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Directed Volcanic Blast as a Tragedy of October 26Th, 2010 at Merapi Volcano, Central Java

Letusan Gunungapi Terarah Sebagai Suatu Tragedi 26 Oktober, 2010 di Gunung Merapi Jawa Tengah

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Abstract

Merapi is an active strato volcano located in Central Java. This volcano is regarded as the most active and most dangerous volcano in Indonesia. Since the twentieth century, the activities have comprised mainly the effusive growth of viscous lava domes and lava tongues, with occasional gravitational collapses of parts of over-steepened domes producing pyroclastic flows, commonly defined as “Merapi-Type”. Since October 2010, however, explosive eruptions of a relatively large size have occurred to VEI 4, and some associated pyroclastic flows were larger and had farther reach than any produced on July 2006. These events may also be regarded as another type of eruptions for Merapi. On October26th, 2010 such event happened, even though it was not caused by pyroclastic flows of the dome collapses, about thirty people were killed including Mbah Marijan, known as the Merapi volcano's spiritual gatekeeper, who was found dead at his home approximately 4 km from the crater. The Yogyakarta Palace subsequently confirmed his death. This time the disaster was caused by a sudden directed blast that took place at 17:02 pm throughout Cangkringan, Kinahrejo Village, at the south flank of Merapi Volcano. The victims were the local people who did not predict the blast threatened their areas, because they believed that the pyroclastic flows from the dome collapses as long as they knew, did not threaten their areas, and pyroclastic flows would flow down following the Boyong River as the closest valley to their village. The blast swept an area about 8 km^2, reaching about 5 km in distance, deposited thin ash, and toppled all trees to the south around the Kinahrejo and Pakem areas. The blast that reached Kinahrejo Village seemed to have moderate temperatures, because all trees facing the crater were not burnt. However, the victims were affected by dehydration and blanketed by fine ash.

Keywords: Merapi, Merapi-type, pyroclastic flow, directed blast, Kinahrejo Village

Abstrak

Merapi adalah gunung api strato yang terletak di Jawa Tengah. Gunung ini merupakan gunung api paling aktif dan paling berbahaya di Indonesia. Sejak abad kedua puluh, kegiatannya terutama berupa pertumbuhan lava efusif kental dalam bentuk kubah dan lidah lava, yang sesekali gugur secara gravitasi pada lereng curam dan menghasilkan awan panas yang disebut “awan panas guguran”, yang dikenal dunia sebagai "Tipe-Merapi". Sejak 26 Oktober 2010, karakteristik Merapi tersebut berubah menjadi letusan eksplosif vertikal berskala VEI-4, akibat guguran lava besar-besaran yang hampir menghabiskan seluruh tubuh kubahnya. Aliran piroklastik yang terkait lebih besar dan lebih jauh jangkauannya daripada yang diproduksi pada Juli 2006. Kejadian ini juga dapat dianggap sebagai letusan tipe lain untuk Merapi. Pada 26 Oktober 2010 peristiwa tersebut terjadi, meskipun tidak disebabkan oleh aliran piroklastik dari runtuhan kubah, tetapi sekitar tiga puluh orang tewas, termasuk Mbah Marijan, yang dikenal sebagai pengawal spiritual Gunung Merapi, yang ditemukan tewas di rumahnya sekitar 4 km dari kawah. Keraton Yogyakarta kemudian mengkonfirmasi kematiannya. Bencana tersebut disebabkan oleh letusan terarah yang terjadi se-

cara mendadak pada pukul 17:02 ke arah Desa Kinahrejo, Cangkringan, di lereng selatan Gunung Merapi. Para korban adalah penduduk setempat yang tak menduga bahwa letusan mengancam mereka. Selama ini mereka percaya bahwa awan panas guguran dari kubah lava, tidak akan mengancam daerah mereka. Setahu mereka awan panas selalu mengalir mengikuti lembah Kali Boyong yang merupakan lembah terdekat ke desa mereka. Letusan terarah itu menyapu wilayah sekitar 8 km^2, mencapai jarak sekitar 5 km, mengendapkan abu tipis, dan menumbangkan semua pohon ke arah selatan sekitar daerah Kinahrejo dan Pakem. Letusan yang mencapai Desa Kinahrejo tampaknya memiliki suhu moderat karena semua pohon yang menghadap ke kawah tidak hangus. Namun, korban terkena dehidrasi dan diselimuti oleh abu halus.

Kata kunci: *Merapi, Tipe-Merapi, awan panas, letusan terarah, Dusun Kinahrejo*

Introduction

On October 26th, 2010, a large amount of dome-collapse pyroclastic flows of Merapi Volcano were generated over a period of several hours, after which the pyroclstic flows activity abruptly ceased. A portion of these pyroclastic flows travelled southward, and previous pyroclastic flows in 2006 travelled also toward the south. The 2010 pyroclastic flows descended mainly the Boyong and Kuning Valleys (Figure 1). The largest pyroclastic flows had occurred since September 2010 until October 2010,

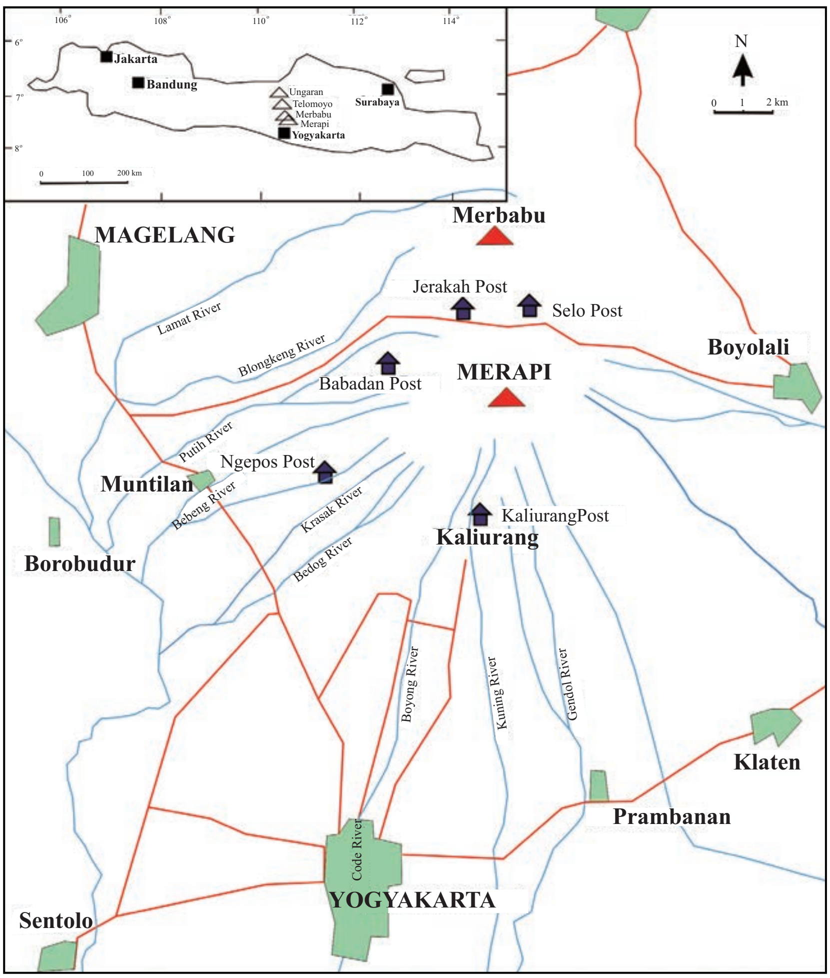

Figure 1. Location map of Mount Merapi. Hut symbols indicate observation posts.

travelled as far as 15 km. Collectively, the pyroclastic flows damaged a sector of area, although some co-ignimbrite ash clouds rose several km above the region of deposition covering the area of the eastern part of West Java.

The Merapi Volcano is famous internationally for its nearly continuous and frequent lava dome activity, hazardous dome-generated pyroclastic flow eruptions. It has become the reference volcano for the so-called "Merapi-type" of pyroclastic flows, *i.e.* relatively small-volume, low energy pyroclastic flows generated by gravitational collapse of parts of a lava dome (Escher 1931; MacGregor, 1952; MacDonald, 1972). Despite the frequent reference in volcanological literature to "Merapi-type" pyroclastic flows at other locations worldwide, very few detailed observational reports of the eruptions of Merapi, including the timing, origin, and behaviour of the pyroclastic flows, are available in the literature.

The previous eruptions in 2006 in respect to representative of the Merapi's eruptive activity in the recent past (Figure 2) provide an opportunity for a better description of "Merapi type" pyroclastic flows at their type locality. A striking feature of some of the 2010 pyroclastic flows is that they comprised an unexpectedly large and destructive ash-cloud surge component. The 2010 pyroclastic flow deposits include a volcanic blast deposit and a block-and-ash flow facies emplaced surrounding the Gendol, Kinahrejo, and Pakem areas.

The directed volcanic blast is a powerful explosion with a significant laterally-directed component,

Figure 2. Dome-collapse pyroclastic flows become a reference internationally for Mount Merapi as “Merapi-type”.

which can generate devastating, high energy pyroclastic density currents. Directed blasts can be very devastating events. Over the past century there have been 31,000 fatalities from blast eruptions. Initial blast velocities can be from 223 - 435 m/sec. Material from the initial blast cloud itself was very hot ranging between 100° and 300° C (Belousov *et al.*, 2007). Topography in this area had no affect on the movement of material in the directed blast cloud. Between 8 and 19 miles of the volcano, trees were flattened and resembled toothpicks aligned in the same direction on surrounding hillsides (Siebert, 1984).

The term “directed volcanic blast” was used for the first time by Gorshkov in 1959, who studied the eruption of Bezymianny Volcano in Kamchatka in 1956. Blast eruptions are relatively common events. At least ten times occurred between 1888 and 1997, which is about one every ten years. (Francis, 1993).

Sampling and Analytical Methods

Volcanic blast deposits of 2010 eruption collected around the Kinahrejo Village consist of grey ashes. Ash was also collected from inside the houses. A scanning electron microscopy (SEM) and an energy-dispersive X-ray spectrometer (EDS) were also used to analyzed the ejecta. Observation in the field is mainly focused on the destructed areas by volcanic blast surrounding Kinahrejo Village, Kali Gendol, and Kali Kuning areas.

Chronology of October 2010 Pyroclastic Flows

The chronology of the pyroclastic flow is based on eyewitness reports by observers located at the Kaliurang observation post. The post, about 15 km from the summit, was very close to the pyroclastic flows that descended the Boyong and Kuning Valleys. On October 26th, 2010 a large block avalanches occurred without warning, followed by a sudden directed blast that took place at 17:02 pm throughout Cangkringan, Kinahrejo Villages at the south flank of Merapi Volcano. The victims were the local people who did not predict the blast threatened their areas, because they believed that the pyroclastic flows from the dome collapses as long as they knew, did not threaten their areas, and pyroclastic flows would flow down following the Boyong River as the closest valley to their village.

The October 26, 2010 eruption of Mount Merapi did not initially produce an eruption column. Instead, the initial eruption was a directed blast. This blast was a result of depressurization triggered by an initial landslide of a large dome collapsed toward the south flank of the volcano (Figures 3 and 4). The area affected by the directed blast extended greater than 5 km from the volcano. Everything within 5 km of the directed blast area was either removed or destroyed. Topography in this area had no affect on the movement of material in the directed blast cloud. Between 3 - 5 km of the volcano, trees were flattened in the same direction to the south-southeast directions. Material in the blast cloud was somewhat channelized within this zone. Less than 3 km from the volcano, trees were seared black due to hot gases. Possibly, the material from the initial blast cloud itself was very hot ranging between 100^{o} and

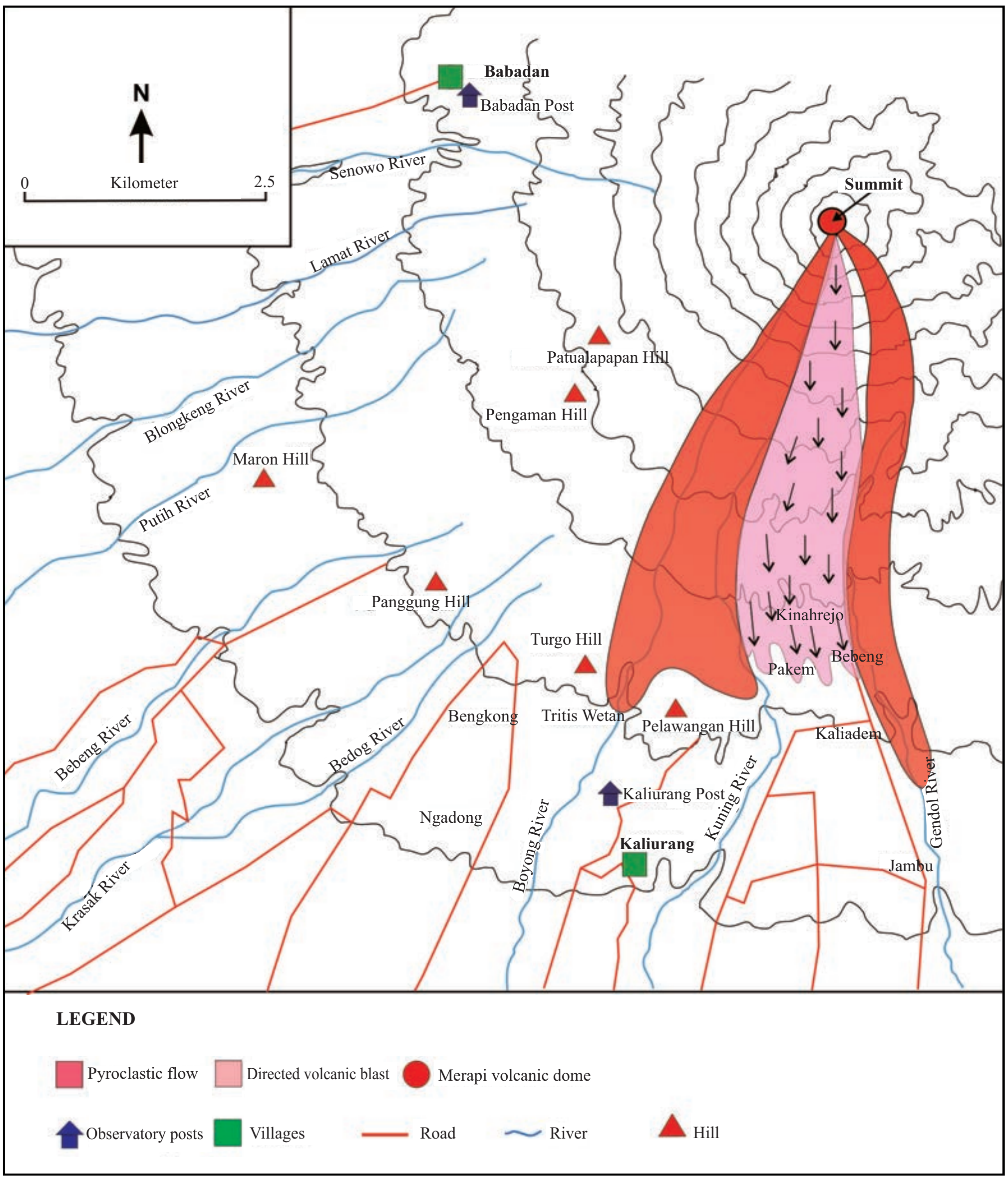

Figure 3. Map of the damaged area caused by pyroclastic flows and directed blast.

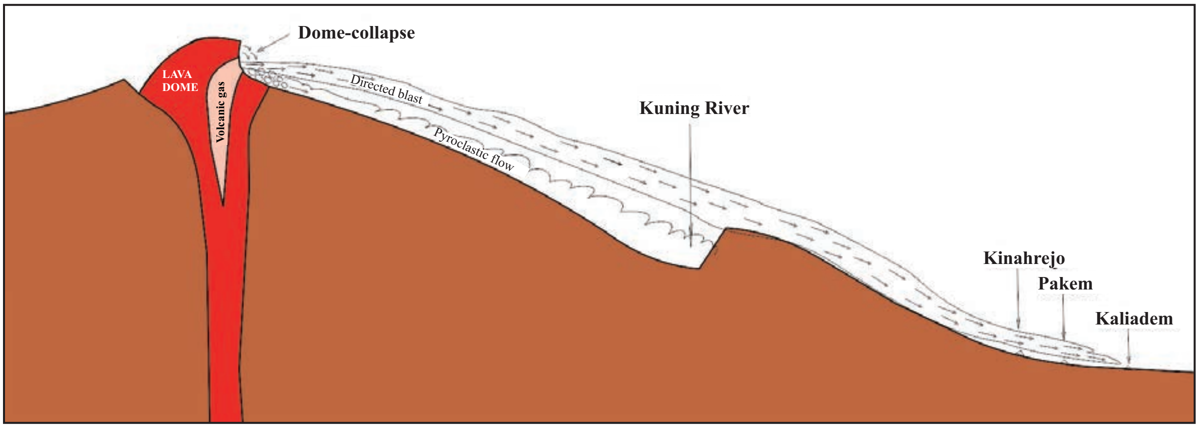

Figure 4. Schematic diagram of the directed blast occurrence of Mount Merapi on October 26, 2010.

300°C (Figures 5 and 6). Several people were killed by the directed blast of Merapi Volcano in the area greater than 3 km from the volcano. In this area all trees which facing the crater were not burnt (Figures 7 and 8). However, the victims were affected by dehydration and blanketed by fine ash.

Figure 5. Most of the trees laid down toward south and were seared black due to hot gases.

Figure 7. About 5 km in distance, deposited thin ash, and toppied all trees to the south around the Kinahrejo area.

Figure 6. The bamboo trees toppied by the blast and deposited ash with moderate temperatures in Kinahrejo.

Figure 8. The roof of Mbah Marijan's House was swept by the blast and emplaced into the southern part (Courtesy Youtube).

Temperature of Merapi Pyroclastic Flow Deposits

Emplacement temperatures of the channelled block-and-ash-flow deposits can be relatively high (Voight and Davis, 2000). Typically the temperature at the source of the lava dome is about 850° - 1000°C (Bemmelen, 1949), with fumarole temperature at Merapi is as high as 900°C (Symonds, 1993). By the time a pyroclastic flow has flowed a few kilometers, the temperature of the debris has dropped considerably. Bemmelen (1949) reported block-and-ash flow deposit emplacement temperatures of 400° - 450°C. The topic is complex in that the interior temperatures of large clasts may be much hotter than clast-surface temperatures; thus the definition of "bulk temperature" is not simply established.

Temperature decreases can result from radiant heat loss during transport, mixing near the source with older cooler lava or edifice material, incorporation of cold loose talus or alluvial debris, and mixted with river water. In some instances, as in 2010, the block-and-ash deposit was reported by eyewitnesses to be incandescent red soon after deposition, suggesting temperatures about 550°C. Bemmelen (1949) noted that larger blocks of lava could set fire to the forest, but generally no large-scale fires are initiated at Merapi. On the other hand, Hartmann (1933) reported the occurrence of COS, a compound formed from sulfur and organic matter at temperatures >400°C in Merapi block-and-ash flow deposits.

Deposit temperatures of ash-cloud deposits need to be considered in context. The temperature regime of glowing clouds is poorly documented, but rapidly evolves from point to point and over time. The highest temperature is in interior parts, whereas around the margins, expansion and air entrainment cause rapid cooling (Voight and Davis, 2000). Furthermore, the surge clouds are commonly erosive, and as in this investigation, the transported particles include cool soil material incorporated within the surge. The clouds are hotter on high-flank regions, and cool with descent. Likewise, particle concentration within the ash-cloud is greater on high-flank regions, and there the deposits are thicker; much heat is lost from the ash-cloud as coarse hot particles settle out.

The ignition temperature of wood is dependent on many variables, such as wood type, size, and shape of wood object, rate and period of heating, moisture content, and oxygen supply. Ignition occurring within a few minutes or less requires wood temperatures of >300°C (Voight and Davis, 2000).

In this regard, it is also important to distinguish between the temperature of an object at the time of ignition, and the temperature of the ash cloud or deposit that has heated the object. Heat conduction theory indicates that the temperature of an object is substantially less than the enclosing medium, so the behaviour or condition of an object indicates only the minimum emplacement temperature of a deposit. The temperatures for the several-meter thick pyrocalstic flow deposits are indicated from polymeric objects collected from Kinahrejo area (Figure 9). Most of the objects collected did not display a sharp melting range, but polyethylene terephthalate used in common commercial water bottles displayed the melting range of 245° - 265°C (Schneider, 1996).

In the present case, the blast deposits was studied within a few kilometers of the summit, beyond which the ash from the directed blast developed buoyancy as a result of sedimentation and heating of entrained air. Thus, the ash deposit temperatures estimated here apply only to the distal region; they are minimum values for the ash as a whole. In Kinahrejo, some thin ash deposits with moderate temperatures were noted (Figures 10 and 11); these were genetically associated with the channelled block-and-ash flow emplaced simultaneously nearby Opak River valley. The blast devastated an area of about 8 km^2, reaching about 5 km in distance, deposited thin ash, and toppied all trees to the south around the Kinahrejo and Pakem areas (Figure 3).

Figure 9. A sharp melting of polyethylene terephthalate used in common goods. The melting was less than 300°C.

Figures 10 and 11. Thin ash deposits with moderate temperatures were not seared black the area.The victim affected by dehydration and blanketed by fine ash (Courtesy Youtube).

Conclusion

The tragedy of October 26, 2010, Merapi eruption was not caused by pyroclastic flows of the dome collapses, but about thirty people were killed including Mbah Marijan, known as Merapi volcano's spiritual gatekeeper, who was found dead at his home approximately 4 km from the crater. This time the disaster was caused by the volcanic blast.

The temperatures for the several meter-thick pyroclastic flow deposits are indicated from polymer objects collected from Kinahrejo area. Most of the objects collected did not display a sharp melting range, but polyethylene terephthalate used in common commercial water bottles displayed the melting range of less than 300^{o}C. Temperatures for the ash-blast deposit in Kinahrejo region are not well constrained but are presumed <200^{o}C, based on polymeric behaviour, and human victims. In Kinahrejo some thin ash deposits with moderate temperatures were noted; these were genetically associated with the channelled block-and-ash flow emplaced simultaneously nearby Opak River valley. The blast devastated an area of about 8 km^2, reaching about 5 km in distance, deposited thin ash, and toppied all trees to the south around the Kinahrejo and Pakem areas. The human victims particularly affected by dehydration and blanketed by fine ash.

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