Sci. Rep. Kanazawa Univ.,
Vol. 16 No. 1, pp 61-72
June 1971

Terrestrial Heat Flow in Hokuriku District, Central Japan

Yoshiteru KONO and Yoji KOBAYASHI

Department of Earth Sciences, Faculty of Science.
Kanazawa University

(Received 31, May, 1971)

ABSTRACT Terrestrial heat flow values at 16 stations in Hokuriku district are estimated from observed temperature distribution in boreholes and thermal conductivity of rock samples.

The results indicate that terrestrial heat flow in Hokuriku district is generally high and an average is 2.85×10^{-6} cal/cm^2. sec.

Introduction

The data on the terrestrial heat flow in Hokuriku district, Central Japan, have been scarce. In their pioneering works on the heat flow in the Japanese Islands, UYEDA and HORAI (1964) and HORAI (1964) gave two data, at Nakatatsu and Kamioka mines.

In order to discuss the genesis of heat flow anomaly, we need the data at stations with the intervals of 30 km (crustal thickness) or less, so the data at hand are too scarce for such a purpose that we have started to critically compile the heat flow data in this district. The following is a preliminary report along this line.

Acknowlegements

Data of temperature profiles and lithological columnar sections were kindly offered from Dr. Dairoku Saito in Hot Spring Research Association of Ishikawa Prefecture (Ishikawa-ken-Onsen-Kaihatsu-Kenkyu-Kyokai), Dr Torao Otsuka in Nagoya Branch of Geological Survey of Japan, and the president Hichihei Ishiguro of Spa Kintaro, Uozu, Toyama Prefecture. We would like to express our sincere thanks for their courtesy and kind advices.

We also thanks to Professor Yoshio Kaseno for his valuable advices on geology of this field and assistance in sampling of rock specimens.

This work has been supported by the Scientific Research Fund of the Ministry of Education.

Stations

We could collect the data at 16 stations in Hokuriku district. They belong to Fukui, Ishikawa, and Toyama Prefectures, and Fig. 1 and Appendix show their locations, and Table 1 includes the descriptions of individual sites. Detailed boring sites, werever available, are shown in Fig. 4 and 6. They are all bore-holes, whose depths range from 200 to 800 m. More data were collected, but they were not suitable to discuss the terrestrial heat flow, mainly because they are shallower than 200 m.

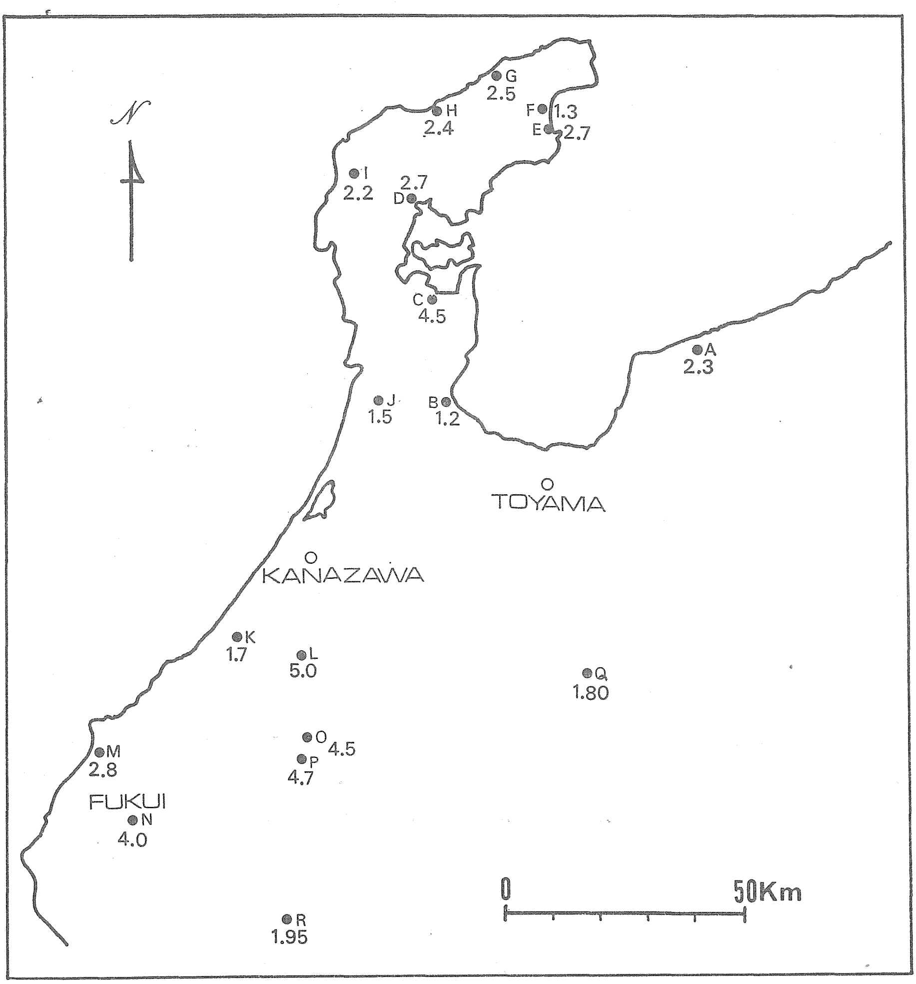

Fig. 1 Index map to Table 1 and distribution of terrestrial heat flow obtained from the present study. Data at Kamioka and Nakatatsu mine (UYEDA and HORAI, 1963) are also plotted for reference.

Table 1 Index, boring depth, temperature gradient, thermal conductivity and terrestrial heat flow at the individual stations.

Locality	Boring Depth (m)	Main rock type	$\Delta T/\Delta Z$ (°C/100m)	K (cal/cm. sec. deg.)	Qs (cal/cm². sec.)	Ref.+
A Uozu	800	T.* Sandstone	5.2	4.5×10^{-3}	2.34×10^{-6}	KIN
B Himi	800	T. Shale	7.35	1.64	1.20	GSJ
C Nanao	600	T. Andestic tuff breccia	9.9	4.50	4.45	GSJ
D Anamizu	500	T. Andesitic breccia	4.75	4.50	2.14	OKK
E Koiji	400	T. Andesitic tuff breccia	6.1	4.50	2.74	OKK
F Ukai	400	T. Diatomite	7.9	1.64	1.30	OKK
G Maura	250	T. Dacitic tuff	5.18	4.81	2.49	OKK
H Nebuta	330	T. Andesitic tuff breccia	5.4	4.50	2.43	OKK
I Monzen	200	T. Rhyolitic tuff	4.6	4.81	2.21	OKK
J Shio	300	T. Tuff breccia	3.26	4.50	1.47	OKK
K Komatsu	300	T. Rhyolitic tuff	2.0	8.38	1.68	OKK
L Tedori	400	Rhyolite	8.38	6.0	5.03	OKK
M Mikuni	150	T. Andesitic tuff	5.3	4.81	2.82	OKK
N Fukui	200	T. Andesite	8.33	4.81	4.00	TSUKANO & SASAJIMA (1965)
O Kuwajima	170	Mesozoic Sandstone	6.5	6.96	4.52	BESSHO & FUJI (1967)
P Shiramine	280	Mesozoic Sandstone	6.8	6.96	4.73	id.
Q Kamioka	388	Palaeozoic gneiss	2.77	6.49	1.80	UYEDA & HORAI (1963)
R Nakatatsu	180	Mesozoic skarn	2.90	6.71	1.95	id.

* T. means Tertiary.

+ Ref. represents data sources of temperature distribution : KIN is Spa Kintaro, GSJ is Nagoya Branch of Geologicbl Survey of Japan, OKK is Onsen-Kaihatsu-Kenkyu-Kyokai of Ishikawa Prefecture.

Temperature gradients

Temperature data in the bore-holes were available through the courtesy of Nagoya Branch of Geological Survey of Japan, Hot Spring Res. Assoc. of Ishikawa Prefecture, and Spa Kintaro. The data ontocations N,O, and P were read from the description of bore-holes (TSHUKANO and SASAJIMA, 1965; BESSHO and FUJI, 1967). Fourteen holes were drilled to search hot springs and two were for natural gas fields. Temperature distribution and lithological columnar sections of these holes are illustrated in Fig. 3 to 8.

Temperature gradients are read carefully from these graphs, and they are summarized in Table 1 as $\Delta T/\Delta Z$.

Temperature was measured just or a few days after the completion of a bore-hole. Generally, reliable temperature gradients can be obtained one month or more after the completion of the drilling. Therfore, our data measured soon after the drilling may represnt minimum gradients at the individual stations, but still they are significantly high as compared to the general heat flow values in and around the Japanese Islands.

Thermal conductivity

The thermal conductivity of the rocks was measured on the specimens from the drilling sites. Samples were collected from the drill-cores so far as available, and those from surface out crops were collected for the stations, from where core-samples were not available. The thermal conductivity of these samples was measured by a divided-bar, steady-state method on water-saturated samples as described by KONO *et al.* (1969). Results are shown in Table 1 as an average of two or three measurements.

Terrestrial heat flow

Terrrestrial heat flow Qs is calculated foom a formula

$$Qs = K \cdot \Delta T/\Delta Z. \qquad (1)$$

where K is the thermal conductivity and $\Delta T/\Delta Z$ is the temperature gradient. The results are given in Table 1 and are plotted in Fig. 1. These values represent possible minimum Qs as mentioned previously. An arithmetic mean of the present 16 data is 2.85×10^{-6} cal/cm^2. sec., and is higher than the world average of 1.5×10^{-6} cal/cm^2. sec.

Discussion

The distribution of terrestrial heat flow values on the Japanese islands and the bottom of the Japan sea (YASUI, KISHII, WATANABE and UYEDA, 1966), and mean heat flow value in Hokuriku district obtained here are shown in Fig. 2. The present data are concordant with the general tendency of heat flow distribution obtained hitherto. Correlation between the distributions of Neogene volcanics and present heat flow cannot be detected.

The present heat flow data are mainly based on the hot-spring drillings except localities B and C, which are drilled for natural gas exploitation. Thus these data could be biased for high heat flow. The data for natural gas holes, however, also show high heat flow, comparable to more or less thermally stable mining areas such as Kamioka and Nakatatsu (UYEDA and HORAI, 1963). Furthermore, it is necessary to notice that almost of these drilled holes have not been used for hot spring sources. Therefore, there is a distinct regional tendency that Hokuriku district is a high heat flow terrain, whose terrestrial heat flow is comparable or slightly higher than the neighbouring regions such as the Japan Sea to the north and the Palaeozoic to Mesozoic terrains to the south.

Overall high heat flow in a region from Hokuriku district to the Japan Sea is concordant with the thermal regime as postulated by SHIMAZU and KONO (1969).

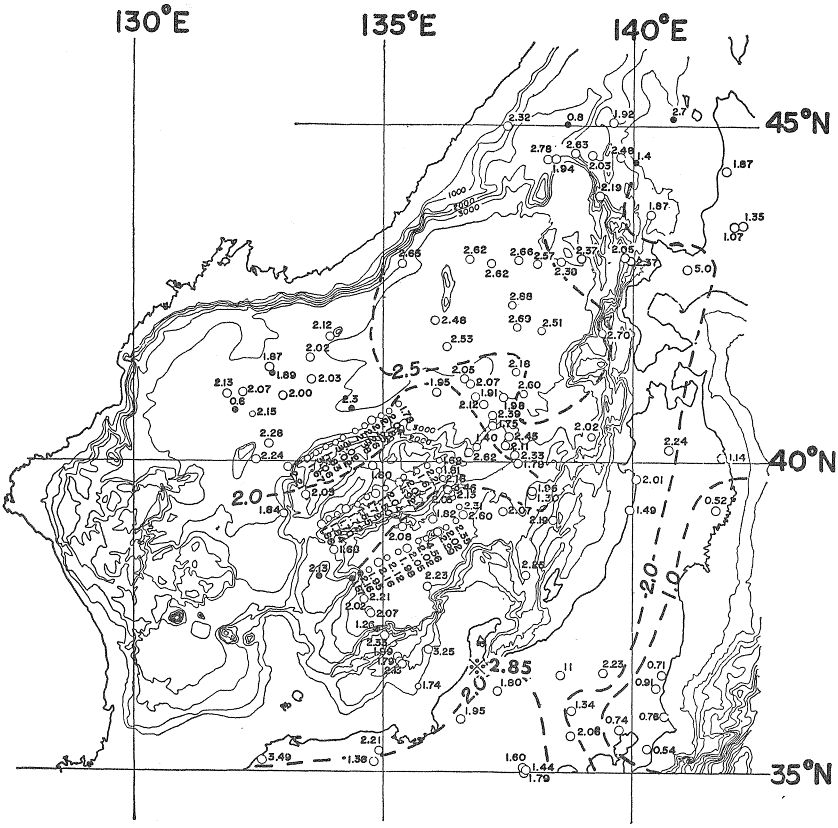

Fig. 2 Distribution of terrestrial heat flow in a region from the Japanese islands to the Japan Sea (YASUI *et al.*, 1966). An asterisk on the Noto peninsula represents an average of the data obtained here.

References

BESSHO, B., and N. FUJI, 1967, Geology and geothermal exploitation of the upper stream of Tetori River in Central Japan (in Japanese with English abstract). *Bull. Fac. Education, Kanazawa Univ.*, No. 16, Nat. Sci., 107–117.

HORAI, K., 1964, Studies of the thermal state of the Earth. The 13th paper : Terrestrial heat flow in Japan. (A summary of the terrestrial heat flow measurement in Japan up to December, 1962). *Bull. Earthq. Res. Inst.*, Vol. **42**, 93–132.

KONO, Y., K. NAKAGAWA, O. HASUKAWA, and H. YASHIKI, 1969, Physical properties and palaeomagnetic studies of andesite at the Noto Peninsula, Japan (in Japanese with English abstract). *Earth Sci. (Chikyu-Kagaku)*, Vol. **23**, 243–251.

SHIMAZU, Y., and Y. KONO, 1969, Surface heat flow and thermal state of the Japanese Islands area (in Japanese with English abstract). *Zisin (Jour. Seismol. Soc. Japan)*, II, Vol. **22**, 121–130.

TSUKANO, Z., and S. SASAJIMA, 1965, An example of the exploitation of a spring, with reference to the Spa Amasugo, Fukui city (in Japanese with English abstract). *Mem. Fac. Lib. Arts, Fukui Univ., Ser. II; Nat. Sci.*, No. 14, Part 6, 117–147.

UYEDA, S., and K. HORAI, 1963, Studies of the thermal state of the Earth. The eighth paper :

Terrestrial heat flow measurements in Kanto and Chubu districts, Japan. *Bull. Earthq. Res. Inst.*, Vol. 41, 83–107.

………… and …………, 1964, Terrestrial heat flow in Japan. *J. Geophys. Res.*, 69, 2121–2141.

YASUI, M., T. KISHII, T. WATANABE, and S. UYEDA, 1966, Studies of the thermal state of the Earth. The 18th paper : Terrestrial heat flow in the Japan Sea (2). *Bull. Earthq. Res. Inst.*, Vol. 44, 1501–1518.

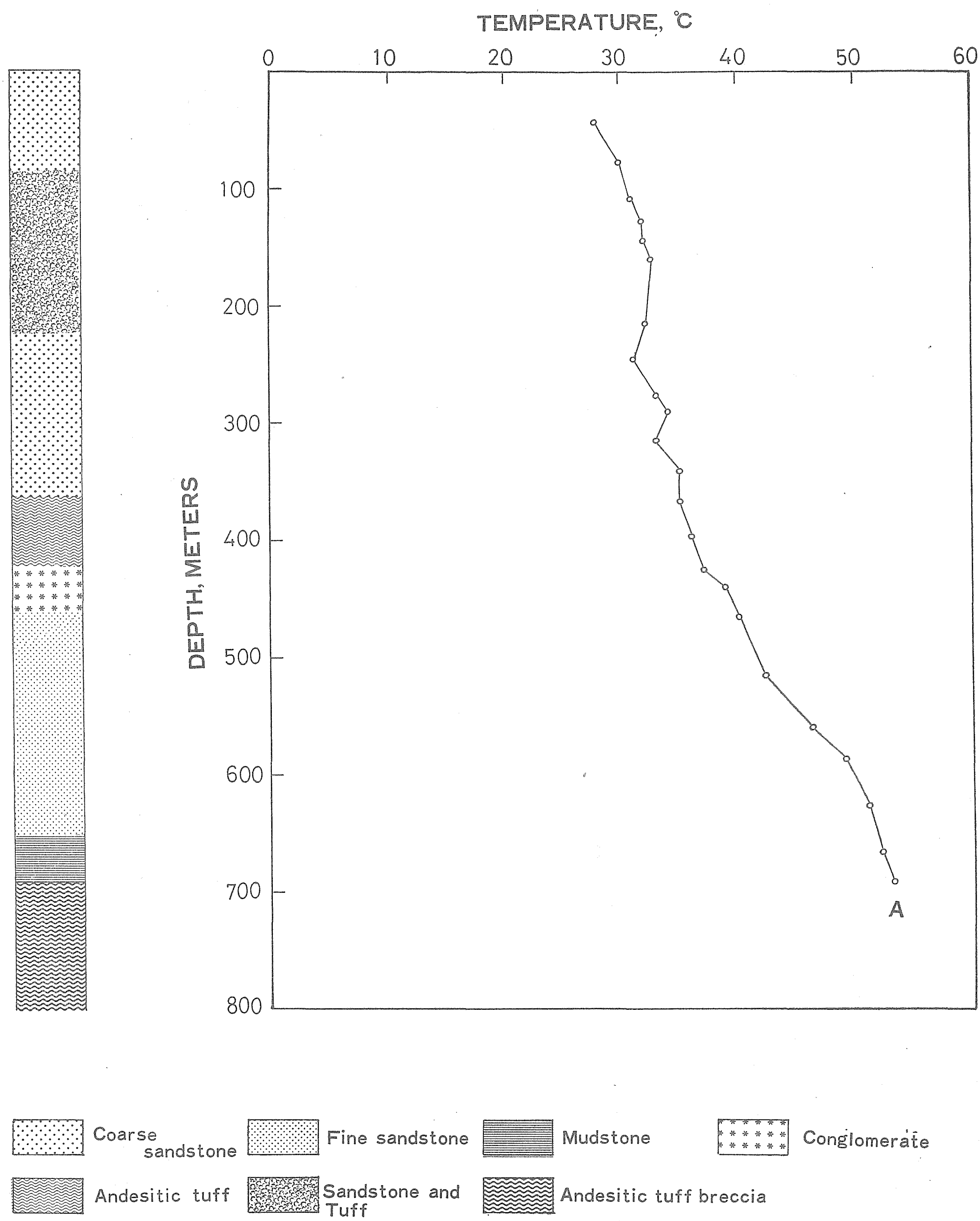

Fig. 3 Temperature distribution and lithological columnar section at Uozu.

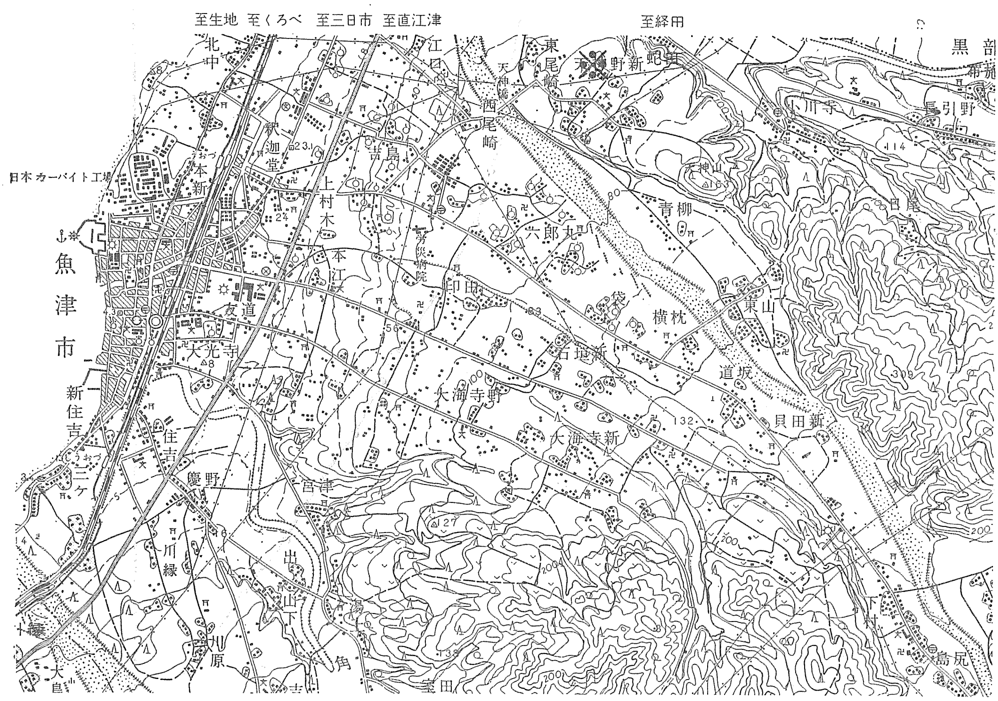

Fig 4 Location map of boring site at Uozu (1/50,000 map of Uozu).

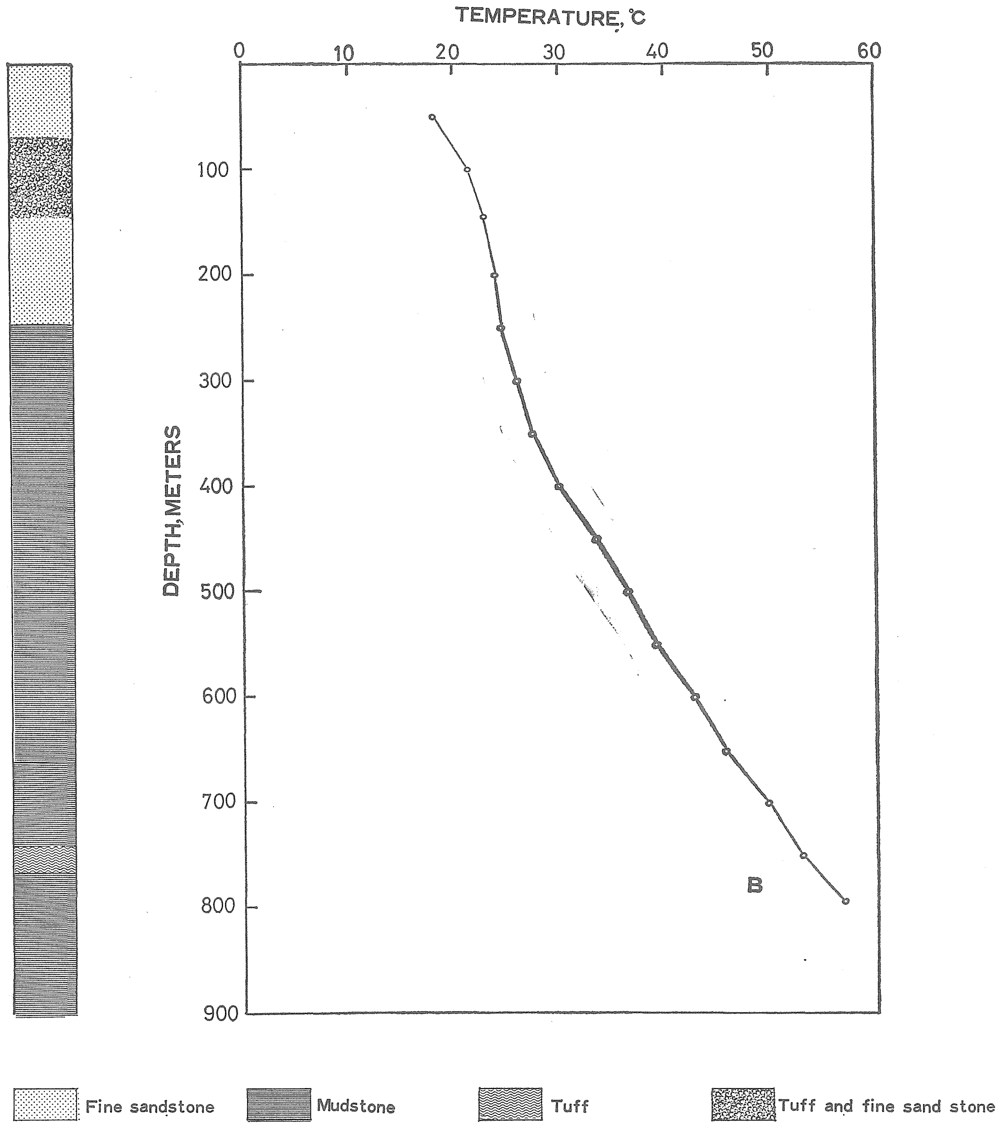

Fig. 5 Temperature distribution and lithological columnar section at Himi.

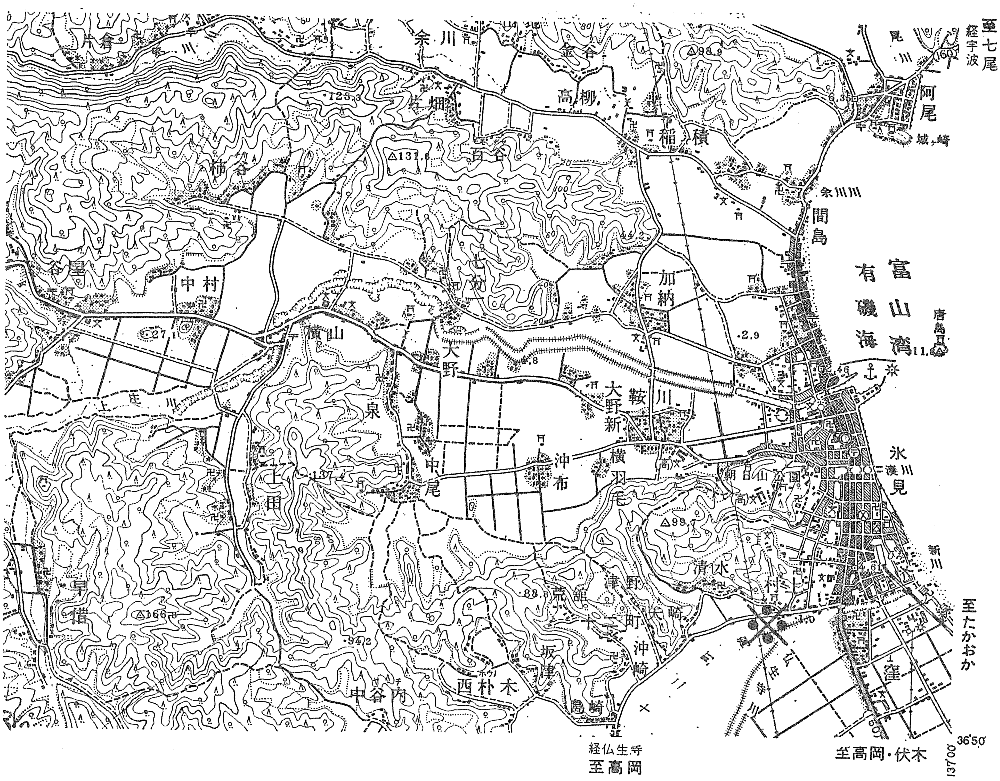

Fig. 6 Location map of boring site at Himi (1/50,000 map of Ōchigata).

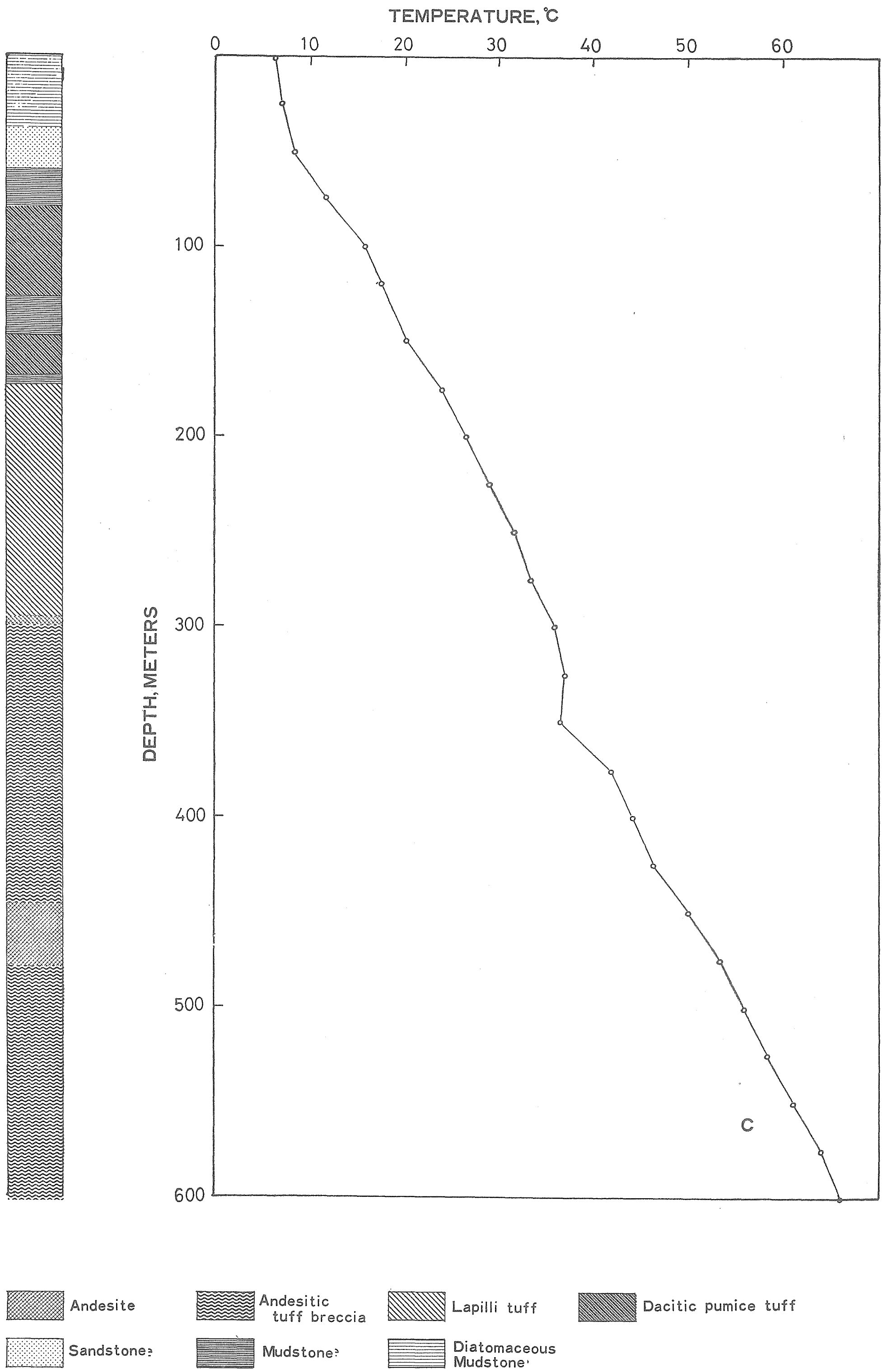

Fig. 7 Temperature distribution and lithological columnar section at Nanao.

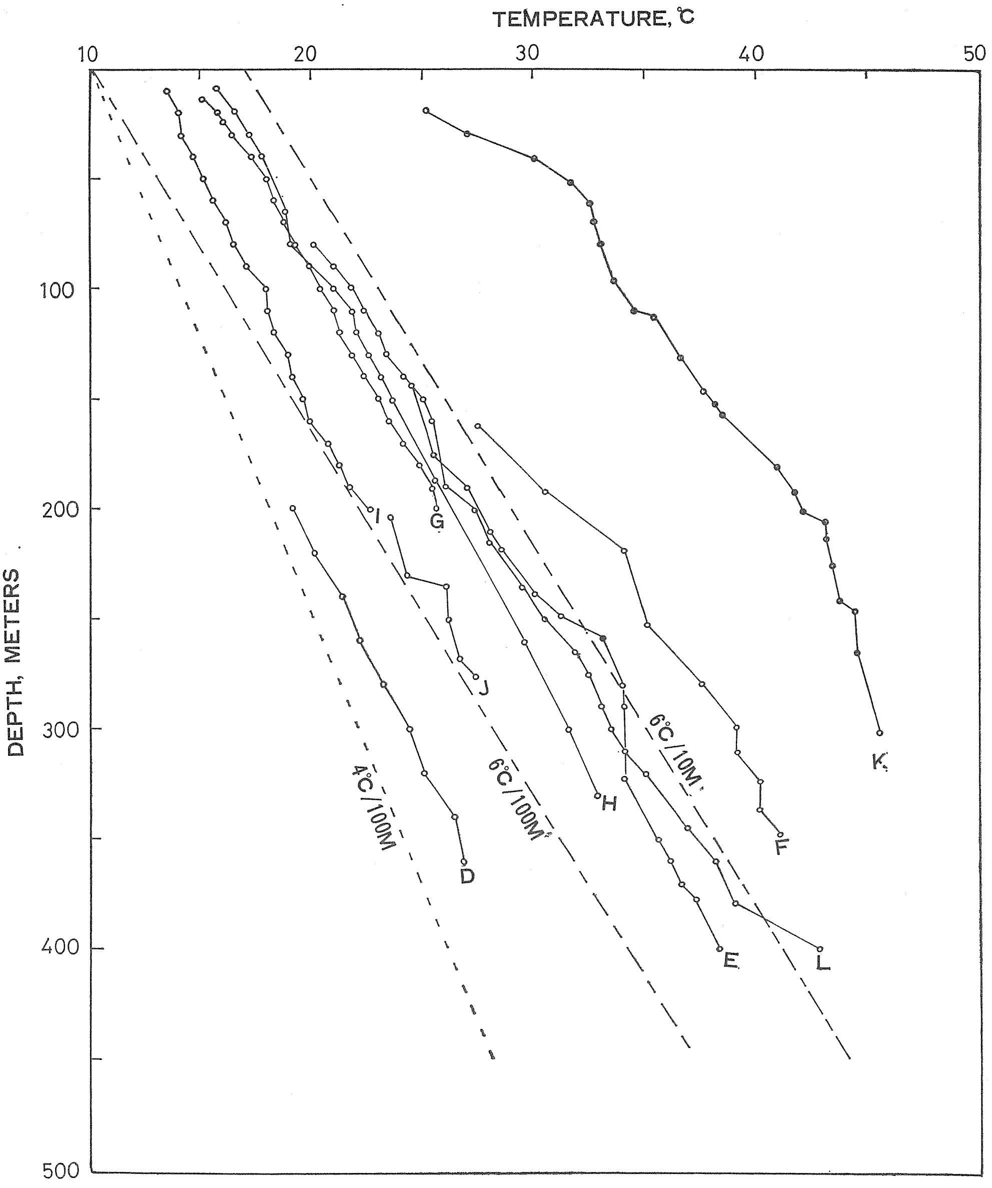

Fig. 8 Temperature distributions at the sites of Anamizu to Tedori in Table 1.

Appendix

		Japan	Latitude (North)	Longitude (East)
A	Uozu	魚　津	36°53′	137°28′
B	Himi	氷　見	36°51′	137°00′
C	Nanao	七　尾	37°05′	136°56′
D	Anamizu	穴　水	37°14′	136°55′
E	Koiji	恋　路	37°23′	137°15′
F	Ukai	鵜　飼	37°24′	137°15′
G	Maura	真　浦	37°29′	137°07′
H	Nebuta	寝　豚	37°24′	136°57′
I	Monzen	門　前	37°17′	136°47′
J	Shio	志　雄	36°51′	136°50′
K	Komatsu	小　松	36°24′	136°28′
L	Tedori	手　取	36°19′	136°40′
M	Mikuni	三　国	36°15′	136°10′
N	Fukui	福　井	36°03′	136°15′
O	Kuwajima	桑　島	36°12′	136°39′
P	Shiramine	白　峰	36°10′	136°38′