problem, because erosion processes become more extensively in the area and will cause another sedimentation problem in low lying areas down stream.

Potato farm almost occupies Dieng area even at areas potentially affected by toxic gases.

Many farmers work in the farm during the day time, it becomes more dangerous when the weather is cloudy. There were many farmers killed by the lethal volcanic gasses from their land in different occasions. The volcanic gasses emitted from the clayey layers of the weak fault zone. Cracks of altered ash fall layers capture had caused the toxic gasses come out of the earth and then be released to the air. Because the gas is heavier than the air, it will accumulate in a lower areas like valleys. So, some valleys in this area will become more dangerous in the morning or during cloudy day.

The low flux of the gasses has caused the appearance of the gasses to the air unpredictable, depends on the pressure and capture layer. The gasses are colorless and no smell, the area becomes more dangerous. Farmers or other human being can be killed by high sudden accumulation of gasses, especially in a valley.

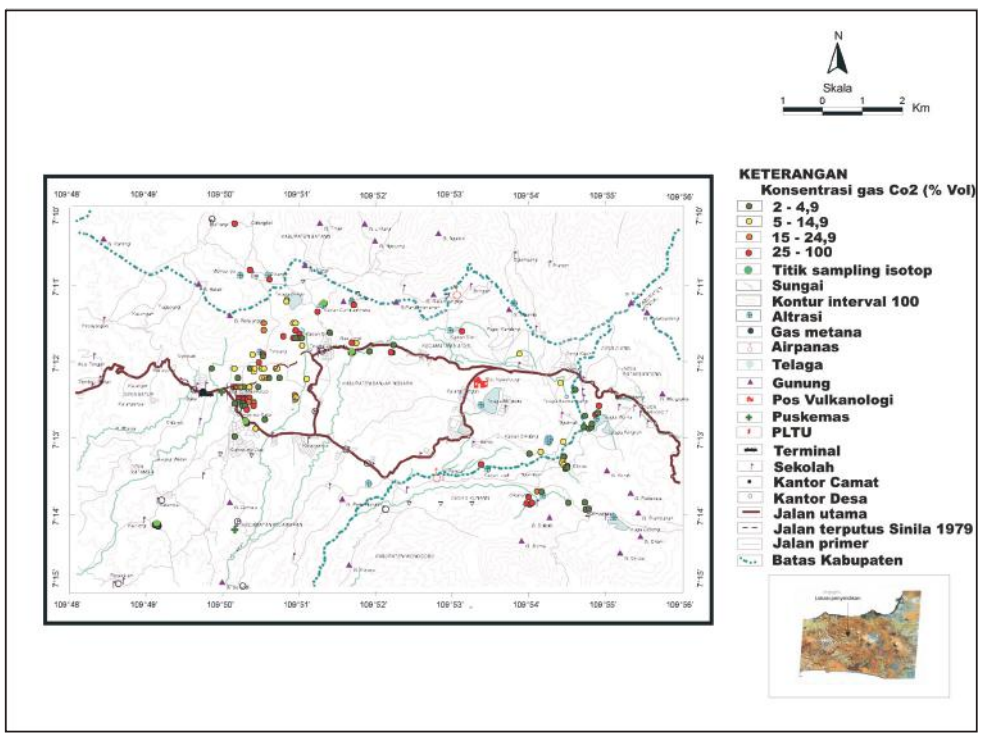

Figure 9. Distribution of lethal volcanic gasses of Dieng Volcanic Complex.

Cone Growth in Calderas

Indonesia has many pre historic calderas across the country, but there are only two caldera forming eruptions occurred during historic time, i.e.: Krakatoa in 1883 and Tambora in 1815. Both caldera formations were caused by huge pyroclastic flow producing eruptions those were spread over widely to the surrounding areas. The 1883 tsunami of Krakatau eruption had caused affected along the coastal areas of Sumatra, Java, Kalimantan, and India. The eruption column of the eruption reached a height of more than 10 km and killed 36,541 people. The 1815 eruption of Tambora volcano had devastated broad areas around the volcano and killed 92,000 people, mostly the victims were caused by drought and covered by thick pyroclastic fall and ignimbrite deposits. Supriatman (2006) stated that two Kingdoms in the area were disappeared because of the eruption. These eruptions are very famous in the world as the biggest eruption in historical time record that had caused poverty and also known as the year without a summer**.**

After the formation of the caldera, volcanic activity usually continues to build new volcanic cone. Most of them are small in sizes, whereas the big ones are in the form of stratocones, such as Widodaren and Segarawedi cones inside the Sand Sea Caldera (Tengger – Bromo), Blau and Papak cones inside the Ijen Caldera. Older caldera formation will bear several post caldera cones, most of them have big strato-cones. The younger caldera formation on the other hand, usually only bear small cones, such as Rinjani, Krakatoa, and Batur Calderas. Generally, the cone produces small scale of pyroclastic falls and lava flows of strombolian type eruption (Fig. 10). The distribution of eruption products is concise inside the caldera, at night this eruption is very attractive event for tourists to see.

DISCUSSION

The characteristics of eruptions of Indonesian active volcanoes is divided into five types. To understand the characteristics of their eruptions is very important for the Center for Volcanology and Geological Hazard Mitigation to monitor and to map the hazard areas. Their fertile soil, good scenery, cool weather, and rich in minerals, volcanoes become attractive points for people to come and to live around its flanks, to cultivate the soil for farming, mountaineering, sport etc. Monitoring and studying the eruption characteristics of the Indonesian active volcanoes are important and very useful in the attempt of mitigation and prediction of volcanic eruption in the future.

Each volcano has different character of eruption, and it has different impact to the surrounding areas when eruption occurs. In the last four decades, Indonesian active volcanoes are divided into five different eruption characters. The first eruption characteristics are volcanoes with lava domes on the summits. These first types are very active volcanoes with eruption range of 1 – 5 years.

With time eruption characteristics of each volcano may change from one type to another or the other away around, for instant Ibu

Figure 10. Anak Krakatau is one of many strato-cones which was born inside a Caldera. At present the eruption products distribution is concise inside the caldera. Photograph: CVGHM collection.

volcano in North Maluku has lava plug in its crater. This volcano erupts every 30 minutes with a small plume as high as 50 – 100 m. Merapi eruption in 2006 produced a big lava dome on its summit, of which glowing lava avalanche that traveled to the southeast, south, and southwest slopes at a distance of up to 5 km away from the dome. The volume of the new dome of Merapi is quite big approximately 4 – 5 million cubic meter which filled in the old crater.

The magma supply beneath Merapi is keep flowing until the vent was plug by the new big lava dome. With time the accumulation gas content below the new lava dome will result in the increase of the pressure beneath the dome. When pressure beneath the dome is exceeded, a violent eruption may occur, and instead of lava flows an explosive eruption can occur. In case this event takes place a new eruption characteristics happens.

The second eruption characteristics are volcanoes with crater lakes. An eruption is commonly initiated with phreatic eruption then followed by magmatic eruption, but in other volcanoes probably just phreatic, without be-

ing followed with magmatic eruption. Every eruption, the Kelud volcano was always followed by a short magmatic eruptions. Its big energy yields a big volume of pyroclastic flows and pyroclastic falls producing eruption. At first, its eruption sequence begin with the empting of the crater lake water that contribute a big floods of eruption lahars flowing through Bladak River. The distance of the floods and eruption lahars is depending on the volume of the Crater Lake, the bigger the volume of crater lake, the farther the eruption lahars flowing down stream. The eruption history of Kelud shows that the number of victims was closely related to the volume of the crater lake water, the bigger the volume the more the victims caused by the eruption. Another similar eruption characters was the Awu eruption in 2002-2003 where its crater lake was emptied and then grew a new lava dome inside the crater. By looking at the fact of both volcanoes, it is likely that they may have different eruption characters than that of their latest eruption.

The third eruption characteristics are volcanoes with open vent system where the eruptions are continuously occurred all day long. These kinds of volcanoes are the most active volcanoes in Indonesia as active as the volcanoes with lava domes. In general, these volcanoes with open vent system are the most active volcanoes, where the domes are smoking all time.

The fourth kind of eruption characteristics are volcanoes with lethal gasses eruption such as Dieng volcanic complex. The volcanic complex was faulted by several faults where the major one oriented in east – west and southeast – northwest trend. These faults are burried by young pyroclastic fall deposits. Some of the faults are still active. In late March 2006 the west – east fault in the southern area of Dieng volcanic complex was active and had caused the seismicity in this area. The activity of Dieng volcanic complex increased, the alert level was upgraded to level two. A local tectonic earthquakes were felt by local people. The existence of earthquakes is worrying, since it can break the ash falls cap layers, that resulted in the released of the deadly toxic volcanic gases.

The appearance of the lethal volcanic gasses is unpredictable, when, where and which areas will be affected is not easily predicted and decided. Mapping of faults and the distribution of the lethal volcanic gasses are very useful for mitigation efforts to protect and to avoid people and other living things from being killed by the lethal volcanic gasses. Several Hindu's Temples were built in the area about in a century.

The fifth kind of the eruption characteristics is volcanic cone inside the calderas. Within the last four decades these eruptions occurred in a small scale producing several lava flows and air fall deposits. Strombolian eruptions are very common occurred in this eruption characters. The air fall deposits are usually composed of basaltic andesite – andesite, ash to block fragments which are distributed only around and inside the caldera. The explosive eruptions are generally in the form of ash col-

umn of about 300 – 1000 m high (Fig. 10). Some examples of these cones inside caldera are Mt. Anak Krakatau inside the sea bottom Krakatau caldera, Mt. Barujari inside Rinjani caldera, and Batur volcano inside Batur caldera.

By understanding the characteristics of all most active volcanoes in Indonesia, hopefully be very useful in mitigating and prediction of volcanic eruption. Monitoring is meant to tell the local when volcanic activity is increasing, what to do, ¸where they have to go for evacuation. As long as there is no significant change either instrumentally or physically, the change of eruption characteristics of the coming eruption may not likely.

CONCLUSIONS

About 13 % of the world's active volcanoes. are located in Indonesia. Tectonically, the active volcanoes are the result of a collision between Indian-Australian, Eurasian, and Philippine Plates. The active volcanoes of Indonesia are divided into five eruption characteristics, namely: volcanoes with lava domes; crater lakes; open vent systems; lethal gasses; and volcanic cones inside the caldera (post caldera formation volcanic activity).

The most active volcanoes of Indonesia are the open vent systems. They erupt daily in small scale of pyroclastic falls.

The most dangerous are volcanoes with crater lakes on the summit. They erupt violently with big energy to empty the crater lake water, take place in short time duration, producing pyroclastic falls and pyroclastic flows and usually accompanied with eruption lahars.

The change of magma composition may also change the eruption characteristics of volcanoes.

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