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The August 2010 Phreatic Eruption of Mount Sinabung, North Sumatra

Letusan Freatik Gunungapi Sinabung Agustus 2010, Sumatra Utara

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Abstract

Mount Sinabung, located in Karo Regency, North Sumatra Province, is a strato volcano having four active craters. Since its latest eruption about 1,200 year ago, a phreatic eruption occurred on August 27th, 2010. The eruption took place in Crater-I, which was initiated by a greyish white plume and then followed by black plumes as high as 2000 m above the crater. Altered rock fragments and ash were erupted during this event. The altered rocks show a development of argillic alterations which was formed in the hydrothermal system in depth. The alteration zone is formed along the northeast-southwest and northwest-southeast trend across the three craters. All of the craters are actively discharging solfataric gases, of which sulphur deposits are resulted, and they have been quarried by the local people. The age of the latest magmatic eruption was dated by ^{14}C method from the charcoal sample found in the pyroclastic flow deposits near Bekerah Village.

Keywords: Mount Sinabung, phreatic eruption, argillic alteration, ^{14}C method

Sari

Sinabung adalah gunung api strato yang terletak di Kabupaten Karo, Sumatra Utara, dan mempunyai empat kawah aktif. Setelah erupsi magmatik terakhir 1.200 tahun lalu, pada 27 Agustus 2010 terjadi letusan yang bersifat freatik. Letusan eksplosif yang terjadi pada Kawah I tersebut mengeluarkan asap hitam yang sebelumnya diawali oleh letusan asap putih kelabu, memuntahkan abu dan batuan teralterasi. Batuan teralterasi tersebut menunjukkan perkembangan alterasi argilik yang terjadi dalam sistem hidrotermal dan merupakan hasil interaksi antara cairan asam dengan batuan. Zona alterasi yang terbentuk memanjang dengan arah timur laut-barat daya dan barat laut-tenggara yang berpotongan di Kawah I, Kawah II, dan III, dan merupakan kawah kembar yang cukup aktif mengeluarkan gas solfatara, sehingga banyak masyarakat yang menambang endapan belerang di tempat tersebut. Pentarikhan umur ditentukan dengan metode ^{14}C dari percontoh arang kayu dalam endapan awan panas hasil erupsi magmatik yang ditemukan di sekitar Kampung Bekerah.

Kata kunci: *Gunung Sinabung, erupsi freatik, alterasi argilik, metode ^{14}C*

Introduction

Mount Sinabung is a strato volcano, located in Karo Regency, North Sumatra Province (Figure 1). It is a solitary volcano that has a single peak, and classified as B-Type, because since the 1600's there was no record of eruptive activity. This volcano has four main craters on its summit. In general, the activity of Mount Sinabung are in the form of solfatar and fumaroles around the crater areas, the peak and in the area around the old crater, on the wall, and in the bottom of the valley that extends to the east and southeast at a distance of 300 m (Neumann van Padang, 1951).

There was no eruption recorded since 1,200 years ago. During this period, the activities of the volcano are in the form of solfataric and fumarolic emissions nearly from all craters. Formerly, the sublimate sulphurs were quarried by the local people to obtain good sulphur for sale (Figure 2a, b), but since the

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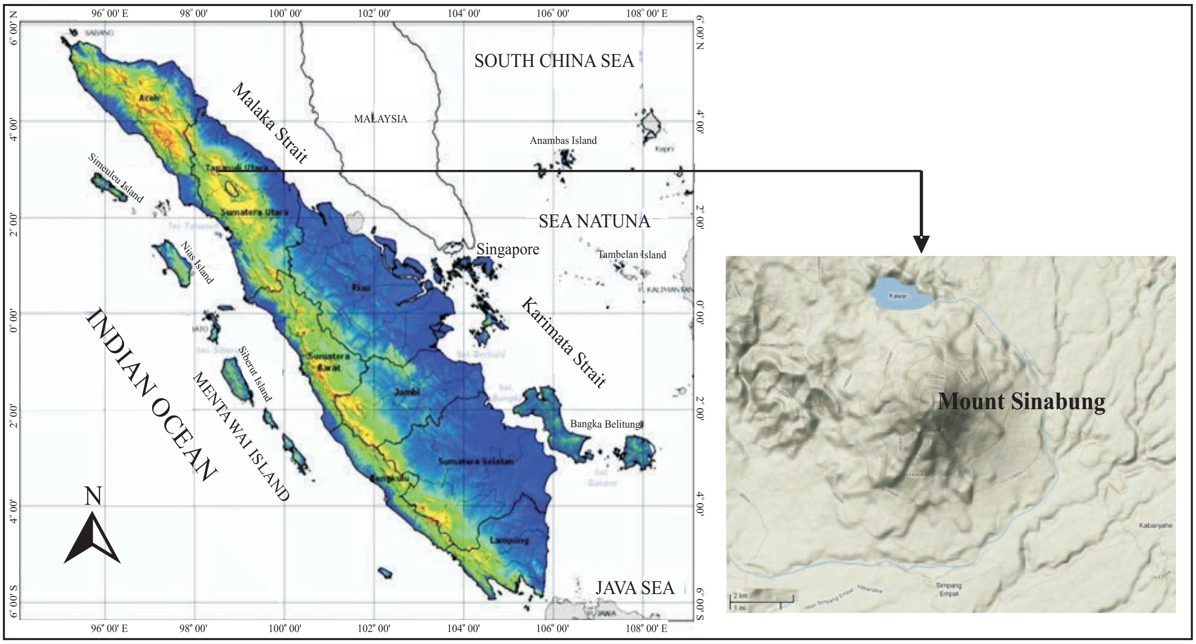

Figure 1. Locality map of Mount Sinabung, North Sumatra.

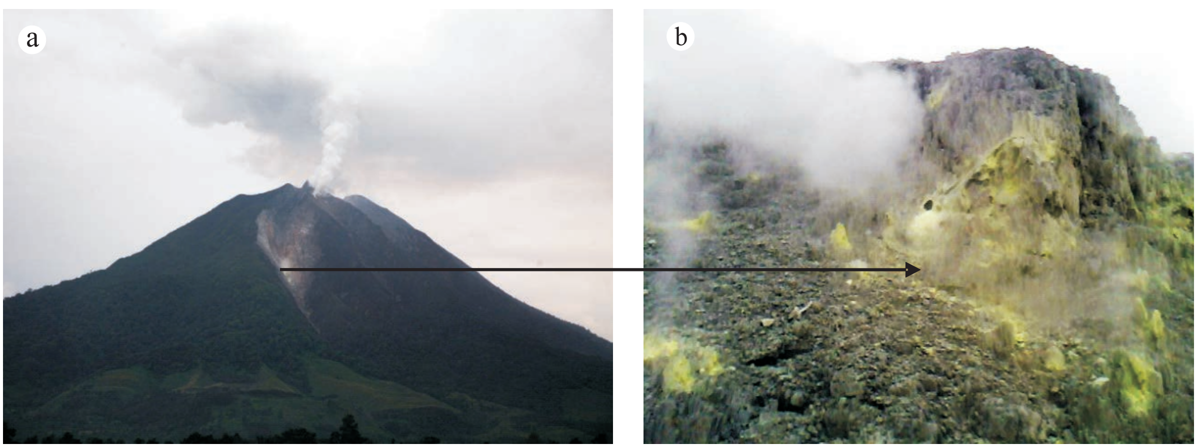

Figure 2. Mount Sinabung (a), and its solfataric activity at Crater - IV (b).

last decade the sulphur mining was stopped due to the decrease in sulphur content which was probably caused by the decrease of volcanic activities. Therefore, the sulphur deposits were not economically a promising business.

Before the 30th of August 2010 eruption, the activity of the volcano was just in the form of solfataric and fumarolic gas emission, and there was no eruption recorded. This volcanic phenomenon, is probably due to the presence of a large volcanic plug that blocked the diatreme that prevented the volcanic gas from passing through, therefore, there was no eruption occurred. Figure 3 shows a volcanic plug found in Crater - I that is located on the peak of volcano. Moreover, there was no monitoring instrumments installed before the first eruption. Luckily, some seismometers were installed at several locations around the slopes and transmitted to the emergency observatory located about 7 km to the southeast of the volcano, hence the next eruptions could be anticipated.

Figure 3. Lava plug at Crater-I.

On August 27, 2010, at 18:15 pm, the first phreatic eruption showered the east-southeast flank with volcanic ash (Figure 4), and on August 28, a thin white smoke was observed nearly all day long. On August 29, 2010 at 00:08 pm, the activity of Mount Sinabung increased which was characterized by a crumbling sound that came from Mount Sinabung. With regard to these activities, the Head of Centre for Volcanology and Geological Hazard Mitigation classifies Mount Sinabung into A-Type volcano.

Figure 4. First eruption occurred on August 27th, 2010, at 18:15 pm (Photo: Local people).

The first eruption occurred on August 27th, 2010, at 18:15 pm (local time), where the ashfall had caused a darkness during the evening. This eruption surprised the people surrounding the volcano, because they have never experienced any volcanic eruption since thousands of years. The more interesting thing is that this is the first time for them to watch a volcanic eruption, even their ancestors who lived in Karo Highlands had never witnessed it before. Because the volcanic ash fall took place during the evening, it had caused the people living around the Sinabung volcano confused and they didn't know what to do and where to go.

The eruptions of August 30th, 2010, was the ascending magma which tried to destroy the stable old lava dome; as the result the eruption was split into two directions, through Crater III and IV. As long as the lava plug has not been destroyed by eruption, it is likely that the future eruption will exhibit the same style and pattern of eruption.

Based on experiences of some volcanoes, there is a close relationship between repose period duration of eruption. Galunggung eruption in 1982 for example, after 60 years of rest, and its eruption ceased after erupting for 11 months; meanwhile, in 1982-1983 Mount Colo in Central Sulawesi erupted violently within 9 months after 82 years of repose (Katili and Siswowidjojo, 1994). Mount Ibu, a B-Type volcano in North Halmahera, is back in active after 15,000 years being dormant and it has erupted for almost a year, and then its status was changed into Type-A volcano. With respect to the current status, therefore, a permanent volcano observatory should be built and equiped with adequate monitoring instruments. Moreover, the local government should be prepared to deal with this scenario, such as to have a quick response team, to provide evacuation barracks etc. when the volcano erupts at any time. Based on the latest eruption, the current occupied areas are potentially affected by future eruptions. Therefore, for safety reason the land use around the volcano should be rearranged.

Geologic Setting

Sinabung volcanic unit is included to the highlands morphology section extending from eastern Berastagi across the southern plains. This morphology covers an area of 15 km^2, that consists of volcanic mountains extending from the eastern part of Wampu canyon to Berastagi. The summits of this mountainous morphology are higher than 1500 m, where the highest peak which is 2451 m a.s.l is Mount Sinabung, while Mount Sibayak is only 2212 m a.s.l. Cameron *et al.* (1982) deduced that the radial patterns of the river valleys were formed by volcanic peaks and generally associated with primary volcanic landforms. The valleys tend to develop on the north slopes. Morphology of the karst is present in the west part consisting of Permian limestones.

The regional stratigraphy of Mount Sinabung is shown on the Geological Map of Medan (Cameron *et al.,* 1982), describing that the Sinabung lava flows are composed of andesitic to dacitic composition. Based on radiometric dating method, in general the age of volcanic rocks of Mount Sinabung eruptive products are Holocene.

The volcanic belt of the Sumatra Island is constructed by Indo-Australian Plate subducting below the Eurasian Plate. The movement direction of oceanic plate which is relatively oblique to the axis of the island resulted in a dextral transverse fault along the axis of Sumatra Island. A major fault zone is situated around Kotabuluhpasar (Alas-Renun Depression), in the southeast of Kotacane, North Sumatra of about 25 km in distance from Mount Sinabung southwestward. The fault zone parallel to the first fault of the Sumatran Fault in the northeast through Mount Batang extending to the southeast through Bohorok and Wampu Rivers in the northwestern part of Mount Sibayak (Katili, and Hehuwat, 1967). According to Cameron *et al.* (1982) most of the faults in this fault zone are estimated extending to the southeast through Mount Sibayak volcanic complex, but the fault is buried by the volcanic eruptive products of Pleistocen age. Mount Sinabung formed in the northwest edge of the fault. The lavas from the volcano are composed of andesite to dacite. The fault line along the western Toba, that contributed to the occurrence of Mount Sinabung extends to the northeast until Mount Sibayak. With regard to the eruption of Sinabung many questions arise, among others what is the relationship between Sinabung volcanic activity with the active fault of Sumatra. Theoretically, there is a relationship between volcanic and tectonic activity, how and why magmas from the subduction zone rise to the surface.

Sampling and Analitical Methods

Some samples of 2010 eruption products consisting of grey ash and altered rocks have been collected from Bekerah area. A scanning electron microscopic (SEM) and an energy-dispersive X-ray spectrometer (EDS) analyses were also performed to study the ejecta. Some charcoal samples found in pyroclastic flow deposits (Figure 5) of previous eruption was collected for ^{14}C dating. The ^{14}C analysis was conducted at the Quaternary Geology Laboratory, the Center for Geological Survey, Geological Agency, in Bandung.

Figure 5. Charcoal log is found within the last pyroclastic flow deposit and ^{14}C dating gives age of 1,200 years BP.

Products of 2010 Eruption and Discussions

Sinabung volcanic deposits consist of pyroclastic flows and lava flows. The pyroclastic fall deposits are sparsely deposited. Its exposure is usually associated with pyroclastic flows as co-ignimbrite. Meanwhile, the coarse-grained ones such as sand and volcanic bombs are distributed around the summit, whereas lahar deposits are deposited around the foot.

Pyroclastic flow deposits are found in the southeastern flank of Mount Sinabung near Bekerah Village. This unit is suggested as the youngest pyroclastic flows from the latest magmatic eruption of Sinabung. This unit is characterized by reddish-grey ash falls, very coarse-grained, angular shaped, angular scoriaceous bombs; set up in andesite lithic components, ash, and sand matrix. Intact log charcoal found in this deposit which was dated with ^{14}C at the Laboratory of the Center for Geological Survey in Bandung gives an age of 1,200 years. But, Setsuya Nakada (oral communication, 2011) suggested that the age of the pyroclastic flow unit ranges between 800 to 900 years. The lithic bomb components are grey andesite, hard, aphanitic texture, vesicular, holocrystalline, coarse grained quartz mineral, with predominant feldspar and pyroxene as phenocrysts.

The phreatic eruption was initiated by a column of tephra as high as a 1,000 m above the surnmit, but a strong wind blew the tephra a few kilometer to the southeast. Furthermore, very thin ash was blown eastward as far as l0 km away from the vent, whereas the tephra consists primarily of shattered rocks and mineral fragments originating from the host rocks that were carried along during the eruption. Most of the ash deposits contain silicon and oxygen (SiO_2), iron oxide (magnetite), sodium, calcium, aluminum silicate (anorthite), iron sulfide (pyrite), and potassium hydroxide, aluminum silicate (alunite) (Figure 6).

The August 30, 2010 eruption was the first major climatic eruption of several explosive ones that took place in both instead of the existing older lava plug. A twin eruption columns of tephra as high as 3,000 m above the summit (Figure 7) was spread repeatedly towards the southern flank during the event. Tephra refers to all airborne volcanic ejecta of an eruption which fallout from a volcanic plume, including ash-

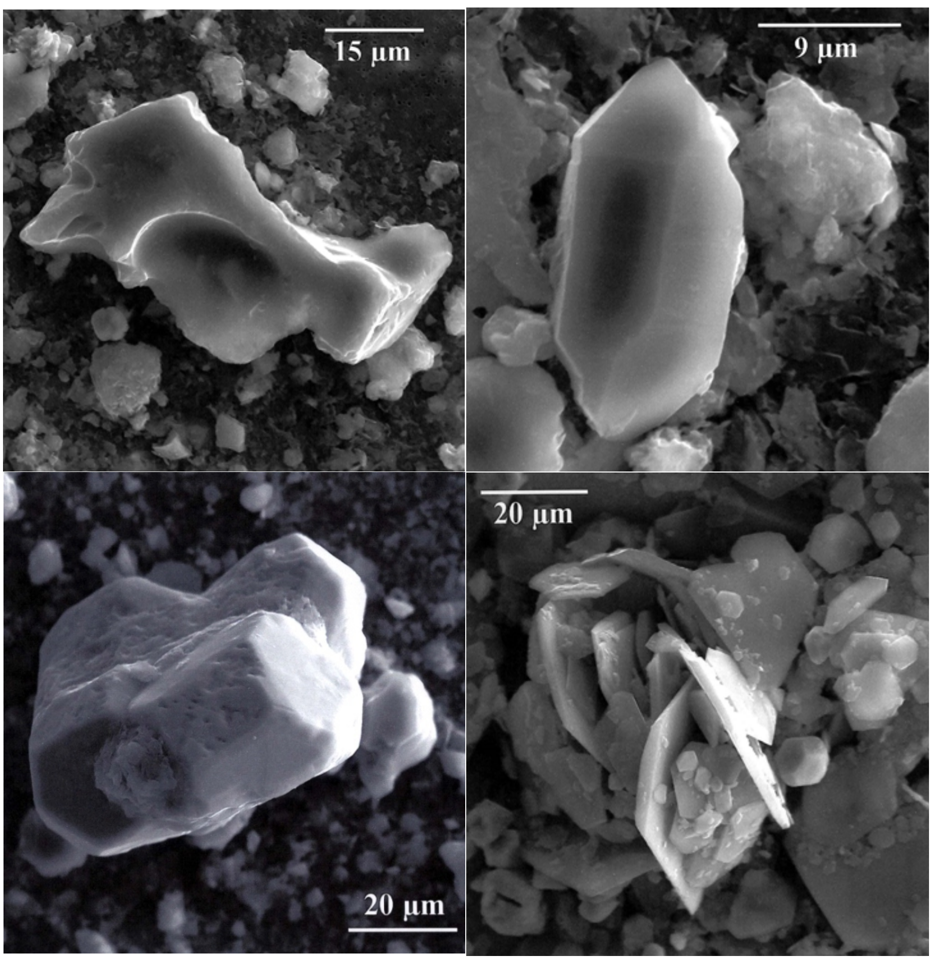

Figure 6. Photomicrograph of scanning microscopic analysis result showing completely altered rock fragments. Clockwise: (a) altered pyrite, (b) alunite, (c) altered quartz, and (d) altered glass.

Figure 7. The eruption of explosive episodes producing a twin column of tephra as high as 3,000 m above the summit.

size (less than 2 mm in diameter) and larger rock fragments surrounding the crater. ln this period, it also erupted altered mineral fragments (Figure 5) which indicated opening of the vent in the summit crater. The vent had been cleared of older rocks, and a high pressure steam was escaping through it to the surface (Henley and Ellis, 1983). The microscope analyses of ash deposits showed agglomerates? of altered glass, quartz, alunite, anhydrite, and kaolinite (Figure 6). These minerals indicate a phreatic contribution that reflect hydrothermal system in depth. The tephra was spread southeastward from the volcano and it was about 1 mm thick ash fall at Kabanjahe area, about 12 km from the vent (Figure 8), but near the vent, the tephra deposit was as thick as 20 to 40 cm consisting of altered rock fragments (Figure 9).

Figure 8. Ash deposit of about 8 mm thick found around Bekerah Village.

Figure 9. Ash deposit about 50 m from the new vent at the summit. There is no indication of juvenile materials, whole rock materials have been altered.

Conclussions

The recent activity of Mount Sinabung is characterized by a phreatic eruption that took place in July to September 2010 after 1,200 years of repose. The ash deposits were distributed to the southeastern and eastern flanks of the volcano. It contains silicon dioxide/silica (SiO_2), magnetite, anorthite, pyrite, and illite which are typical of hydrothermal alteration minerals, and the ash has undergone a strong hydrothermal alteration.

The eruption of Mount Sinabung had surprised the people living around the volcano, because they have not been experienced by any volcanic eruption for more than a thousands of years. Moreover, there is nobody who has witnessed volcanic eruption, even their ancestors of whom living now in the Karo Highlands.

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