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Seismicity South of Guntur volcano, West Java, Indonesia

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Synopsis

Guntur is a volcano complex located 35 km SE of Bandung, West Java, Indonesia. Explosive eruptions frequently occurred at Guntur crater during the period from 1690 to the middle of 19th century, however, no eruption has occurred for 167 years after the 1843 eruption. In spite of dormancy of eruptivity, seismicity of the Guntur volcano is high and earthquake swam sometimes occurred. In order to locate the earthquakes in wider area around the volcano, we installed 8 temporary stations around the volcano in addition to the permanent seismic stations operated by CVGHM at volcanoes around Guntur. Hypocenters were aligned from north to south at eastern flank of the Mt. Cikuray volcano, south of Guntur, at depths around 6 km from January to April, 2009. After May, earthquake origins were distributed around Darajat geothermal area at depths 2 – 9 km, showing alignment from NW to SE.

Keywords: Guntur volcano, long-term volcanic eruption prediction, volcano-tectonic earthquake, local tectonic earthquake

1. Introduction

Indonesia is earthquakes and volcanoes prone area. Sumatera and Java islands are the most dangerous regions due to dense population. Project “Multi-disciplinary Hazard Reduction from Earthquakes and Volcanoes in Indonesia (Leader: Kenji Satake, Earthquake Research Institute, University of Tokyo, Japan side; Hery Harjono, Indonesian Institute of Science (LIPI), Indonesia side)” was adopted in the framework of Science and Technology Partnership for Sustainable Development program by Japan Science and Technology Agency (JST) and Japan International Cooperation Agency (JICA).

Guntur is a volcano complex located 35 km SE of Bandung, West Java, Indonesia. In the summit area, peaks of Mt. Masigit, Parukuyan, Kabuyutan and Guntur crater are aligned from northwest to southeast (Surmayadi et al., 1998). Guntur volcano is the youngest crater in the complex. Minor fumarolic activity has remained at the crater, while large geothermal area with fumarolic activity is located in the Kamojang, about 5km west of the summit of Guntur. The area extends to Darajat caldera about 15 km southwest of Guntur volcano. There are many actives volcanoes around Guntur volcano, such as Papandayan, Galunggung, Tangkubanperahu, Gede, Salak and Ciremai. The main faults; Cimandiri, Lembang and Baribis strike in the center of West Java (Nakamura et al., 1998).

According to historic records, all the eruptions occurred at Guntur crater. The oldest historic eruption occurred in 1690 and eruptions frequently occurred until the middle of the 19th century (Kusumadinata, 1979). After the last eruption in 1843, no eruption has occurred yet. In spite of the recent dormant eruptive activity for 167 years, seismicity of Guntur volcano has been active. Several tens volcanic earthquakes had been observed per month (Iguchi et al., 1998). Guntur volcano is regarded as high-risk volcano due to high eruptivity in historic times and dense population at the flank of the volcano.

Distribution of hypocenter and focal mechanism of volcanic earthquakes was made clear by some previous study (Iguchi et al., 1996; Suantika et al., 1997; Suantika et al., 1998, Sadikin et al., 2007). Hypocenters of volcanic earthquakes are aligned at the summit area, along the volcanic cones from Guntur to Mt. Masigit, from SE to NW at depths of 2-4 km. volcanic earthquakes beneath the summit are shallower (<4km) with normal fault mechanism (Sadikin et al., 2007). The other alignment of hypocenters is recognized from Gandapura caldera to Mt. Gajah. In addition, volcanic earthquakes occur around Kamojang area west of the summit. In the Kamojang area, earthquakes are distributed from Gandapura (NE) to Darajat caldera (SW) at depth of 5-10 km, with the strike-slip focal mechanism, similarly to tectonic earthquakes in inland area. The volcanic earthquakes from Kamojang to Darajat are distributed along the fault south of Guntur volcano (Alzwar et al., 1992). However, the hypocenter distribution in Darajat geothermal region, southwest of the Kamojang has not been well determined due to the insufficient coverage of seismic network.

Seismicity in Indonesia has been monitored by Badan Meteologi, Klimat dan Geofisika and hypocenters and focal mechanism of tectonic earthquakes with magnitude more than 4 are well determined by US Geological Survey (Syahbana et al., 2009). However, micro seismicity has not been grasped yet at any region, especially at around Guntur volcano and its surrounding.

In this study, we determine the hypocenter of local earthquakes, which has not been well identified by only seismic stations at Guntur volcano, by using seismic stations around the volcano. The seismic network with these stations covers the Kamojang- Darajat geothermal areas and triangular Guntur–Papandayan-Galunggung region. In order to extend the seismic network wider and densely, 8 temporary stations have been added in October 2009 and March 2010. Distribution of hypocenters and temporal change of seismicity around the Guntur volcano is discussed on tectonic and geological setting in this region.

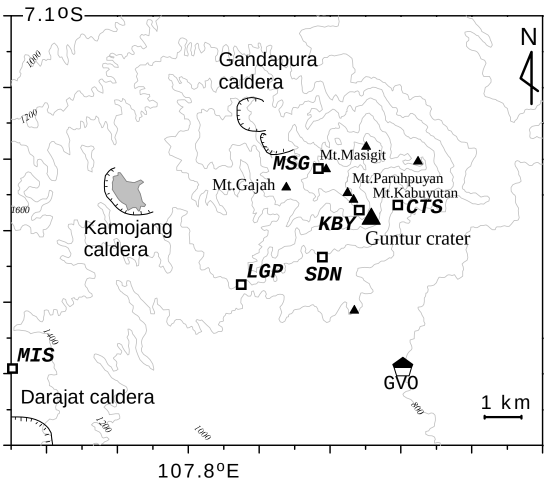

Fig. 1 Locations of seismic stations at Guntur volcano. Squares indicate seismic stations and triangles show peak of cones. GVO is Guntur Volcano Observatory.

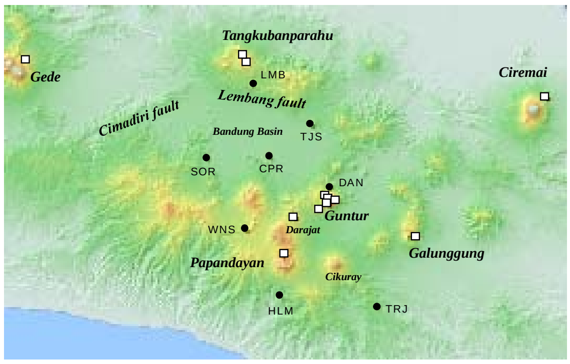

Fig. 2 Location of seismic stations in West Java. Squares indicate permanent stations operated by CVGHM and solid circles show temporary stations installed by this study.

2. Observation

In order to monitor the volcanic activity of Guntur, Volcanological Survey of Indonesia (VSI, present: Center for Volcanology and Geological Hazard Mitigation; CVGHM) started high gain observation at Cities station 1.1 km east of the Guntur crater in 1989. Sakurajima Volcano Research Center, Disaster Prevention Research Institute of Kyoto University added 3 stations at the southeast to southwestern flank of the volcano to locate hypocenter of volcanic earthquakes in October 1994. CVGHM sometimes updated the seismic network. At present, 6 seismic stations are operated at CTS, KBY, SDN, MSG, LGP and MIS. Fig. 1 shows location of seismic stations. Each station is equipped with short-period (1 Hz; L4C Mark Product) seismometer. Station LGP has 3-componet and the others have only vertical component. The seismic signals are transmitted to Guntur Volcano Observatory (GVO) by FM radio telemeter and transmitted signals are digitized at sampling rate of 100 Hz by analogue-to-digital converter (LS-7000, Hakusan). The digital data based on WIN format are recorded in a PC and simultaneously transmitted to the main office of CVGHM in Bandung via VSAT. Analogue signals from KBY station are recorded on a drum recorder (PS-2 Kinemetrics) continuously for real-time monitoring.

CVGHM has monitoring stations at volcanoes Papandayan, Galunggung, Tangkubanperahu, Ciremai, Salak and Gede in West Java. The seismic stations are available to improve the coverage of seismic network around Guntur volcano. These stations have same specification of station CTS at Guntur volcano.

In order to optimize the seismic network around the Guntur volcano, 8 temporary stations were installed among the permanent stations located at the volcanic region. Stations DAN, WNS, HLM and TRJ were setup in October 2009. And observation started at stations CPR, SOR, LMB and TJS around Bandung Basin in March 2010. The locations of seismic stations are shown in Fig. 2. Each temporary station is equipped with 3-components short-period seismometer (2Hz, h=0.7, KVS-300, Kinkei System) and the seismic signals are sampled at a rate of 250 Hz with quasi-24 bits resolution and stored in Compact flash memory cards (maximum 24GBytes) with original format in logging device EDR-X7000. The original format can be converted

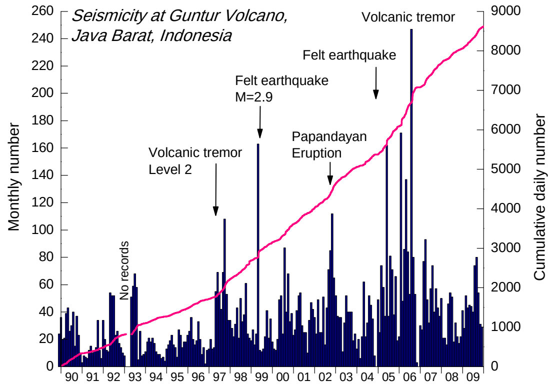

Fig. 3 Monthly number of volcanic earthquakes at Guntur volcano during the period from 1990 to 2009

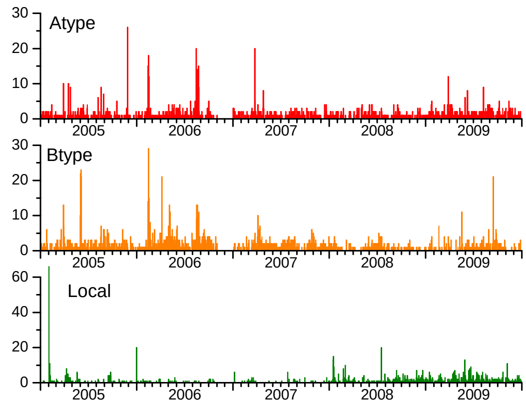

Fig. 4 Monthly number of VA-type, VB-type and local tectonic earthquakes during the period from 2005 to 2009.

into WIN format. Power consumption of the data logger is quite low 0.04W. The low power consumption and large capacity of memory enable us to conduct long-term operation.

3. Seismic activity

3.1 Seismicity of volcanic earthquake

Fig. 3 shows monthly numbers of volcanic earthquakes at Guntur volcano. The monthly numbers have been counted by events with >10μm/s maximum amplitude and <3 s time interval of P and S-wave onsets on the seismograms of station CTS. In normal state of Guntur volcano, the monthly numbers are <20. The monthly numbers sometimes remarkably increased. For example, seismicity of volcanic earthquake increased in May the monthly number attained at the peak in October counting the number of 108 (Iguchi et al., 1998).

Fig. 4 shows monthly numbers of volcanic and local tectonic earthquake since 2005. CVGHM defines 3 categories based on S-P time interval. VB-type is a type of volcano-tectonic earthquake, however it is difficult to identify S-wave clearly due to quite short S-P time interval. The S-wave is clearly identified in VA-type. In this case, The S-P time interval range from 1 to 4 s. Local earthquakes have S-P time interval between 4 and 10 s. Sadikin et al. (2007) determined the location of VA-type and VB-type earthquakes. Based on their calculation, VB-types are located in the summit area from Mt. Masigit to Guntur crater. On the other hand, VA-type earthquakes are distributed from Gandapura caldera to Kamojang geothermal area. However the hypocenters of local earthquakes have not been well determined well.

Some local tectonic earthquakes were felt around Guntur volcano. It is inferred that hypocenters of the felt earthquake on February 5, 2005 was located northwest of the Guntur volcano; however precise location of the hypocenter was not well determined because the seismic network did not cover the inferred hypocenter location. The felt earthquake was followed by 120 after-shocks. The number of local tectonic earthquakes increased from 2008.

In this study, local earthquakes recorded at the permanent stations in West Java have been selected. Firstly, we picked up earthquakes at station MIS southwest of the Guntur. When the events were recorded at >4 stations, the events is counted for local tectonic earthquakes.

Daily numbers of local earthquakes defined by this study is shown in Fig. 5. The numbers in January and February 2009 ranged from 5 to 12 events per month, however only 4 events identified in March. The seismicity attained at higher level after April and 20-30 events occurred during the period from April to August. The seismicity peaked on May 30 counting 9 events per day. The activity decreased almost 10 events per month after September.

We recognized 189 events as local tectonic earthquakes and selected 101 earthquakes with well defined P and S-wave onset and recorded at among

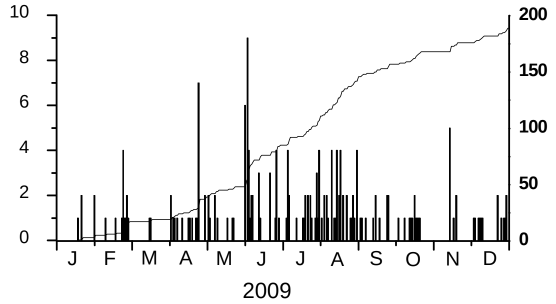

Fig. 5 Daily numbers (left axis) and cumulative numbers (right axis) of local tectonic earthquakes in 2009

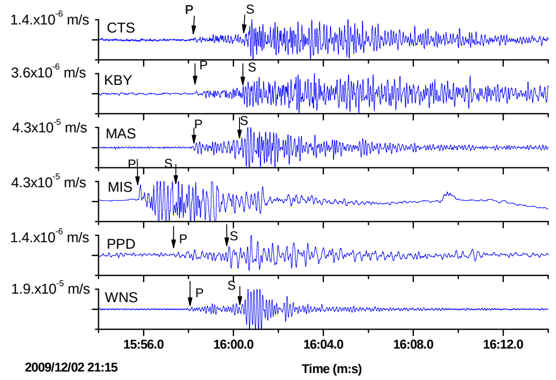

Fig. 6 An example of waveform set of local tectonic earthquake

permanent stations at Guntur, Papandayan, Galunggung and temporary stations (Table 1). These events mostly have S-P time interval shorter than 7s. An example of seismograms of typical local earthquake is shown in Fig. 6. The vertical component seismogram at observed stations shows clear P and S-waves with S-P time interval < 4s.

Magnitude is calculated from seismogram at the station MIS using an empirical relationship of magnitude (M) and duration ($t_{F\text{-}P}$, in second) of the earthquake (Iguchi et al., 1998) as follows;

$$M = 2.024\log_{10} t_{F-P} - 1.816\ .$$

The magnitude ranged from 0.8 to 2.0 in 2009. Earthquake with M>0.8 can be detected by this seismic network.

The seismic energy (E, erg) release was estimated from magnitude by the formula (Gutenberg-Richter, 1956);

$$\log_{10} E = 11.8 + 1.5M\ .$$

Cumulative seismic energy release in 2009 was 1.5×10^{16} erg.

Table 1 Selected events and results of hypocenter determination

No	Event	Latitude (°)	Longitude (°)	Depth (km)	Lat. err (km)	Long. err (km)	Depth err (km)	N	*M*
1	09011500	-7.3245	107.9078	6.729	0.191	0.048	0.848	5	1.3
2	09011813	-7.3531	107.9117	9.276	0.235	0.074	0.804	5	1.1
3	09011814	-7.3440	107.9126	5.741	0.311	0.106	0.98	5	1.4
4	09012800	-7.3192	107.8846	4.226	0.134	0.080	0.986	5	1.7
5	09020606	-7.3542	107.8847	7.402	0.142	0.078	0.637	6	1.2
6	09021410	-7.3578	107.8332	4.264	0.155	0.096	0.983	6	1.2
7	09021915	-7.3325	107.9037	6.169	0.181	0.058	0.949	6	1.2
8	09022002	-7.4452	107.8405	4.535	0.273	0.112	0.993	6	1.7
9	09022014	-7.3982	107.8382	4.475	0.297	0.134	0.996	6	1.4
10	09022204	-7.3525	107.9090	11.187	0.176	0.051	0.590	6	1.6
11	09022319	-7.3170	107.9053	5.653	0.142	0.056	0.959	6	1.5
12	09022423	-7.3793	107.9169	5.542	0.342	0.112	0.994	6	1.3
13	09031312	-7.3489	107.9049	10.684	0.165	0.045	0.590	6	1.1
14	09031422	-7.3870	107.9215	6.743	0.246	0.072	0.913	7	1.0
15	09032104	-7.3491	107.9104	6.179	0.235	0.068	0.967	6	1.2
16	09033000	-7.3666	107.8956	5.989	0.230	0.080	0.371	6	1.6
17	09033007	-7.4575	107.8573	4.861	0.206	0.065	0.945	6	1.5
18	09033100	-7.3679	107.9095	9.576	0.284	0.066	1.367	6	1.3
19	09040401	-7.3712	107.8352	4.410	0.198	0.100	0.986	5	1.9
20	09040816	-7.3129	107.7569	4.084	0.342	0.433	0.830	4	2.0
21	09041320	-7.4548	107.8129	4.050	0.406	0.190	0.998	6	2.0
22	09042100	-7.3880	107.9145	4.701	0.371	0.138	0.997	6	1.1
23	09042102	-7.4166	107.8513	4.099	0.351	0.152	0.996	6	1.4
24	09042116	-7.3565	107.9057	4.588	0.384	0.137	0.996	5	1.3
25	09042607	-7.3757	107.9170	5.295	0.316	0.116	0.991	6	1.3
26	09043000	-7.3024	107.8927	6.273	0.207	0.067	0.935	4	1.3
27	09051423	-7.3586	107.8430	6.310	0.156	0.084	0.407	5	1.7
28	09051911	-7.2978	107.9007	5.736	0.133	0.056	0.925	7	1.2
29	09052404	-7.3533	107.7531	4.324	0.276	0.273	0.799	7	1.7
30	09052506	-7.2114	107.7321	3.073	0.473	0.643	0.155	6	1.7
31	09052802	-7.3060	107.7009	3.799	0.213	0.226	0.14	7	1.6
32	09052814	-7.2221	107.7412	3.887	0.479	0.629	0.467	6	1.9
33	09052815	-7.2640	107.7362	4.887	0.081	0.191	0.271	6	1.8
34	09053004	-7.2709	107.8038	3.964	0.119	0.138	0.938	4	1.7
35	09053004	-7.2571	107.7486	4.176	0.078	0.280	0.762	5	1.6
36	09053005	-7.2532	107.7257	6.373	0.230	0.543	0.501	6	1.7
37	09053006	-7.2660	107.7527	7.362	0.242	0.503	0.652	5	1.4
38	09053021	-7.2443	107.6975	6.798	0.239	0.563	0.403	6	1.4
39	09053021	-7.2396	107.6970	4.829	0.261	0.656	0.537	5	1.5
40	09053021	-7.2548	107.7414	3.284	0.230	0.826	0.364	5	1.8
41	09053022	-7.2603	107.7564	3.203	0.134	0.450	0.779	5	1.4
42	09053022	-7.2809	107.7006	2.519	0.646	0.638	0.716	5	1.4
43	09053102	-7.2475	107.7084	6.399	0.269	0.648	0.458	5	1.3
44	09053102	-7.2392	107.6884	5.248	0.270	0.664	0.553	5	1.5

45	09053103	-7.2435	107.7017	6.343	0.283	0.667	0.449	5	1.7
46	09060103	-7.2875	107.7393	1.831	0.447	0.624	0.839	5	1.0
47	09060203	-7.3141	107.7566	2.526	0.663	0.336	0.717	5	1.7
48	09060207	-7.3171	107.7743	3.477	0.431	0.147	0.883	6	1.7
49	09060821	-7.1616	107.8435	8.334	0.295	0.199	0.21	6	1.1
50	09060821	-7.1708	107.8426	9.306	0.383	0.271	0.275	6	1.1
51	09060901	-7.1383	107.8262	3.364	0.145	0.089	0.115	5	1.1
52	09061702	-7.2343	107.7384	3.885	0.298	0.461	0.455	6	1.1
53	09061722	-7.2351	107.6701	3.292	0.214	0.750	0.948	6	1.4
54	09061722	-7.2374	107.6741	3.116	0.198	0.725	0.842	6	1.4
55	09062109	-7.2875	107.7203	1.701	0.229	1.921	0.792	5	1.2
56	09062217	-7.2064	107.7424	1.890	0.331	0.378	0.092	6	1.3
57	09062217	-7.2173	107.7378	1.919	0.397	0.562	0.192	6	1.5
58	09062221	-7.1456	107.7864	4.047	0.240	0.134	0.349	5	1.3
59	09070120	-7.2771	107.7228	3.444	0.245	0.274	0.424	6	1.1
60	09070121	-7.3069	107.7473	4.043	0.245	0.312	0.464	6	0.9
61	09071320	-7.2418	107.6441	3.228	0.266	0.869	0.993	7	1.4
62	09071404	-7.2626	107.7488	3.755	0.136	0.436	0.987	6	1.7
63	09071721	-7.2236	107.7533	3.833	0.578	0.738	0.733	5	1.8
64	09071902	-7.2989	107.7627	2.530	0.717	0.245	0.973	5	1.7
65	09071904	-7.3172	107.7291	2.750	0.539	0.582	0.342	5	1.8
66	09072417	-7.2023	107.7222	5.327	0.532	0.654	0.87	5	1.8
67	09072505	-7.3725	107.7951	3.833	0.489	0.212	0.983	6	1.8
68	09072600	-7.2887	107.7378	2.268	0.582	0.693	0.995	6	1.9
69	09072602	-7.2039	107.8067	9.399	0.303	0.220	0.317	6	1.1
70	09072602	-7.1334	107.7821	4.028	0.190	0.106	0.481	6	1.1
71	09072603	-7.2062	107.8025	9.125	0.291	0.214	0.31	6	1.0
72	09073004	-7.2162	107.7201	3.269	0.385	0.572	0.148	6	1.0
73	09081702	-7.2620	107.7337	3.367	0.726	1.170	0.998	5	1.0
77	09082505	-7.1265	107.8025	2.921	0.160	0.103	0.199	5	1.0
78	09082505	-7.1132	107.7949	3.277	0.271	0.144	0.369	5	1.2
79	09090404	-7.2337	107.6632	3.032	0.223	0.836	0.962	6	1.0
80	09090922	-7.3472	107.7928	4.123	0.400	0.209	0.998	6	1.0
81	09091823	-7.2854	107.7205	3.032	0.492	0.463	0.596	6	1.1
82	09091823	-7.3619	107.7877	4.370	0.393	0.222	0.986	6	1.2
83	09091900	-7.2957	107.6943	2.768	0.342	0.244	0.242	7	1.3
84	09091900	-7.2884	107.7379	2.727	0.524	0.52	0.885	6	1.4
85	09100214	-7.2313	107.7350	3.897	0.593	0.89	0.987	5	1.1
86	09100602	-7.2966	107.7524	4.520	0.169	0.215	0.442	6	1.9
87	09101410	-7.2288	107.7631	5.870	0.727	0.902	0.54	5	1.1
88	09102716	-7.2755	107.7036	3.170	0.430	0.334	0.571	6	1.3
89	09110702	-7.2098	107.7341	2.893	0.361	0.476	0.107	6	1.0
90	09110702	-7.2017	107.7210	3.416	0.345	0.458	0.084	6	1.0
91	09110702	-7.2313	107.7356	3.241	0.487	0.872	0.543	6	1.0
92	09110715	-7.2361	107.7687	7.359	0.696	0.866	0.506	5	1.2
93	09110715	-7.2081	107.7323	3.961	0.346	0.459	0.976	5	0.9
94	09110715	-7.2166	107.7407	6.058	0.611	0.765	0.645	5	1.4
95	09111108	-7.2238	107.7467	6.444	0.737	0.928	0.607	5	0.9
96	09111220	-7.2530	107.7392	4.620	0.073	0.214	0.309	6	1.0

97	09112621	-7.2206	107.7374	2.370	0.404	0.604	0.245	6	1.1
98	09112711	-7.2113	107.7577	3.975	0.506	0.600	0.547	5	0.8
99	09120321	-7.2784	107.7153	1.733	0.288	0.578	0.471	5	1.1
100	09120122	-7.2500	107.7260	2.886	0.195	0.714	0.510	5	1.3
101	09120221	-7.1953	107.7046	4.164	0.368	0.517	0.389	5	1.0

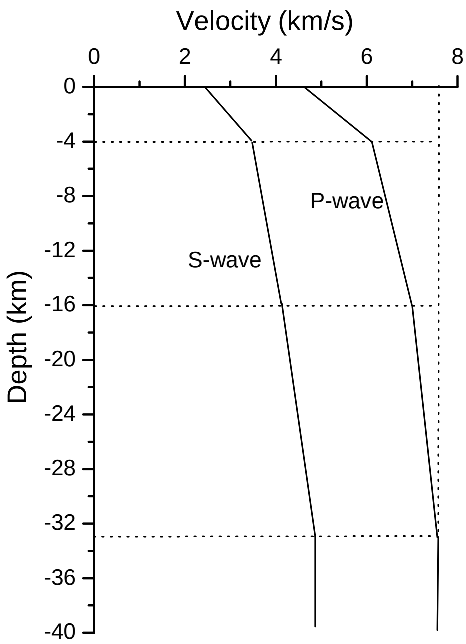

Fig. 7 P- and S-wave velocity structure used for hypocenter determination

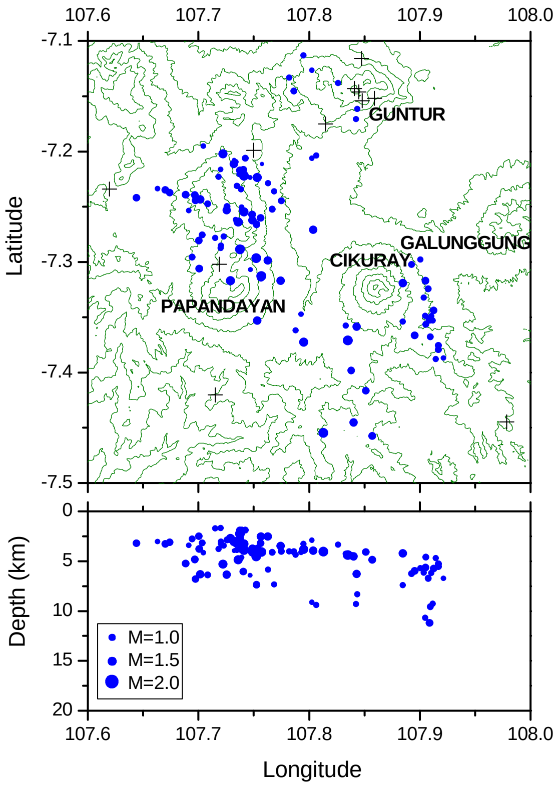

Fig. 8 Hypocenter distribution in area south of Guntur volcano in 2009. Top: Epicenter, Bottom: hypocenters plotted on the vertical cross-section in east-west direction. Dots are hypocenter and crosses are seismic station.

4. Hypocenter distribution

Hypocenters of the local earthquakes were determined by using arrival times of P and S-wave at more than 4 stations. The velocity structure used for hypocenter calculation was adopted from Geophysics and Meteorology Agency of Indonesia. Kartodinomo (1996) studied the velocity structure in West Java and identified three layers. The P-wave velocities in top, middle and bottom layer are 4.3 km/s, 6.1 km/s and 7.0 km/s with thickness of 4km, 12km and 17 km respectively. For S-wave, V_p/V_s=1.73 is assumed. Hypocenters were calculated using “hypomh” software (Hirata and Matsu’ura, 1987). In this program, P and S-wave velocity increase with depth. Then, the parameters in 3 layers obtained by Kartodinomo (1996) are modified as shown in Fig. 7.

Obtained locations of hypocenters are listed in Table 1. The hypocenter distribution in 2009 is shown in Fig. 8. The hypocenters are mainly distributed around Darajat geothermal area and Papandayan volcano. In addition, the hypocenters were located at eastern flank of Mt. Cikuray. The depths distributed around 2-9 km in Darajat geothermal field, and about 2-6 km below Papandayan volcano, while the hypocenters at Mt. Cikuray were identified at depths 4-12 km. From the pattern of epicenter in Fig. 8, 4 clusters are identified. First cluster located at west of the summit of Guntur volcano. This area is known as Kamojang geothermal area. The second and third clusters extended from northwest to southeast at Darajat geothermal field and near Papandayan volcano. The last cluster was found at eastern flank of Mt. Cikuray and the epicenters are aligned from north to south at eastern flank.

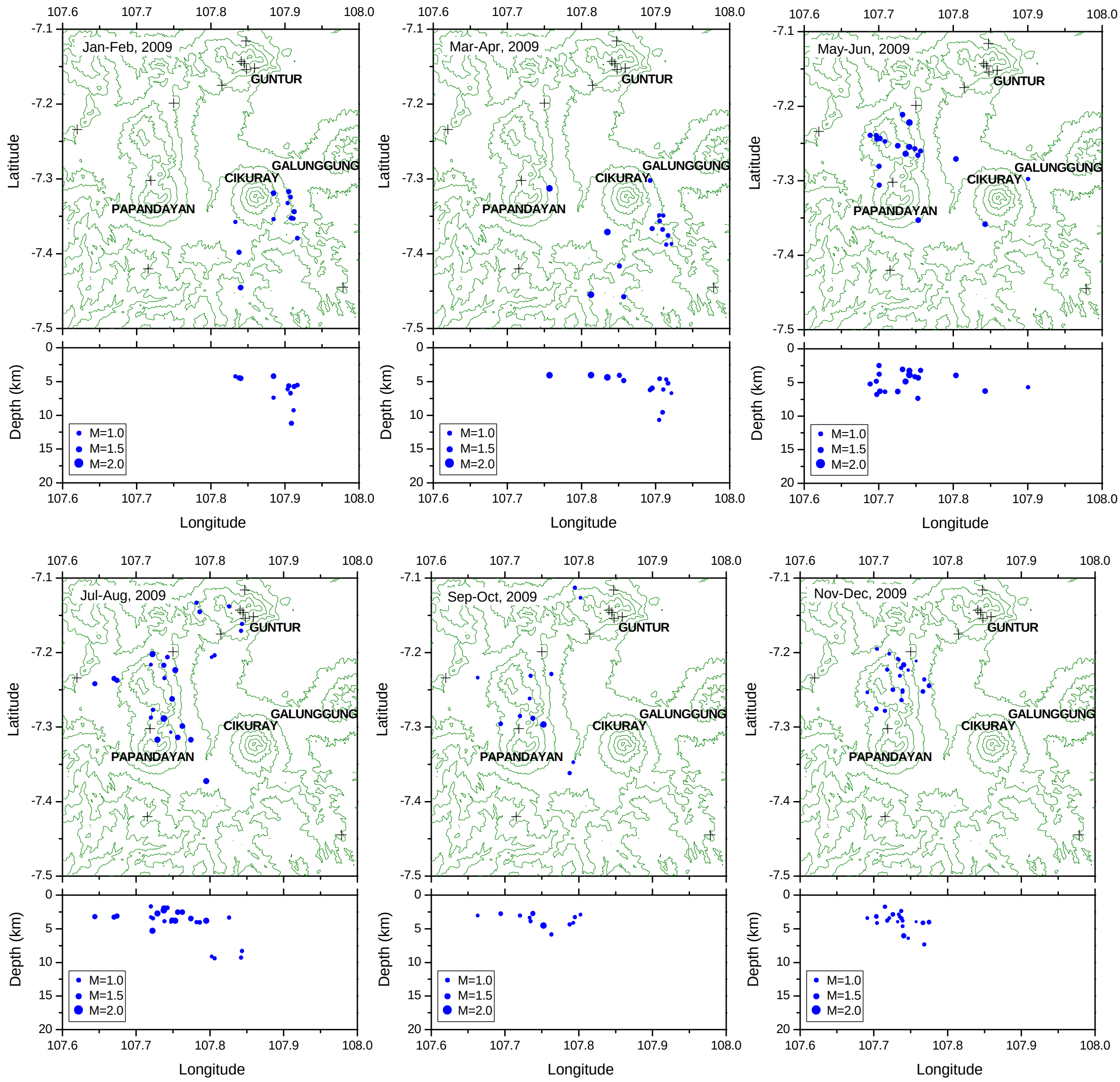

Fig 9 Temporal change of hypocenter distribution

Fig. 9 show temporal change of hypocenter distribution every 2 months. The hypocenter separated into southeast flank and southwest flank of Cikuray volcano at depth of 4-12 km below sea level during the period from January to April. However, in the period of May – July, the seismicity moved to the area from Papandayan volcano to the Darajat caldera and some of them also clustered at Kamojang caldera at depths of 2 – 10 km below sea level. The numbers of events decreased in September and October beneath Papandayan volcano and at Darajat geothermal area. The seismicity resumed in November and December at depth of 2-9 km beneath Darajat geothermal area.

5. Effect of temporary stations

The hypocenters were determined by adding 4 temporary stations (DAN, HLM, WNS and TRJ) from the end of October. Fig. 10 shows the effect of adding the temporary stations in the hypocenter calculation. When one or more of the temporary stations were added to the permanent stations in hypocenter calculation, the epicenter relatively moved toward to the direction of added stations. When stations WNS and TRJ were added in calculation, the epicenter moved to the location near station WNS (top of Fig. 10). Similar effect was recognized when station TRJ was added.

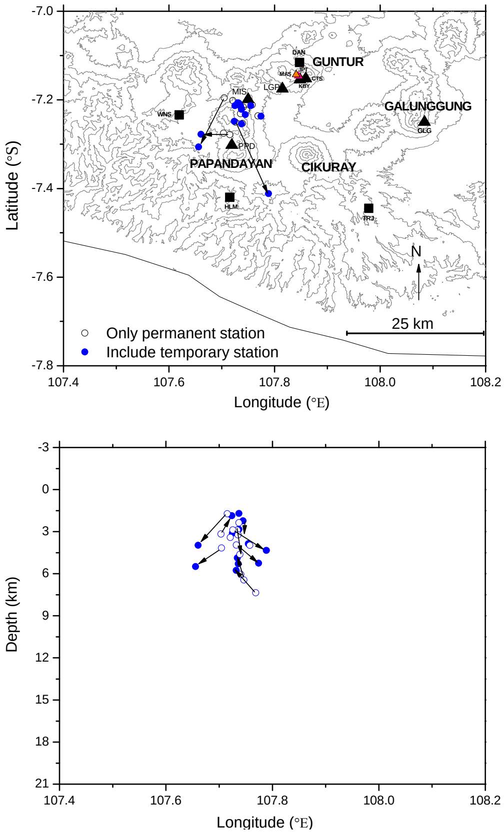

Fig. 10 Effect of adding temporary stations. Open circles indicates hypocenters determined only by permanent stations. Dots are locations determined by adding temporary stations. Top: epicenter. Bottom: vertical cross-section in east-west direction.

Focal depth also changed when the temporary station were added as shown in the bottom of Fig. 10b.

6. Discussion

Distribution pattern of hypocenters beneath the summit area of Guntur volcano was discussed with fault pattern and alignment of cones of volcano in Guntur volcano complex (Sadikin et al., 2007). Volcanic earthquakes beneath the summit area aligned along the volcanic cones; Mt. Masigit, Parupuhyan, Kabuyutan and Guntur crater and paralleling distributed from Gandapura caldera to Mt. Gajah. The latter hypocentral zone coincides with fault of normal fault-type. Distribution pattern of hypocenter distribution in this study is compared with fault pattern south of Guntur volcano complex obtained by Alzwar et al. (1992) as shown in fig. 11.

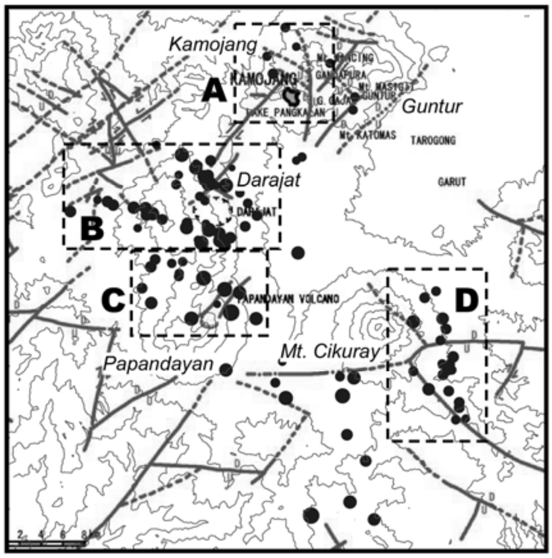

Fig. 11 Relation of hypocenter distribution and fault. Fault pattern was modified from Alzwar et al., (1992). A, B, C, and D regions represent of hypocenter distribution at region of Guntur volcano, Darajat Geothermal field, Papandayan volcano and Cikuray volcano, respectively.

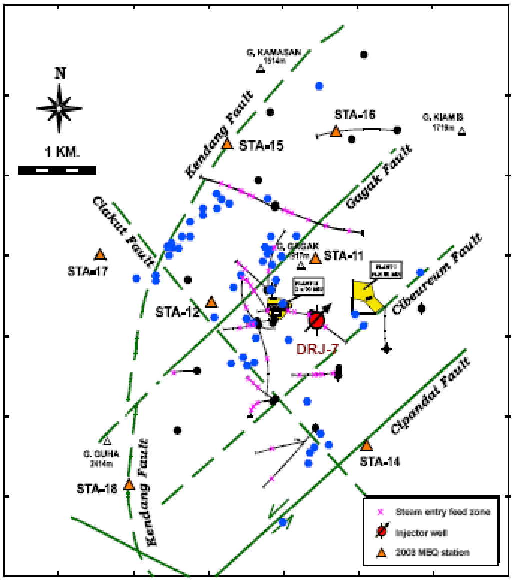

Fig. 12 Micro earthquakes distribution in 1997 and faults around Darajat geothermal field and (Pramono and Colombo, 2005)

Here we divide the hypocenter distribution into 4 regions. Region A is Kamojang area west of the summit of Guntur volcano. Hypocenter distribution was elongated in the direction from northeast to southwest as shown by the previous studies (Iguchi et al., 1998; Sadikin et al., 2007). There are a lot of fumaroles in Kamojang caldera. It is possible that the earthquakes were triggered by hydrothermal activity. Sadikin et al. (2007) obtained strike-slip fault with N-S extension and E-W contraction for the mechanism in this area. The earthquakes may be affected by tectonic stress.

Region B is the most dense hypocenter zone located at Darajat geothermal field. Pramono and Colombo (2005) shows many faults such as Ciakut, Kendang, Gagak and so on based on the distribution of micro earthquakes as shown in Fig. 12. There are two alignments of hypocenters from northwest to southeast in region B. Longer alignment corresponds to Ciakut fault striking from northwest to southeast; however shorter alignment from northwest to southeast was not recognized by Pramono and Colombo (2005). They interpreted the hypocentral distribution by two pararel faults; Kendang, and Gagak striking northeast to southeast. The shorter alignment of fault in this study may be better to be interpreted by a fault parallel to Ciakut fault striking from northwest to southeast.

Hypocenters in region C are distributed north flank of Papandayan volcano. The hypocenter zone extends from northwest to southwest, similarly to Ciakut fault.

Considering hypocenter distribution by Iguchi et al. (1998) and Sadikin et al. (2007) in Kamojang area and those by Pramono and Colombo (2005) and in this study in Darajat area and its southwestern part, the hypocenters of earthquakes are dominantly distributed from northeast to southwest along Kendang fault. However, distribution pattern changes at Darajat geothermal area. Hypocenters are dominantly distributed from northwest to southeast, conjugating the Kendang fault.

Hypocenters are also distributed in region D around Mt. Cikuray. Rasjid et al. (1989) detected seismic wave propagating from Mt. Cikuray; however the hypocenters were not determined well. In this study, hypocenters of earthquakes were found at eastern flank aligning from north to south at depth around 6 km and southwestern part of the mountain. Cikuray is a quaternary volcano and no historic eruptions were recorded. It is difficult to judge the seismicity was caused by volcanic activity or tectonic stress, however the alignment of hypocenters at eastern flank seems to obey the tectonic fault.

7. Conclusions and future works

Hypocenters of earthquakes south and southwest of Guntur volcano were determined. Hypocenters are aligned in the northeast to southwest direction from Kamojang caldera to Darajat geothermal area. Hypocenter distribution pattern spatially changes at Darajat, aligning from northwest to southeast and 3 chains of hypocenters were recognized from Darajat to Papandayan. Local earthquakes were detected around Mt. Cikuray.

Focal mechanism of earthquakes from Darajat to Papandayan volcano and around Mt. Cikuray has not been determined yet. The focal mechanisms have to be determined to understand tectonic of this area.

Felt earthquakes sometimes occurred north of Guntur volcano, for example in 2000 north of the volcano (east of Bandung city) and in 2005 northwest of the volcano (southeast of Bandung). To grasp the seismicity, we installed 4 stations in Bandung Basin in March 2010 considering effect of tectonic stress due to Cimandiri, Lembang, and Baribis faults.

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References

Alzwar, M., Akbar, N. and Bachri, S. (1992): Geological map of the Garut and Pameungpeuk quadrangle, Jawa. Geological Research and Development Center.

Gutenberg, B. and Richter, C. F. (1956): Magnitude and energy of earthquakes, Ann. Geofis., Vol.9, pp.1-15.

Hirata, N. and Matsu'ura, M. (1987): Maximum-likelihood estimation of hypocenter with origin time eliminated using inversion technique, Physics of the Earth and Planetary Interiors, Vol. 47, pp. 50-61.

Iguchi, M., Ishihara, K., Takayama, T., Suantika, G., Tjetjep, W. S., Sukyar, R., Sutawidjaja, I. S., and Suganda, O. K., (1996): Seismic activity at Guntur volcano, West Java, Indonesia. Ann. Disas. Prev. Res. Inst., Kyoto Univ., No. 39B-1, pp. 1-11 (in Japanese with English abstract).

Iguchi, M., Ishihara, K., Sutawidjaja, I. S., Suantika, G., Hendrasto, M. and Suganda, O. K., (1998): Evaluation of the 1997 Activity at Guntur volcano, West Java, Indonesia. Proc. Symposium on IDNDR projects-Volcanology, Tectonics, Flood and Sediment Hazards, Bandung, pp. 115-122.

Kartodinomo S. (1996): Seismic velocity structure in West Java and surroundings, Indonesia, For the course of seismology, 1995-1996, International Institute of Seismological and Earthquakes Engineering.

Kusumadinata, K. (1979): Data dasar gunungapi Indonesia. Direktorat Vulkanologi (in Indonesian).

Nakamura, K., Ito, K., Wada, H., Asada, T., Tanaka, T., Setyadi, B., Kuntjoro, W, and Kahar, J. (1998): Gravity survey crossing the Lembang fault and Cimandiri faults. Proc. On the symposium on Japan-Indonesia IDNDR project, 1998, pp. 215-221.

Pramono, B. and Colombo, D. (2005): Microearthquake characteristic in Darajat geothermal field, Indonesia, Proceedings World Geothermal Congress, Antalaya, Turkey, pp. 24-29.

Rasjid, S. A., Kusmana and Samid (1989): Laporan penyelidikan kegempaan Komplek vulkaniki G. Guntur-Papandayan, Januari-Maret 1989, Proyek penyuelidikan gunungapi dan panasbumi, Direktorat Vulkanologi, pp.1-81.

Sadikin, N., Iguchi, M. Hendrasto, M. and Suantika, Gede (2007): Seismic activity of Volcano-tectonic Earthquakes at Guntur volcano, West Java, Indonesia During the Period from 1991 to 2005, Indonesian Physics Journal, Vol. 18, No.1, pp. 21-28.

Suantika, G., Suganda, O. K., Iguchi, M. and Ishihara, K. (1997) Hypocentral distribution and focal mechanism around Guntur volcano, West Java, Indonesia. Ann. Disas. Prev. Res. Inst., Kyoto Univ., No. 40, IDNDR, S.I., pp. 5-11.

Suantika, G., Suganda, O. K., Iguchi, M. and Ishihara, K.,(1998) Hypocentral distribution and focal mechanism around Guntur volcano, West Java, Indonesia. Proc. Symposium on IDNDR projects-Volcanology, Tectonics, Flood and Sediment Hazards, Bandung, pp.

Surmayadi, M., Kartadinata, M. N., Budianto, A. and Sasongko, Y. (1998): Geological map of Guntur volcano, West Java, Volcanology Survey of Indonesia.

Syahbana, D. K., Suantika, G. and Solikhin, A. (2009): Earthquake Hazard Map Western Part of Java. Center for Volcanology and Geological Hazard Mitigation.

インドネシア・グントール火山以南の地震活動

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要　旨

グントールはインドネシア・西ジャワのバンドン市の南東35kmにある火山群である。19世紀半ばまで頻繁に山頂のグントール火口において爆発的噴火を繰り返してきたが，1943年の噴火を最後に160年以上噴火が発生していない。一方，火山性地震及び周辺の地震活動は活発であり，今後の火山活動を予測する上で地震活動は重要な指標となる．火山地質災害軽減センターが火山監視用に設置した観測点に加え，グントール火山周辺の8点に地震計を設置した。2009年1～3月まではグントール火山の南にあるチクライ山の東山麓で地震活動が活発であった。5月以降12月まではダラジャット地熱地帯における地震活動が活発となり，地震の震源は北西－南東方向の深さ2-9kmに配列することが分かった。

キーワード：グントール火山，長期火山噴火予知，火山構造性地震，局地地震