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The utilization of geothermal energy for the direct use in Mengeruda, Flores Island, Indonesia

Herry SUNDHORO[1], Sjafra DWIPA[1], Asnawir NASUTION[2], Hiroshi TAKAHASHI[3], Janes SIMANJUNTAK[1], Arif MUNANDAR[1] and Takehiro KOSEKI[3]

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Abstract: At least eight hot springs, and weakly altered rocks occur along the NE-SW trending fault as geothermal surface manifestations. Judging from the results from these surveys, it is considered that the geothermal system is probably *an out-flow type.* The constructed models of the Gou and Mengeruda geothermal areas also show that geothermal fluids seem to be an out-flow system. The purpose of this paper is to evaluate whether the Mengeruda prospect area is adequate for direct or indirect use in geothermal utilization. Using the results of geological, geochemical and geophysical surveys, Mengeruda is recommended for a direct use of geothermal energy. The direct use geothermal energy is drying agroindustrial products, hydrating and tourism.

1. Introduction

The Mengeruda geothermal area is situated about 10 km northeast of Bajawa, Ngada District, Flores Island, East Nusa Tenggara. The surveyed area covers about 10 km^2 and lies between 8°42'00" - 8°44'50" S latitude, and 121°3'30" - 121°07'00" E longitude (Fig. 1).

The installed electric power generated from diesel is used for domestic energy demand such as lighting, industry, harbour, transportation, hotel/restaurant, hospital, education and other uses. However, a small-scale geothermal power for electricity was being explored in Mataloko as the next alternative for energy demand. It is approximately 10 km south of the surveyed area.

This paper describes the result of geological, geochemical and geophysical surveys in Mengeruda. Judging from the result of these surveys, it is recommended whether the beneficial utilization geothermal energy is adequate for direct or indirect use for the people and local (district) government.

[1] Directorate of Mineral Resources Inventory. Jl. Soekarno-Hatta No.444, Bandung, 40254 Indonesia
[2] Directorate of Volcanology and Geological Hazard Mitigation. Jl. Diponegoro No.57, Bandung, 40122 Indonesia
[3] Mitsubishi Materials Natural Resources Development Corp., 3-21-1 Nihonbashi-Hamacho, Chuo, Tokyo, 103-0007 Japan

2. Surface manifestation and alteration

Thermal features in the Mengeruda geothermal area occur in the NE-SW trending faults, Mengeruda fault. Features include eight hot springs (Fig. 2) and weakly altered rocks. Hot springs have temperatures up to 42 ℃ and are mostly characterized by a high concentration of acid sulphate water that is a neutral discharge at the surface. The surface alteration of argillic type occurs in the vicinity of Wae Bana and Mengeruda hot springs.

3. Secondary data

All secondary data are adopted from the local government (Ngada dalam angka, 1996). Ngada district has population of about 211,000 people. The average rain fall in the Ngada district is a relatively low rate of 139 mm/year.

4. Evaluation from geology, water geochemistry and geophysical result

Flores Island is a part of the Banda Island arc, which comprises upper Cenozoic volcanic rocks with volcanogenic and carbonate sediments (Hamilton, 1979). The volcanic rocks are dominantly mafic to intermediate calc-alkaline composition, and unconformably underlain by the Tertiary rocks. The

Keywords: geothermal energy, direct use, geothermal exploration, Mengeruda, Bajawa, Inie Lika, Flores, Indonesia

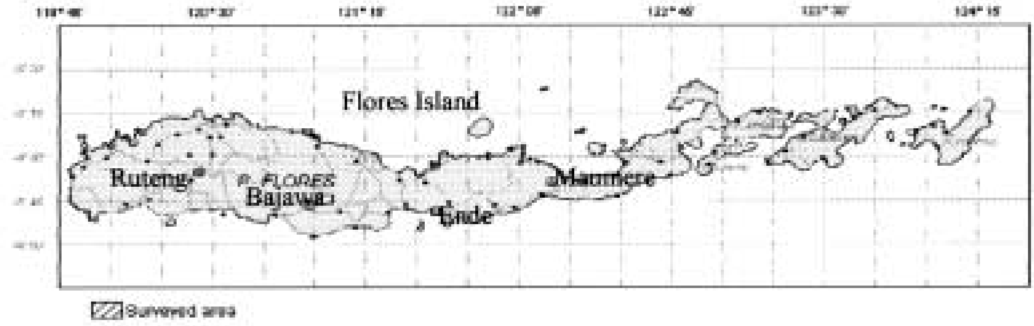

Fig. 1 Location of the surveyed area.

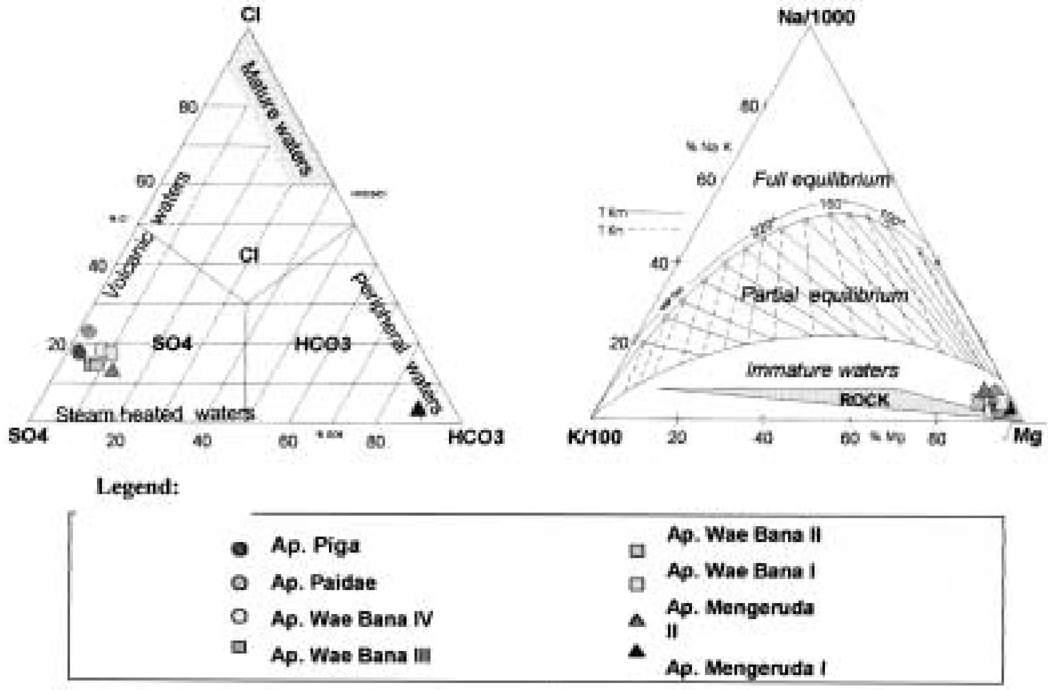

Fig. 2 Triangle diagrams of hot spring types in Mengeruda, Flores Island.

oldest rocks are Miocene sediments exposed at the Nangapanda village in the southern part of the island.

The stratigraphy of the area is similar with the Gou area. Rocks consist of volcanic and sedimentary rocks of Quaternary period. All these rocks are underlain by the basement of the Nangapanda Formation of the Tertiary period. The youngest rocks are derived from Mt. Inie Lika in the Gou area. It is approximately 8 - 10 km in the west of the surveyed area. The Quaternary volcanic rocks consist of Bajawa syn-caldera pyroclastic rock unit, lacustrine sedimentary rocks, Mt. Mataloko volcanic rock unit, Mt. Inie Lika lava, the secondarily reworked surficial deposit like lahar and alluvium. These volcanic rocks are dominantly andesite to basaltic andesite in composition, however there are dacitic-ryolitic rocks. These rocks belong to the Bajawa caldera pyroclastic rocks (syn-caldera rock unit). The secondary or surficial deposit is alluvial. The primary minerals present in the Quaternary volcanic rocks are mainly plagioclase, orthopyroxene, clinopyroxene and volcanic glasses.

Eight geothermal surface manifestations of hot springs, and weakly altered rock occur along the NE-SW trending faults. This trending fault is named Mengeruda fault. The flow rate of Wae Bana (Fig. 3) and Paidae hot springs are between 1 - 5 l/s, while Piga (Fig. 4) and Mengeruda hot springs (Fig. 5) are 100 - 500 l/ s, and the maximum surface temperature of the springs is only 42 ℃. All hot springs are acid sulphate water types except Paidae is a bicarbonate water type. Reservoir temperature calculated by a chemical geothermometer from the neutral Paidae hot spring is less than 138 ℃.

The highest contour value of mercury included in soil is only concentrated in the Mengeruda and Wae Bana surface manifestations. The maximum values

Fig. 3 Hot spring in Wae Bana River.

Fig. 5 Hot spring and hot pool in Mengeruda.

of mercury is only 128 ppb.

The low anomaly contour patterns (less than 5 Ωm) from resistivity of AB/2=1000 m are still open and continues to the western part (to Gou area). Eight hot springs have risen up to the surface along these structures: Piga, Mengeruda I, II, Wae Bana I, II, III, IV and Paidae which are controlled by the Mengeruda fault. All hot spring samples

Fig. 4 Hot spring in Piga.

have been analyzed, and divided into 2 types of hot spring water: an acid sulphate type group: Mengeruda I, II, Wae Bana I, II, III, IV, and a neutral type group: Paidae (Table 1 and Fig. 2).

Mercury soil contour patterns show that the highest value is only concentrated around hot springs. The maximum mercury is only 128 ppb. The highest anomaly contours of CO_2 in the soil air is also only concentrated around hot springs. It is only 0.1 %. Both anomalies of Hg and CO_2 are concentrated only in narrow areas. They are around the Mengeruda and Wae Bana hot springs. Geothermal fluids are leaked out from the NE-SW trending fault.

Resistivity data analyzed in Mengeruda show the contour patterns tend to open to the western area (to Gou and Mt. Inie Lika). The low anomaly of resistivity contours (≤ 5 Ωm) of AB/2=1000 m is only located and concentrated beneath the surface manifestation.

The estimation of the true resistivity beneath the Wae Bana - Mengeruda geothermal manifestation on line M-3 shows that the thickness of resistive layers belonging to Mt. Inie Lika lava is approxi-

Table 1 Chemistry data of hot springs in Mengeruda, Flores Island.

Constituents	Piga	Mengeruda I	Mengeruda II	W.Bana I	W.Bana II	W.Bana III	W.Bana IV	Paidae
pH	3.20	3.22	2.90	2.80	3.24	3.22	3.22	7.16
Cl^-	102.64	152.11	109.00	98.90	101.16	104.11	101.90	7.38
$SO_4^{=}$	585.17	631.42	644.00	631.00	566.81	558.00	640.97	16.53
B	6.08	0.61	1.03	0.71	2.43	2.13	2.13	0.10
SiO_2	82.77	84.38	135.00	134.00	77.95	77.14	81.70	112.60
Na^+	47.34	57.14	50.30	43.00	47.34	49.47	53.17	28.70
K^+	15.48	17.46	18.00	16.10	15.08	15.87	16.67	7.50
Li^+	1.55	1.50	0.03	0.03	1.36	1.45	1.73	0.70
Ca^{++}	102.40	89.60	110.00	118.00	132.80	96.00	92.80	45.00
Mg^{++}	27.84	28.80	34.90	35.50	8.64	22.08	26.88	16.50
HCO_3^-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	268.82
Fe^{+++}	19.92	17.58	17.30	13.60	10.35	14.06	14.70	0.00
NH_3	0.51	0.47	0.04	0.00	0.51	0.46	0.51	0.02
As	0.12	0.12	0.24	0.09	0.08	0.11	0.20	0.19
F	1.00	1.50	3.50	3.00	1.00	1.50	1.00	1.00
Conductivity μs/m	2000	1550	1750	1790	950	1150	1225	310

mately 25 - 50 m, and this layer is underlain by lacustrine sediments with a thickness about 50 - 150 m. A conductive layer below these rocks is probably the Bajawa caldera pyroclastic rocks. The thickness of Bajawa caldera pyroclastic rocks is probably 200 - 500 m, where the thick layer below the Bajawa caldera pyroclastic rocks is probably a Bajawa pre-caldera product with a resistivity between 15 - 17 Ωm. The Bajawa pre-caldera product could not be detected well (Fig. 6). The construction of the Gou and Mengeruda geothermal models shows that the Mengeruda geothermal fluids seem to be an out-flow system (Fig. 7).

5. Constituents of chemistry content

All acid sulphate hot water type group has relatively a higher concentration of chemistry content compared to the Paidae hot spring of neutral type group. These higher concentrations of chemical content are: Cl^-, SO_4^-, Na^+, Ka^+, Ca^{++}, Mg^{++} and Fe^{+++} (Table 1). These higher concentrations of chemical content from the acid sulphate hot-water type probably will be able to heal the body skin and is

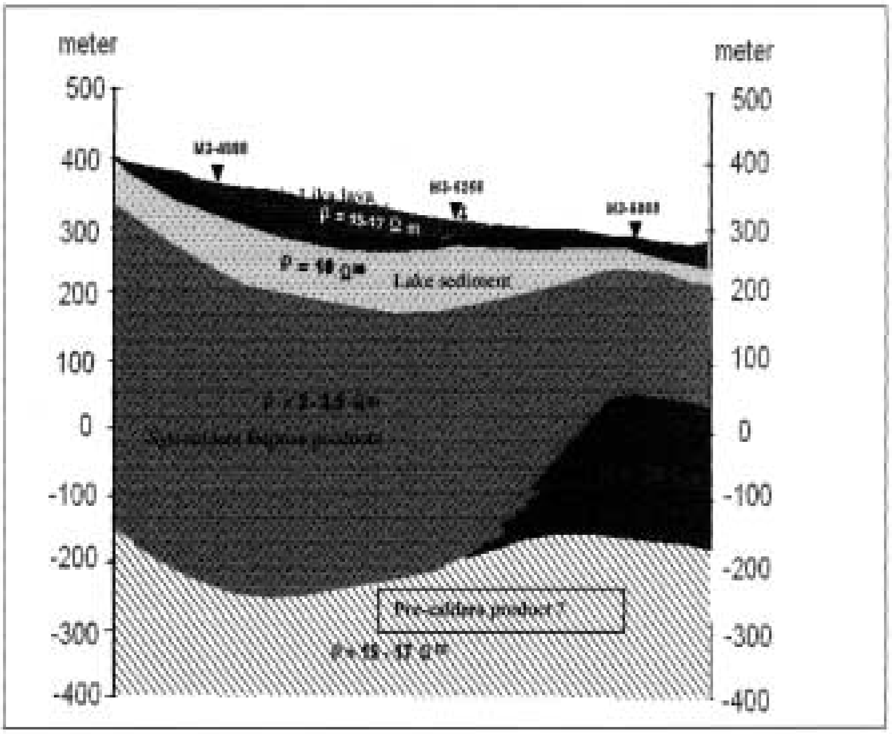

Fig. 6 Vertical section of real resistivity in line M3 in the vicinity of Mengeruda hot spring.

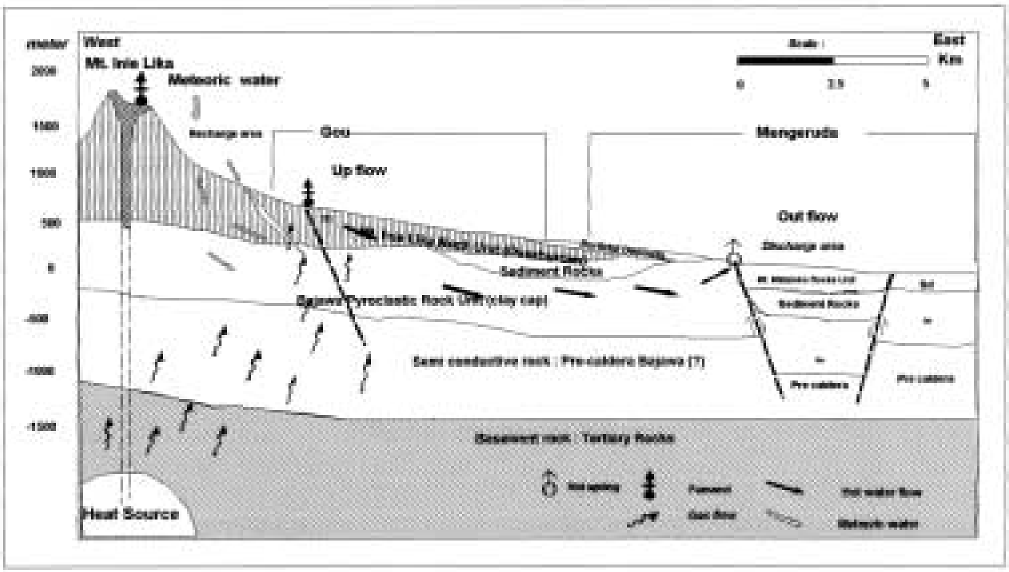

Fig. 7 Constructed geothermal model of Gou and Mengeruda, Flores Island, Indonesia.

useful for body therapeutic or curing.

6. Discussion and conclusions

Judging from the result of geological, geochemical and geophysical data in Mengeruda, it is considered that the Mengeruda geothermal fluid system is probably *an out-flow type.* This area is presumably better developed for a direct use of geothermal energy. The simplest and cheapest utilization of the direct use of geothermal energy is for swimming, bathing, tourism, and for relaxation, body therapy and body curing.

The higher concentration of chemical contents from acid sulphate hot-water type such as Cl^-, SO_4^-, Na^+, Ka^+, Ca^{++}, Mg^{++} and Fe^{+++} probably will heal the body skin and is useful for body therapeutics or curing.

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インドネシア，フローレス島メンゲルーダにおける地熱エネルギーの直接利用

Herry SUNDHORO・Sjafra DWIPA・Asnawir NASUTION・高橋　洋・
Janes SIMANJUNTAK・Arif MUNAMDAR・小関武宏

要　旨

本地域には北東－南西方向の断層に沿って，少なくとも 8 箇所の温泉と弱変質帯からなる地表地熱徴候が存在する．これらを調査した結果から，本地域の地熱系はアウトフロー型であると考えられる．ゴウおよびメンゲルーダ地熱地域について構築されたモデルもアウトフロー型の地熱系を示している．本論文の目的は，メンゲルーダ有望地域の地熱利用形態として直接利用と間接利用のいずれが適しているかを指摘することにある．地質学・地球化学・地球物理学探査の結果によれば，メンゲルーダの地熱エネルギーに対しては直接利用が推奨される．地熱エネルギーの直接利用は農産物の乾燥・加水および観光である．
（要旨翻訳：水垣桂子（地圏資源環境研究部門））