Geophysical Investigations of Ungaran Volcano, Central Java, Indonesia

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GEOPHYSICAL INVESTIGATIONS OF UNGARAN VOLCANO, CENTRAL JAVA, INDONESIA

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SUMMARY – We have been conducting some kinds of investigations for the hydrothermal system of Ungaran Volcano, Indonesia with Gadjah Mada University since 2004. In 2004 and 2005, we mainly researched the Gedongsongo fumarolic area on the southern mountainside of Ungaran Volcano. We carried out infrared and visual imagery observation, and estimated the heat discharge rate of this area at 1.25 MW with the value of the hot springs from the previous study. The result of SP surveys showed some positive anomalies in the vicinity of the fumarole and hot spring zones and the southernmost lower altitude part. The tripartite seismic observation at the Gedongsongo area in 2005 detected active seismicity that includes 4 swarms for 5 days. By using these results, we constructed a conceptual model of the hydrothermal system for the area, which describes that a part of ascending geothermal fluid from the deeper part of Ungaran Volcano changes into a lateral flow, reaches to the ground surface and forms the Gedongsongo fumarolic area. In parallel with these researches, we reanalysed the gravity data of the Ungaran area measured by the Gadjah Mada University team, and drew a Bouguer anomaly map that illustrates the underground structure of Ungaran Volcano.

1. INTRODUCTION

Ungaran Volcano is located in the central Java area of Java Island, Indonesia. It forms an across arc volcanic chain with three other volcanoes (Merapi, Merbabu and Telomoyo, from south to north), and is the northernmost volcano of the volcanic chain (Figure 1). Ungaran Volcano consists of Old Ungaran and Young Ungaran, and the Old Ungaran body is slightly basaltic than Young Ungaran (Figure 2) (Thanden et al., 1996). According to the result of K-Ar radiometric dating, the volcanic activity period of Old Ungaran is older than 0.5 Ma and that of Young Ungaran is younger than 0.3 Ma (Kohno et al., 2006).

The Gedongsongo fumarolic area is one of some geothermal manifestations around Ungaran Volcano. It exists on the southern mountainside of the volcano and there are some fumaroles, steaming grounds, hot springs and hydrothermal alterations in the area. We have been conducting some kinds of investigations for the hydrothermal

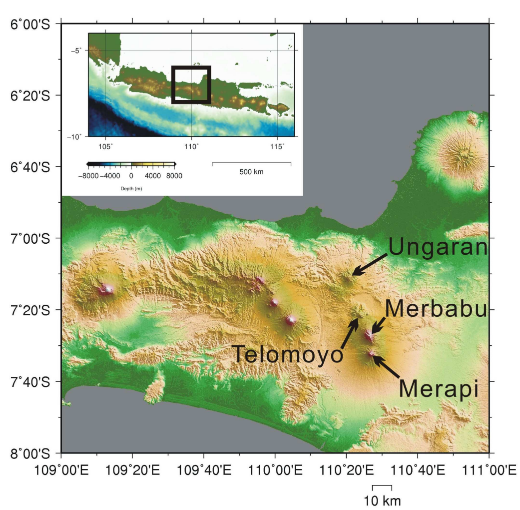

Figure 1 Location of Ungaran Volcano.

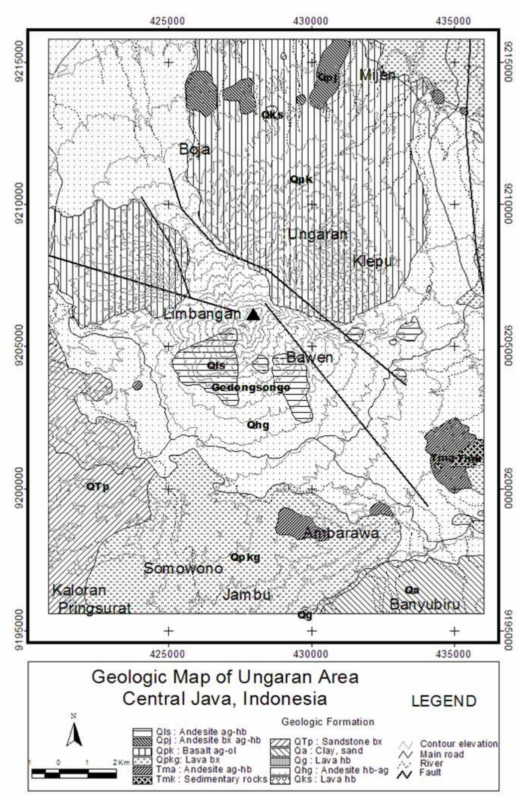

Figure 2 Geological map of Ungaran Volcano (Thanden et al., 1996). The solid triangle indicates the summit of Ungaran. Formation Qpk is classified in Old Ungaran and Formations Qls and Qhg are in Young Ungaran.

system of this volcano with Gadjah Mada University in Indonesia since 2004. In this paper, we report the results of the research at the Gedongsongo area and the gravity survey of Ungaran volcanic area.

2. GEOPHYSICAL INVESTIGATIONS AT GEDONGSONGO AREA

We conducted heat discharge estimations and SP (Spontaneous Potential) surveys at the Gedongsongo area in 2004, and the infrared imagery observation and SP surveys again and the tripartite seismic observation in 2005.

2.1 Heat Discharge Rate

The infrared imagery observations have been conducted at the largest fumarole and 5 high temperature anomaly zones in the Gedongsongo area by the infrared imagers (Thermo Tracer TH3102 by NEC Sa
in 2005) (Figure 3).
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The heat discharge rate in 2004 was estimated as 0.26 MW and that in 2005 was 0.34 MW. Considering the accuracy of this technique, it is concluded that the heat discharge rate did not change.

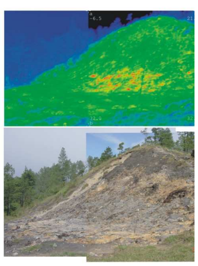
In addition, the maximum diameter of plume method (Jinguuji and Ehara, 1996) was applied to the video images of the steam plume from the largest fumarole ("FM" in Figure 3) in 2004. The estimated heat discharge rate from the fumarole was 0.90 MW.

Moreover, Aribowo et al. (2003) estimated the heat discharge rate by hot spring water from the Gedongsongo area as 0.09 MW. Therefore, the amount of the heat discharge rate from the Gedongsongo area is 1.25 MW.

2.2 SP Surveys

Table 1 Heat discharge rates from the Gedongsongo area in 2004 by using the heat balance technique (Sekioka and Yuhara, 1974).

Area	Sub-area	Distance (m)	Reference Temp. (degC)	Weather and Steam Conditions	Coefficient (HFU/degC)	Heat Discharge (kW)
ALT1	L	38.5	24.5	cloudness=5, light air, inactive	430	33.0
	LM	25.5	24.5	cloudness=5, light air, inactive	430	43.1
	RM	19.8	24.5	cloudness=5, light air, inactive	430	9.7
	RM	14.5	24.5	cloudness=5, light air, inactive	430	5.3
Y5		155.0	20.5	cloudness=5, light air, inactive	430	14.6
X7-L		151.0	21.5	cloudness=5, light air, inactive	430	10.1
X7-R		161.0	21.5	cloudness=5, light air, inactive	430	10.5
FM		16.5	22.5	cloudness=5, light breeze, active	1510	60.1
FMUP	D	17.5	22.5	cloudness=5, light air, active	960	30.2
	UL	21.5	22.5	cloudness=5, light air, active	960	37.4
	UR	21.5	22.5	cloudness=5, light air, active	960	8.9
X8	L	85.5	22.5	cloudness=5, light air, inactive	430	0.8
	RM	36.0	22.5	cloudness=5, light air, inactive	430	0.5
Total						264.2



Heat discharge

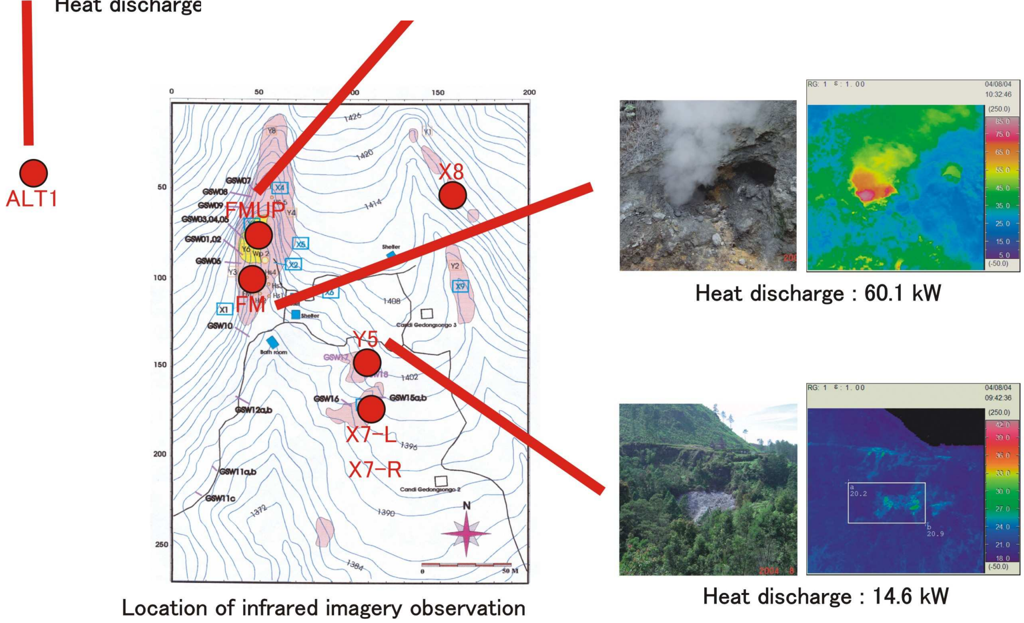


Figure 3 Infrared and visible images of the geothermal manifestations in the Gedongsongo area.

positive anomalies appear in the vicinity of the fumarole and hot spring zones and the southernmost lower altitude part (Figure 4). The result in 2005 shows the same features as that in 2004.

2.3 Seismic Observations

The seismic observation had been conducted by the Gadjah Mada University team at the collapsed wall in 2004, but no event was obtained during the 3-day observation. We conducted the tripartite seismic observation at the same area again in 2005, and 270 micro-earthquake events including 4

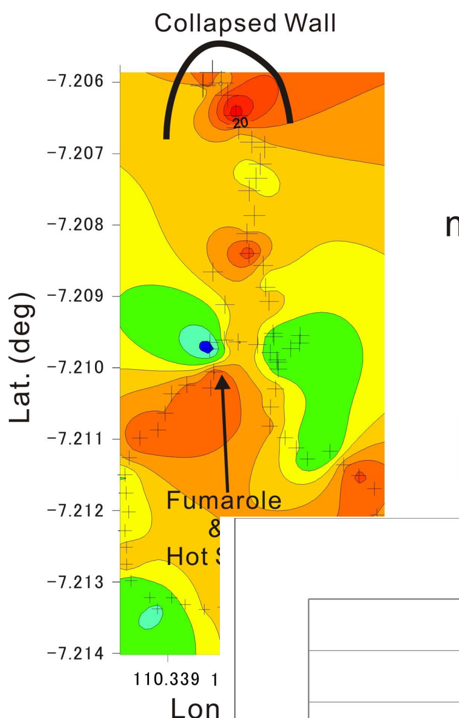


Figure 4 Result of S
area in 2004.

seismic swarms we
Almost all of the
seismic data were nc

hypocentres were successfully determined by the grid search method with 10 m grid (Figure 5). The hypocentres distribute in a shallow region (< 500 m) around the collapsed wall.

2.4 Conceptual Model

We considered the results mentioned above and constructed a conceptual model of hydrothermal system beneath the Gedongsongo area (Figure 6).

A positive SP anomaly usually appears at a location of ascending groundwater flow. Therefore, the SP anomaly in the vicinity of the fumarole and hot spring zones is caused by the spouting hot water. And the cause of the positive SP anomaly in the southernmost part may be the existence of groundwater flow to the ground surface. The positive SP anomaly around the collapsed wall is accompanied by the concentration of the micro-earthquake hypocentres. Therefore, we think that there may be an ascending geothermal fluid, which increases pore pressure of the rock and triggers the micro-earthquakes, from the deeper part of Ungaran Volcano. And the ascending flow changes into a lateral flow, reaches to the ground surface and forms the fumarole and hot spring zones.

3. REANALYSIS OF GRAVITY DATA

In parallel with these researches, we reanalysed the gravity data in the Ungaran area measured by

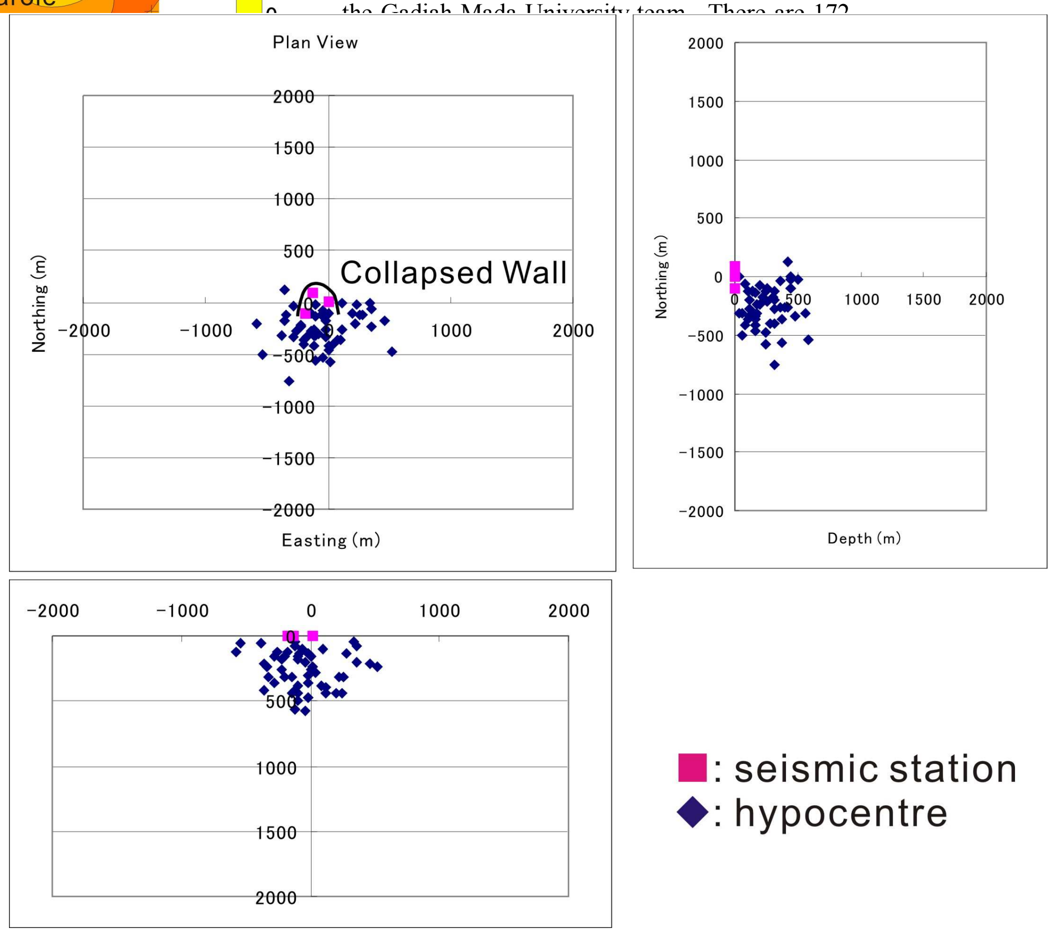


Figure 5 Hypocentres distribution in the Gedongsongo area in 2005.

We drew a Bouguer anomaly map with the Bouguer density of Ungaran Volcano of 2,470 kg/m^3 estimated by the method of Murata (1993) (Figure 7). A large high Bouguer anomaly is shown in the northern part of the summit of

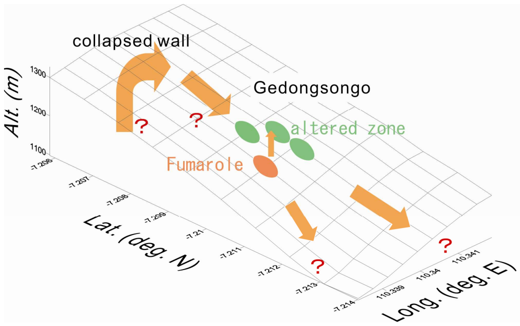


Figure 6 Conceptual model of hydrothermal system beneath the Gedongsongo area.

Ungaran Volcano where the Old Ungaran rock distributes, and the Bouguer anomaly at the Young Ungaran body is lower than surroundings. It is interesting that there is another high anomaly near the Gedongsongo area. The anomaly may be related to the geothermal manifestations of the area.

4. CONCLUSIONS

We have been conducting some kinds of investigations for the hydrothermal system of this volcano with Gadjah Mada University in Indonesia

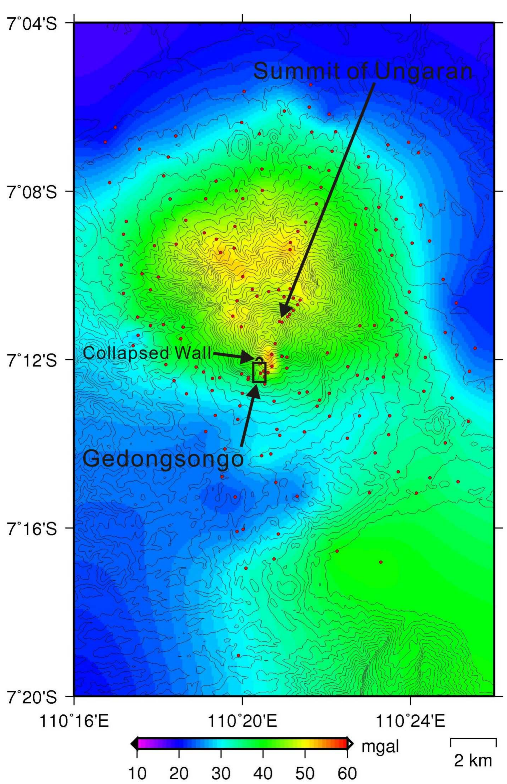


Figure 7 Bouguer anomaly map of the Ungaran area (colour) superimposed on the topography map (contour lines). The red dots indicate the gravity stations.

since 2004.

The heat discharge rate of the Gedongsongo area was estimated as 1.25 MW by using the infrared imagery and visual record with the hot springs data by the previous study.

Some positive SP anomalies were detected around the collapsed wall, in the vicinity of the fumarole and hot spring zones and at the southernmost part of the study area.

270 micro-earthquake events including 4 seismic swarms were recorded during 5-day seismic observation in 2005, and the hypocentres distribute in a shallow region (< 500 m) around the collapsed wall.

We considered these research results and constructed the conceptual model of the hydrothermal system for the Gedongsongo area, which describes that a part of ascending geothermal fluid from the deeper part of Ungaran Volcano changes into a lateral flow, reaches to the ground surface and forms the Gedongsongo fumarolic area.

In parallel with these researches, we reanalysed the gravity data in the Ungaran area measured by the Gadjah Mada University team, and drew a Bouguer anomaly map that corresponds to the distribution of the Young Ungaran and Old Ungaran bodies. There is a high Bouguer anomaly near the Gedongsongo area. The anomaly may be related to the geothermal manifestations of the area.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Aribowo, Y., Pri Utami and Wahyudi (2003). Karakter kehilangan panas alamiah dan alterasi hidrotermal permukaan di area manifestasi Gedongsongo dan sekitarnya daerah prospek panasbumi Ungaran, Jawa tengah. *Proc. Joint Convention Jakarta 2003, 32th IAGI and 28th HAGI Annual Convention and Exhibition*, CD-ROM (in Indonesian).

Jinguuji, M. and Ehara, S. (1996). Estimation of steam and heat discharge rates from volcanoes using maximum diameter of volcanic steam. *Bull. Volcanol. Soc. Japan*, Vol. 41(1), 23-29 (in Japanese with English abstract).

Kohno, Y., Taguchi, S., Agung, H., Pri Utami, Imai, A. and Watanabe, K. (2006). Geological and geochemical study on the Ungaran geothermal field, central Java, Indonesia: an implication in genesis and nature of geothermal water and heat source. *Proc. 4th International Workshop on Earth Science and Technology in Fukuoka, Japan*, 375-382.

Murata, Y. (1993). Estimation of optimum average surficial density from gravity data: an objective Bayesian approach. *Jnl. Geophys. Res.*, Vol. 98(B7), 12097-12109.

Sekioka, M. (1983). Proposal of a convenient version of the heat balance technique estimating heat flux on geothermal and volcanic fields by means of infrared remote sensing. *Mem. National Defence Academy Japan*, Vol. 23(2), 95-103.

Sekioka, M. and Yuhara, K. (1974). Heat flux estimation in geothermal areas based on the heat balance of the ground surface. *Jnl. Geophys. Res.*, Vol. 79(14), 2053-2058.

Thanden, R. E., Sumadirdja, H., Richards, P. W., Sutisna, K. and Amin, T. C. (1996). *Geological Map of the Magerang and Semarang Sheets, Java: Systematic Geological Map, Indonesia*. Geological Research and Development Centre, Indonesia.