

Thermal Process of the Yakedake Volcano, Gifu - Nagano : Takahara and Azusa River Geothermal Zones

Jun IRIYAMA*

(Received May 31, 1991)

Penetration of meteoric water will be difficult in the Karukaya and Takara hot spring areas of the Gamada River geothermal zone, because of the existence of a massive mass of very hard and non-permeable Paleozoic chert and Mesozoic rhyolitic tuff in the underground. It suggests the presence of a hydrothermal system within Yakedake volcano and vicinity.

From the results of self-flowing hot springs, boreholes and fumaroles, the thermal process of the volcano and vicinity is analyzed. A model for the hydrothermal system within Yakedake volcano is also proposed.

INTRODUCTION

The study area is in a rugged section of the southern part of the Japan Northern Alps Mountains (Fig. 1). Yakedake (alt., 2,455m) is a volcano with a lava dome, belonging to the Mt. Norikura volcanic zone. The volcano has been in a dormant state since 1962. However the fumaroles in the summit dome areas of Yakedake and the parasitic volcano, Iwodake (alt., 2,140m) are active. The Yakedake dome is made up of a Quaternary biotite-bearing hornblende andesite (Iriyama et al., 1981) .

The hydrothermal activity is intense in the valleys at the western and southeastern feet of the volcano. There are many hot springs, a geyser and at least one travertine terrace by the hot water flow along the Gamada, Takahara and Azusa Rivers and the tributaries, i.e., the Ashiarai, Shiramizu, Abo and Shiratani valleys. The author has classified the geothermal zones according to the rivers (Iriyama, 1983). The hydrothermal system model of the volcano and the surroundings is proposed. The thermal process in the volcano is also analyzed. A preliminary study of those problems has been performed by the present author (Iriyama, 1981, 1983, 1988 a & b, 1989, 1990) .

GEOHERMAL AREA

Takahara River

There are many hot springs, i. e., the Hirayu, Fukuji, Ipposui and Hitoegane hot springs, alone

*Department of Natural Sciences

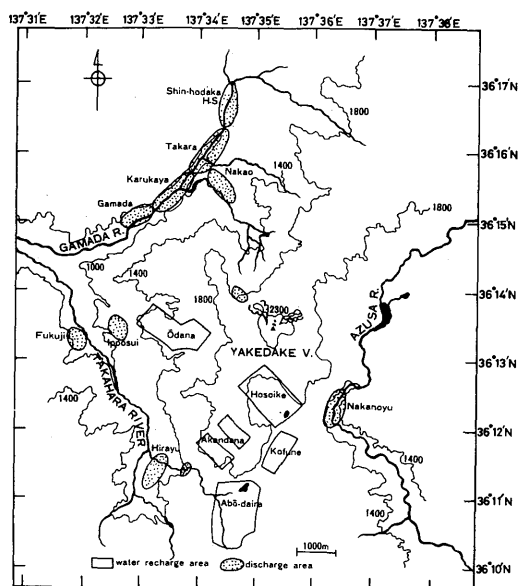


Fig. 1. Location map of water recharge area and hot water discharge area, and general topography in the study area. Contours indicate the altitude above sea level in meter.

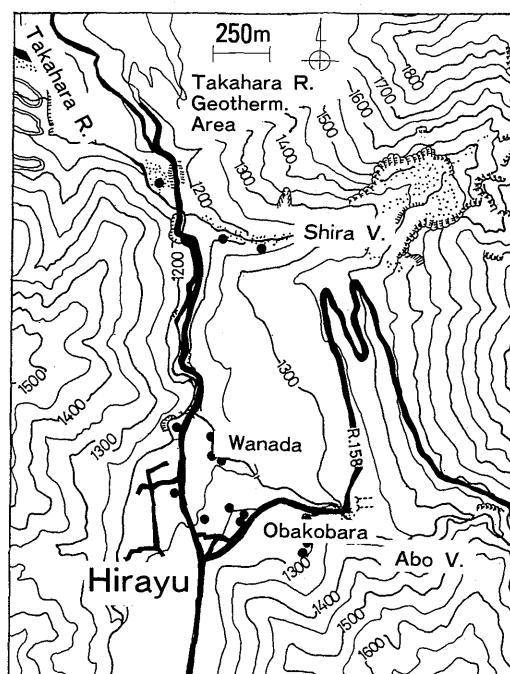


Fig. 2. Locality map of hot springs studied in Hirayu and the surrounding areas, Takahara River geothermal zone. Contours indicate the altitude above sea level in meter.

the Takahara River and the tributaries, i.e., the Abo and Shiratani valleys at the southwestern foot of Yakedake volcano. Their localities and general topography in the study area are shown in Fig. 2.

Thirteen samples of self-flowing spring waters from the Hirayu hot spring area and the surrounding areas were measured for temperature, pH, water discharge and electrical conductivity. The results of the measurement are listed in Table 1. The water sample from the Abodaira swamp

Table 1. Measured physicochemical data of the waters from the Hirayu hot spring area and the surrounding areas, Takahara River geothermal zone (Iriyama et al., 1990) .

Sample No.	Location	Alt. (m)	Temp. (°C)	pH	Flow (l/min)	E.C. (mS/cm)
1	Abodaira	1,600	6.80	6.00		0.080
2	Obakobara	1,290	60.0	8.03	10.	1.21
3	Shinanoji	1,270	27.5	6.44		0.48
4	Shirasagi	1,270	25.6	6.30		
5	Shinanoji-soba	1,260	29.1	6.45		
6	Okadakan	1,260	27.1	6.55		0.48
7	Megusuri	1,230	25.2	6.72		0.54
8	Wanada #1	1,220	46.7			
9	Wanada #2	1,220	56.7	6.23		1.14
10	Wanada #3	1,210	34.8	8.02	30.	0.79
11	Shiratani #2	1,190	43.1	6.42	12.	1.07
12	Yamabushi	1,190	42.3	6.10		0.97
13	Ikeda #2	1,160	48.6	6.55		

(alt., 1,600m), which is a notable source of water supply toward the Hirayu hot spring, showed for pH, electrical conductivity (EC) and temperature values 6.0, 0.080mS / cm and 6.8 °C (12 : 05 ; July 8, 1990), respectively. The Shinanoji water (alt., 1,270m) in the Hirayu hot spring showed for pH, EC and temperature 6.4, 0.48mS / cm and 27.5 °C, respectively. The Megusuri water (alt., 1,230m) in the Hirayu spring showed for pH, 6.7 ; for EC, 0.54mS / cm and for temperature, 25.2 °C. The Wanada # 2 water (alt., 1,220m) showed for pH, 6.2 ; for EC, 1.1mS / cm and for temperature, 56.7 °C . The water sample from the Yamabushi spring (alt., 1,190m ; Fig. 3) located down the Abo valley showed for pH, 6.1 ; for EC, 0.97mS / cm and for temperature, 42.3 °C .



Fig. 3. Self-flowing hot spring of Yamabushi in the Hirayu area.



Fig. 4. Self-flowing hot spring of the Shiratani # 2 well in the Shiratani valley.

The water sample from the Shiratani # 2 well (alt., 1,190m) , which is welling due to many bubbles of CO₂(Fig. 4), showed for pH, 6.4; for EC, 1.1mS / cm and for temperature, 43.1 °C . As is shown in Fig. 5 the vertical temperature in the Shiratani # 2 well was a constant i.e., 43.1 °C ,

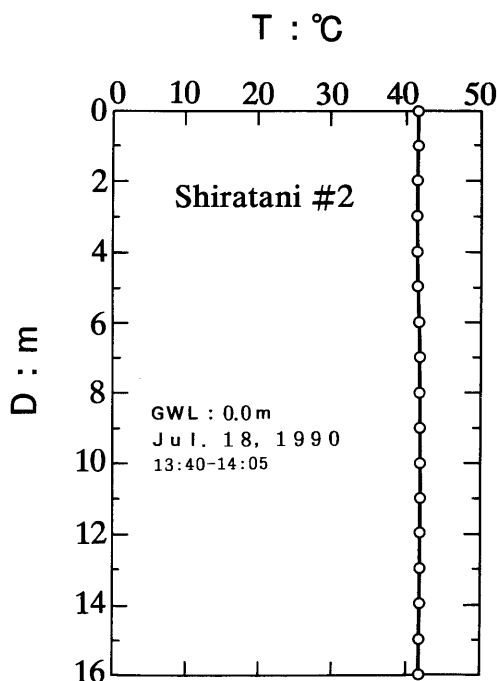


Fig. 5. Vertical distribution of temperature in the Shiratani # 2 well, Takahara River geothermal zone.

because of the water ascending very quickly from the bottom of well to the ground-surface due to the gas bubbles. It seems that this hot water in the Shiratani valley is of Mt. Shiratani origin inferred from the river system and topography. The vertical temperature distribution in the Nobata well is shown in Fig. 6. The temperature of air at the depth of 0 to 28m and that of water at the depth of 28 to 90m are indicated in this figure. There was a rapid increase of temperature at the depth of 70 to 90m. The temperature gradient in the stratum was about 3.5 °C / m, which is a very high value. In spite of the fact that Obakobara hot spring (alt., 1,290m) is located in relatively low altitude at the foot of the volcano, it is ejecting a steam from the fracture of Paleozoic slate (Fig. 7).

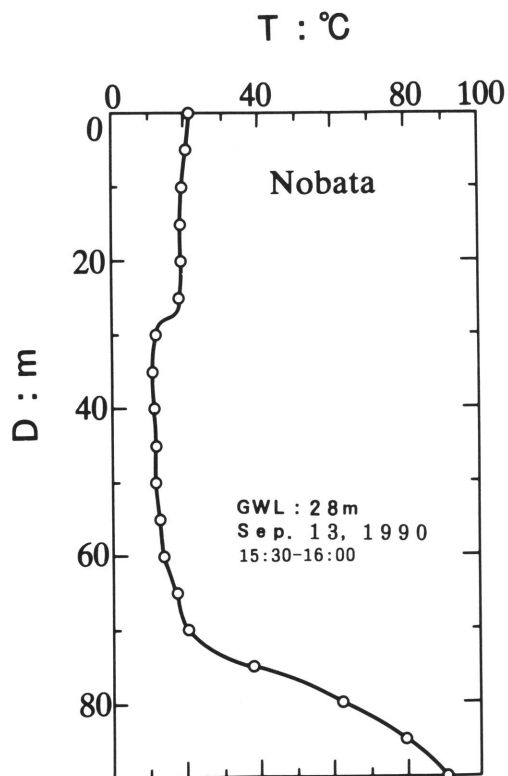


Fig. 6. Vertical distribution of temperature in the Nobata well, Takahara River geothermal zone.



Fig. 7. Self-flowing hot spring of Obakobara in the Hirayu area.

Azusa River

The Azusa River geothermal zone extends about 2,500m from nearby the Kama tunnel, through the Nakanoyu hot spring, to the Sakamaki hot spring along the river. The present study area is located at the southeastern foot of Yakedake volcano. The hydrothermal activity is intense in the Azusa River (Fig. 8) and on the mountainsides along the National Road Route 158. The localities of the self-flowing hot waters, surface temperatures and general topography in the study area are shown in Fig. 9. The numerical value shown nearby the marks of black circle and double circle in this figure indicates the measured temperature of the water and the surface of rock. Contours in this figure indicate the altitude above sea level in meter. The temperatures were measured by thermistor and infrared thermometers, which ranged from 26 °C to 92 °C (Iriyama, 1983) . The highest temperature was observed at the mountainside (alt., 1,300m) in the vicinity of the Nakanoyu-Spa. The boiling point of water at the altitude of 1,300m is 95.5 °C .

The hot waters gushes mainly at the mountainside of Yakedake volcano of the right bank of the Azusa River. It is noted that the coincidence between the landslides and the hot water gushing places is fairly good as shown in Fig. 9. For N1 spot shown in this figure at the altitude of 1,330m, the pH value and temperature of the water sample were 6.2 and 42.3 °C , respectively. For N2 spot (alt., 1,310m), the pH value, temperature and discharge of the water were 6.7, 50.1 °C and 60 l / min, respectively. For N3 spot (alt., 1,260m) , the temperature and discharge of the water were 54.7 °C and 24 l / min, respectively (Iriyama, 1983) .



Fig. 8. Self-flowing hot spring of Nakanoyu in the Azusa River.

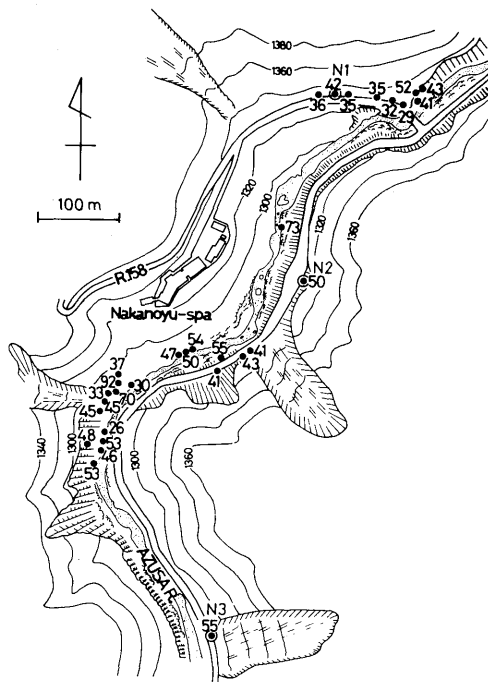


Fig. 9. Locality map of self-flowing hot springs, and the surface temperatures in the Nakanoyu area, Azusa River geothermal zone. Contours indicate the altitude above sea level.

DISCUSSION

Heat Process

Penetration of meteoric water will be difficult in the Karukaya and Takara hot spring areas (see Fig. 1) of the Gamada River geothermal zone, because of the existence of a massive mass of very hard and non-permeable Paleozoic chert and Mesozoic rhyolitic tuff (Iriyama et al., 1981) in the underground. It suggests the presence of a hydrothermal system within Yakedake volcano and vicinity.

In the hot spring area (discharge zone) the hot water flow amounts to 2.16×10^4 l/min (Table 2). On the other hand, in the study area, there are some large basins which the rocks are mainly tuff breccia and volcanic products showing very high permeability for water. The author has considered them to be the cold water absorption zone of the hydrothermal system (Table 2 & Fig. 1; Iriyama, 1981). The total cold recharge area amounts to 18.2×10^6 m² (Table 2). Therefore the mean cold water absorption rate in the recharge area comes out to be 1.2×10^{-3} mm/min. The meteoric water that permeates through the basins is heated at depths by the thermal energy from the magma body and afterwards it ascends through a fracture zone and discharges as a natural hot

Table 2. Hydrothermal water balance of Yakedake volcano.

A. Hot spring water volume(discharge area ; high-temperature zone)		
(1) Gamada River geothermal zone	=	11,700 l/min
(2) Takahara River geothermal zone	=	8,800 l/min
(3) Azusa River geothermal zone	=	1,100 l/min
Total hot spring water volume, A	=	2.16×10^4 l/min
B. Water recharge area(low-temperature zone)		
(1) Abodaira area	=	7.88×10^6 m ²
(2) Hosoike and Akandana areas	=	5.48×10^6 m ²
(3) Kofune area	=	2.80×10^6 m ²
(4) Odana area	=	2.00×10^6 m ²
Total water recharge area, B	=	18.2×10^6 m ²
C. Mean water absorption rate		
D. Precipitation	=	1.2×10^{-3} mm/min
Observed value	=	2,900 mm/yr(Hirayu and Kamikochi)
Σ hot spring water/ Σ precipitation	=	0.22

spring on the ground-surface. The hydrothermal water balance of Yakedake volcano and vicinity is given in Table 2. The mean precipitation at the Hirayu and Kamikochi meteorological stations is observed to be 2,900 mm/yr in the study area (e. g., Yuhara & Ogawa, 1974). Adopting this precipitation value in the present model, the ratio of the total hot spring water volume to the total precipitation in the recharge area of the volcano becomes 0.22. From the comparison of this ratio with those measured in various hot spring areas of the world (0.05 - 0.5 ; Yuhara & Seno, 1977), it will be concluded that the present hydrothermal system model of Yakedake volcano is a reasonable one (Iriyama, 1981).

Small hydrothermal systems are also found in the limited geothermal areas of the volcano. The hydrothermal system in the Hirayu hot spring area and the surrounding areas will be summarized from the present study as follows. The water from the Abodaira swamp (Fig. 10) has the property of meteoric water and shows a minimum value for both of pH and EC (Table 1). As the water permeates under the ground in the Hirayu area, it is subjected to physico-chemical reaction in a deep zone, and then pH, EC and temperature values turn into the high values (Table 1).

On the other hand, there is a heat energy flow from the summit dome of the volcano to the foot (Iriyama, 1990). 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). It shows that the geothermal area is located along and in the river system starting from the summit dome. This relationship between heat- and water-flows in



Fig. 10. View of the Abodaira swamp, Yakedake volcano.

this area is also found in the Azusa and Takehara River geothermal zones (Iriyama, 1990). From this it may be inferred that the direction of heat energy flow from the Yakedake volcano magma body will be coincident with that of the water flow in the river system starting from the summit dome.

Geochemical Speculation

Water samples from N1 and N2 spots were mainly composed of NaCl in the total residue. This suggests that the study area along the Azusa River was under a sea or a salt lake in ancient times.

ACKNOWLEDGEMENTS

I would I like to thank to Prof. Masahiro Ito (Nagoya Univ.) for his valuable comments. I also acknowledge to Messrs. Shigenobu Sekiyama, Hiroshi Shibamoto and Masayuki Hamada for their assistance on field observation.

REFERENCES

- Iriyama, J., 1981. Thermal structure of the Yakedake volcano, Japan : Karukaya and Takara geothermal areas. *Jour. Volcanol. Geotherm. Res.*, 10 : 299 - 308.
- Iriyama, J., 1983. Exploration and development of geothermal energy : A case study of the Yakedake volcano, Gifu-Nagano. I.F. Report (Ishida Foundation pub.), No. 10, pp.196 - 202.
- Iriyama, J., 1988a. Geothermal energy of the Yakedake volcano, Japan. *Proc. Kagoshima Int. Conf. on Volcanoes 1988* (Kagoshima pref. pub.), pp. 871 - 874.
- Iriyama, J., 1988b. Thermal process and geothermal energy in and around the Yakedake volcano, Gifu-Nagano, Japan. *Proc. Int. Symp. on Geothermal energy, 1988* (Geotherm. Res. Soc. Jpn. pub.) . pp. 102 - 103.
- Iriyama, J., 1989. Exploration and development of geothermal energy in the Yakedake volcano, Japan : Thermal process and assessment of geothermal resources in the summit dome areas and Gamada River geothermal area. I. F. Report (Ishida Foundation pub.), No. 16, pp.482 - 487.
- Iriyama, J., 1990. Geothermal process and energy of the Yakedake volcano, Gifu-Nagano, Japan. *Geotherm. Resources Council Trans.*, 14 : 1483 - 1488.
- Iriyama, J., Suzuki, K., Yamada, T., Kobayashi, Y. and Saito, T., 1981. Thermal structure of the Yakedake volcano, Gifu-Nagano. *Geotherm. Res. Soc. Jpn. 1981 Ann. Meeting, Abstr.*, p. 20.
- Iriyama, J., Uchiyama, H., Sekiyama, S. and Shibamoto, H., 1990. Thermal structure of the Takahara River geothermal zone, Yakedake volcano. *Geotherm. Res. Soc. Jpn. 1990 Ann. Meeting, Abstr.*, P5.
- Yuhara, K. and Ogawa, I., 1974. Geothermal survey in the Abo area where a long tunnel is planned. *Geophys. Explor.*, 27 : 1 - 14.
- Yuhara, K. and Seno, K. 1977. Hot and Mineral springs. Chijin-Shokan, Tokyo.