

Geothermal Activity of Yakedake Volcano, Gifu-Nagano and the Surroundings

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The geothermal energy within the summit dome at the altitude of 2,100 to 2,455 m of the Yakedake volcano is calculated to be about 2.5×10^{17} J, which represents a power output of 300 MW_{th} averaged over 30 yrs. The temperatures of solfatara in the northern summit dome at the altitude of 2,240 to 2,270 m range from 63.6 to 92.8° C as of Oct., 1989.

From an investigation of the thermal process in the volcano, it may be inferred that the direction of heat energy flow from the Yakedake volcano magma body will be coincident with that of water flow in the river system from the summit dome.

1. Introduction

The geothermal energy in the Yakedake volcano (alt.2,455 m), Gifu-Nagano, Japan is considered quantitatively. The thermal process in the volcano is also analyzed. A preliminary study of these problems has been performed by the present author (Iriyama, 1988; 1989). Yakedake has a crater lake, which is shown in Fig. 1. The hydrothermal activity is



Fig. 1 View of the crater and the lake of Yakedake from the northern crater-rim, in September, 1986.

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intense in the valleys at the western foot of the volcano and the Nakanoyu area. The hot water flow is discharged mainly from the Gamada River geothermal area (Iriyama, 1981).

The area under investigation is in a rugged section of the southern part of the Japan North Alps Mountains. Yakedake is a volcano with a lava dome, belonging to the Norikura volcanic zone. The fumaroles in the summit dome areas of Yakedake and the parasitic volcano, Iwodake are active.

2. Yakedake and Iwodake Summit Dome Areas

2.1. Yakedake

The author has measured the solfatara temperatures in the Yakedake and the Iwodake summit domes since Aug., 1981 and July, 1980 respectively using a thermistor thermometer with a precision of 0.1°C . The dome is made up of Quaternary biotite-bearing hornblende andesite (Iriyama et al., 1981). The solfatara are found within a dry valley from the crater-rim in the northern summit dome at the altitude of 2,240 to 2,270 m. Their localities and

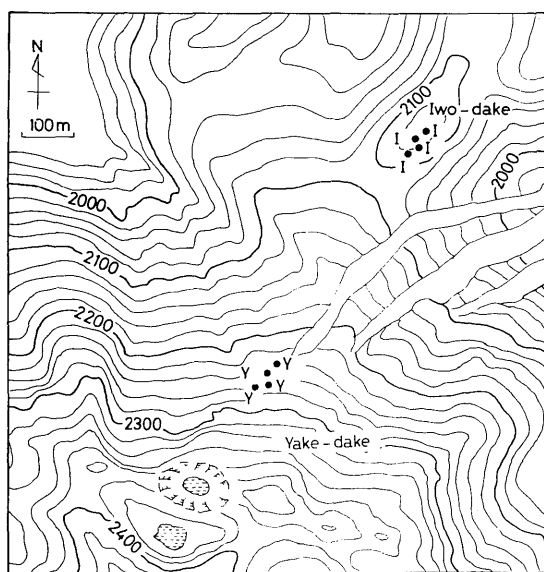


Fig. 2 Locality map of solfatara (Y) and fumaroles (I) studied in the summit dome areas of the Yakedake and the Iwodake volcanoes, respectively. Figures on contours indicate the altitude in meters above mean sea level.

general topography in the study area are shown in Fig. 2. There is a sublimation of sulfur around the solfatara, which is shown in Fig. 3.

Variation of measured temperatures of the solfatara with time since Aug., 1981 are listed in Table 1. The temperatures of six solfatara range from 63.6 to 92.8°C as of Oct., 1989. The boiling point of water at the altitude of 2,250 m is about 92.4°C . Taking into account the results of present temperature measurements and also those by Ossaka (1961) and Sugiura & Mizutani (1978), and also the high geothermal gradient of the volcano (e.g.,



Fig. 3 Photograph of a solfatara of the Yakedake summit lava dome, in September, 1987.

Table. 1 Measured temperatures ($^{\circ}\text{C}$) of the Yakedake's solfatara as a function of time.

Solfa	Oct.9, 1989	Oct.9, 1988	Sep.14, 1987	Sep.7, 1986	Aug.1, 1981
Y 1	77.2	80.2	79.3	77.5	87.5
Y 2	73.5	70.5	67.9	47.6	63.8
Y 3	92.8	92.6	92.7	92.6	80.8
Y 4	92.7	92.7	92.7	92.7	92.0
Y 5	66.9	70.8	60.5		
Y 6	63.6	66.9	68.8		

Yuhara and Iriyama, 1986), one can assume the temperature difference of $\delta T = 400$ deg between the inside and the outside of the dome at the altitude of 2,100 to 2,455 m. Given this temperature difference, for the specific heat and density of andesite, respectively, of $C_p = 1.1 \times 10^3 \text{ J/kg} \cdot ^{\circ}\text{C}$ and $\rho = 2.3 \times 10^3 \text{ kg/m}^3$ and the dome volume of $V = 2.5 \times 10^8 \text{ m}^3$, the geothermal energy G_t within the summit lava dome is calculated to be $2.5 \times 10^{17} \text{ J}$, which represents a power output of $300 \text{ MW}_{\text{th}}$ averaged over 30 yrs.

2.2. Iwodake

The summit lava dome is made up of Quaternary hornblende andesite (Iriyama et al., 1981). The locality map of fumaroles and general topography in the study area are shown in Fig. 2. Many fumaroles are found in the bottoms of the large stones on the southern dome at the altitude of 2,110 to 2,140 m. Some fumaroles appear in the small cylindrical holes on the ground, which is shown in Fig. 4. Mainly steam is discharged from these holes and apertures. Variations of measured temperatures of the fumaroles with time since Sept., 1986 are listed in Table 2. The temperatures of eleven fumaroles range from 40.3 to 64.7°C as of Oct., 1989.

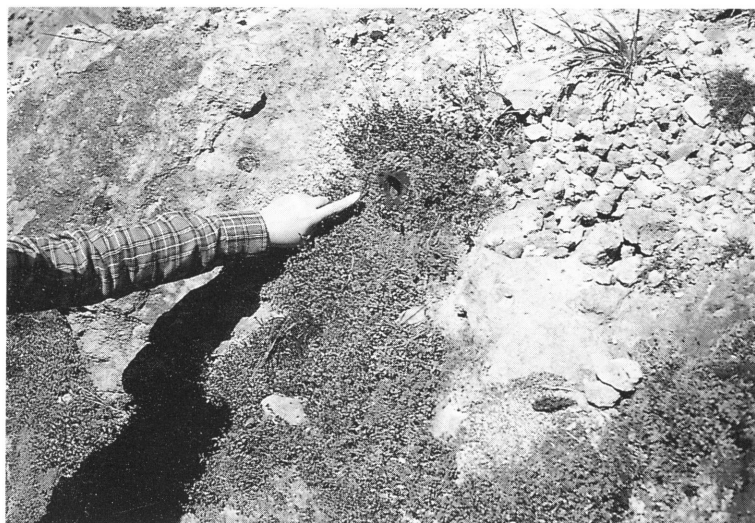


Fig. 4 Photograph of a fumarole of the small cylindrical hole type on the Iwodake summit dome, in September, 1987.

Table. 2 Measured temperatures ($^{\circ}\text{C}$) of the Iwodake's fumaroles as a function of time.

Fumar.	Oct.9,1989	Oct.10, 1988	Sep.14, 1987	Sep.8, 1986
I 1	46.4	47.1	48.6	45.4
I 2	47.9	51.8	52.8	
I 3	60.1	61.8	58.0	
I 4	59.4	61.2	59.2	56.4
I 5	59.8	61.0	56.3	54.8
I 6	40.3	42.8	40.1	39.2
I 7	60.3	62.5	61.9	57.8
I 8	64.7	59.0	65.4	
I 9	58.2	60.5	52.1	
I 10	61.2	62.1	60.0	58.5
I 11	62.6	63.5	62.5	

By assuming $\delta T = 300$ deg and $V = 2.5 \times 10^6 \text{ m}^3$, the geothermal energy G_t within the Iwodake summit dome at the altitude of 2,100 to 2,140 m becomes $1.9 \times 10^{15} \text{ J}$, which represents a power output of 2 MW_{th} over 30 yrs.

3. Geothermal Area

Gamada River

There are many hot springs, a geyser and at least one travertine terrace formed by the hot water flow along the Gamada River and the branch streams, i.e., the Shiramizu and the Ashiarai valleys on the northwestern foot of Mt. Yakedake. Their localities and general topography in the study area are shown in Fig. 5. The data indicate that the subsurface temperatures are high (Iriyama et al., 1989). Especially the temperatures of the shallow part are very high in the Karukaya area.

There was, formerly, an active boiling spring in the vicinity of Karukaya Hotel, which was called "Jigoku", i.e., Hell. The boiling spring was caused to disappear by thick sedimentation of mud and rock flows from the Yakedake volcano. However a geyser suddenly appeared when Yamano Hotel drilled a hole to obtain hot water, down to the depth of 101 m under the Karukaya area in Apr., 1987 whose locality is shown in Fig. 5. Iriyama and Iriyama (1987) named it Karukaya geyser. The eruption of steam and hot water from the geyser is shown in Fig. 6. The vertical temperature distribution in this geyser (alt. 920 m)

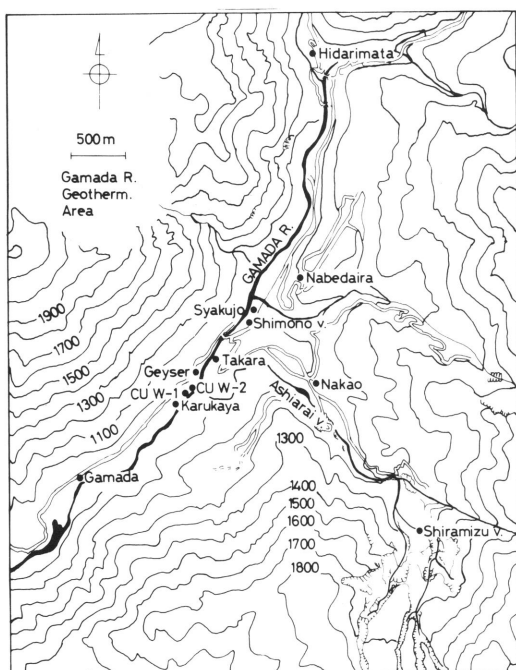


Fig. 5 Locality map of a self-flowing spring, a geyser and hot spring wells studied in the Gamada River geothermal area. Figures on contours indicate the altitude in meters above mean sea level.



Fig. 6 Karukaya geyser in the Gamada River geothermal area, in April, 1987.

is shown in Fig. 7. The temperature at the depth of 100 m was about 140° C at the time shown in this figure. The boiling point of water is about 96.8° C at the altitude of 920 m. The shut-in pressure amounts to 2.2 kg cm⁻² at the well-head during the eruption. On the other hand, the

flow pressure amounts to about 1.4 kg cm^{-2} . From the thermal data in boreholes CU (Chubu Univ.) W 1 and W 2 (well-1 & 2), and the Karukaya geyser, the mean thermal gradient at depths between 0 and 130 m in the Karukaya area is about $1 \sim 1.5^\circ \text{ C/m}$, which shows a very high value. From the lithology data of core samples in the boreholes CU-W 1 & W 2, the subsurface rock structure is made up of Quaternary andesite, very hard Mesozoic rhyolitic tuff and Paleozoic chert.

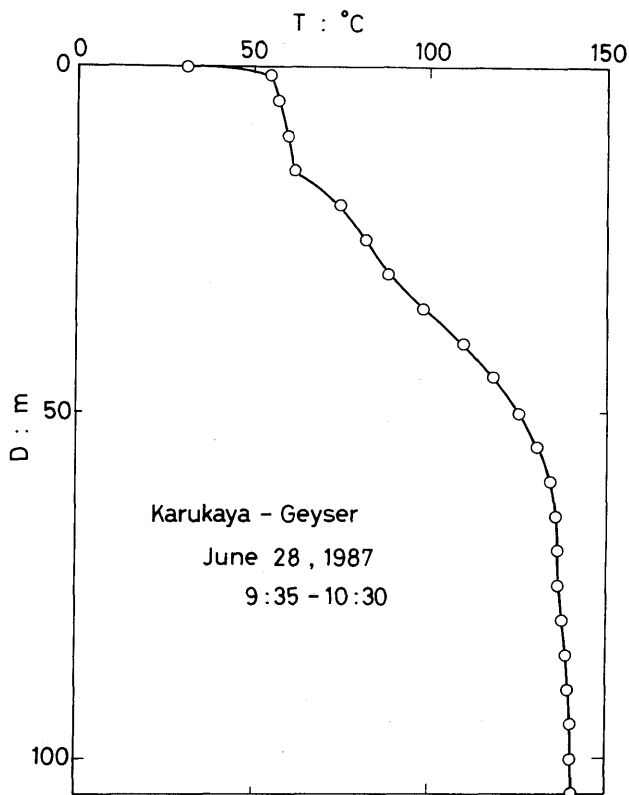


Fig. 7 Vertical temperature distribution in the Karukaya geyser.

4. Discussion

Calculating the heat power output in Section 2, a characteristic time interval of 30 yrs between consecutive eruptions within the summit lava dome was chosen. The latest records of the main eruptions that formed a new crater are as follows; 1962, 1935, and 1915, which supports this value. A big eruption will eject all materials from within the crater having a high heat energy (including the magma body). After the eruption the inside of the crater will cool down, but very soon its temperature will be raised again by ascending and newcoming magma.

There are several geothermal areas along the rivers at the western foot of the volcano and in the Nakanoyu area. The author has classified the geothermal areas according to the rivers (Iriyama, 1983). As shown in Fig. 5, the river system in the Gamada area is as follows; crater-rim (solfatara & fumaroles) → Shiramizu valley (self-flowing hot springs) →

Ashiarai valley (hot springs) → Gamada R. (geyser & hot springs). This shows that the geothermal area is located along and in the river system starting from the summit dome. This coincidence seems good between the other geothermal areas and the river systems of the volcano. From this viewpoint it may be inferred that the direction of heat energy flow from the magma body of the Yakedake volcano will be coincident with that of the water flow in the river system starting from the summit dome.

The author has made up a model of the hot water movement, which indicates that the magma heat along and in the crater and the dome is transferred to the foot of the volcano and that the direction of heat flow coincides with the water flow in the river system starting from the crater-rim. Because of the potential of hot water along and in the river has a low value in the rugged section of the Japan North Alps Mountains, the heat is concentrated in the domain beneath the river and the valley. Another possibility is that a magma body or a branch of the main magma might be located beneath the geothermal zone. In this case the lavas will flow out over the surface through a fissure and a fault and/or in the case of a high viscosity andesite lava will form a dome in the geothermal zone. However, to the author's knowledge, there are no indications of such geological phenomena in the river geothermal areas.

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