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10. Studies of the Thermal State of the Earth.
The 11 th Paper:
Terrestrial Heat Flow Measurements in Kyushu District, Japan.

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Abstract

Terrestrial heat flow was measured in 5 localities in Kyushu District. Of these 5 localities, one (Takamatsu) is a coal mine, while the other 4 (Izuhara, Kushikino, Makimine, Taio) are metal mines. Geothermal gradients measured in these localities are 2.93°$C/100\,m$ in Izuhara (Taishu mine), 3.06°$C/100\,m$ in Takamatsu, 1.71°$C/100\,m$ in Taio, and 2.57°$C/100\,m$ in Makimine, respectively. In Kushikino no reliable thermal gradient was obtained. Combining the thermal gradients with thermal conductivity of rocks in each locality, values of heat flux were obtained as follows; $2.18\times10^{-6}\,cal/cm^2\,sec$ in Izuhara, $1.92\times10^{-6}\,cal/cm^2\,sec$ in Takamatsu, $1.79\times10^{-6}\,cal/cm^2\,sec$ in Makimine, and $1.05\times10^{-6}\,cal/cm^2\,sec$ in Taio. The results indicate a relatively high (more than $2\times10^{-6}\,cal/cm^2\,sec$) heat flow in Tsushima, an island about 100 km north-west of Kyushu proper, while in Kyushu proper heat flux is high but only on the $1\times10^{-6}\,cal/cm^2\,sec$ level. It is necessary to make more measurements to discuss the detailed distribution of terrestrial heat flow in the District.

1. Introduction

The present Paper is the fourth of a series of reports on the geothermal study of Japanese Islands undertaken by the Earthquake Research Institute.[1),2),3)] The localities of 5 places are shown in Fig. 1. They are Taishu Pb-Zn mine, (Izuhara, in Tsushima Island), Takamatsu coal mine, Makimine Cu-Fe mine, Taio Ag-Au mine and Kushikino Ag-Au mine . As will be shown later, in Kushikino mine, underground tempe-

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1) S. UYEDA and K. HÔRAI, *Bull. Earthq. Res. Inst.*, 41 (1963), 85.
2) S. UYEDA and K. HÔRAI, *Bull. Earthq. Res. Inst.*, 41 (1963), 109.
3) K. HÔRAI, *Bull. Earthq. Res. Inst.*, 41 (1963), 137.

rature seemed to be disturbed too much to obtain any reliable geothermal gradient.

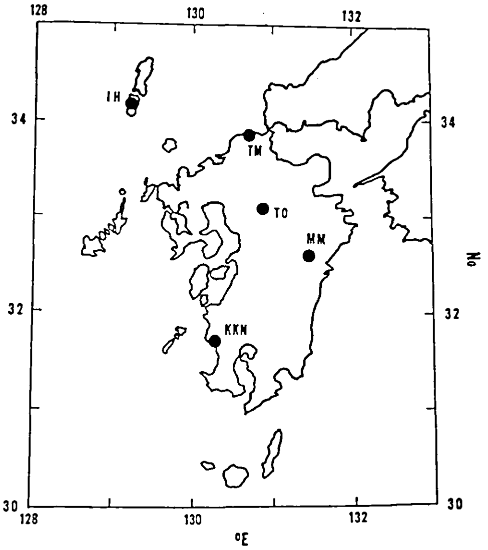

Fig. 1. Localities of heat flow stations in Kyushu District.
IH : Izuhara TM : Takamatsu
TO : Taio MM : Makimine
KKN: Kushikino

2. Izuhara

Underground temperature was measured in several boreholes of the Taishu Mine (34°12–15′N, 129°14–15′E), Izuhara, Tsushima Island, Nagasaki Prefecture (Fig. 1, Fig. 2). Temperature was measured in 3 boreholes, i.e., Shirotake No. 4, Oita deep-bore No. 1, and Himi deep-bore No. 5 (Fig. 2). These boreholes were drilled from the ground surface vertically or slightly slantwise for the purpose of prospecting.

The temperature distribution along these boreholes is indicated in Fig. 3 a, taking the altitude rather than the depth as the ordinate. When the temperatures are plotted against the depth they show less consistency. This may mean that the underground isotherms in Taishu Mine are horizontal rather than parallel to the surface topography. Temperature was also measured in 4 holes drilled from the drifts of the mine, but, as indicated in Fig. 3 b, no reliable thermal gradient

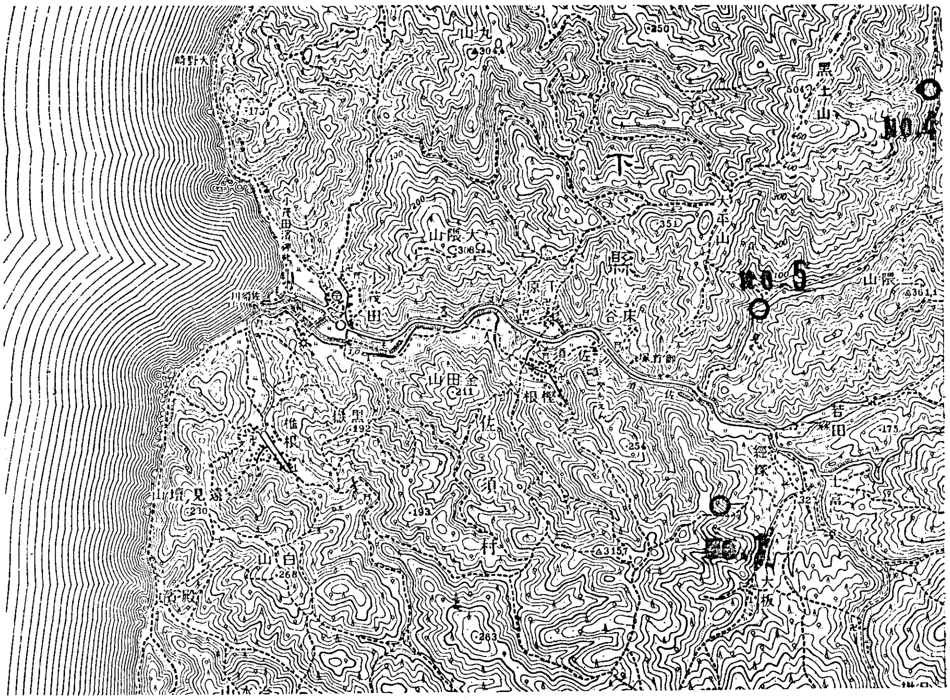

Fig. 2. Localities of the boreholes used in Taishu Mine, Izuhara. The map covers the area from 34°12′ N to 34°15′ N in latitude and from 129°10′10″4 E to 129°15′10″4 E in longitude.

No. 4: Shirotake No. 4 boring.
No. 5: Himi deep bore No. 5.
No. 1: Oita deep bore No. 1.

was observed, owing presumably to the shortness of the hole length or such causes as water circulation *etc*. In Fig. 3 a, temperature distribution along the boreholes Shirotake No. 4 and Oita deep-bore No. 1, shows a fairly clear linear relation between temperature and altitude, while along the borehole Himi deep-bore No. 5 temperature shows an unusual curvature. It will be worth mentioning that the abnormal curvature might be caused by the disturbance presumably owing to the underground water circulation forced by the drainage in the mine, considering that the former two holes were at some distance away from the underground mining drifts and the latter was cut near them. Four short boreholes which showed disturbed temperatures (Fig. 4) are also situated in the nearby area. Temperature gradient, calculated by the method of least squares from the undisturbed temperature distribution along the boreholes Shirotake No. 4 and Oita deep-bore No. 1, is $2.93 \pm 0.04 °C/100\ m$.

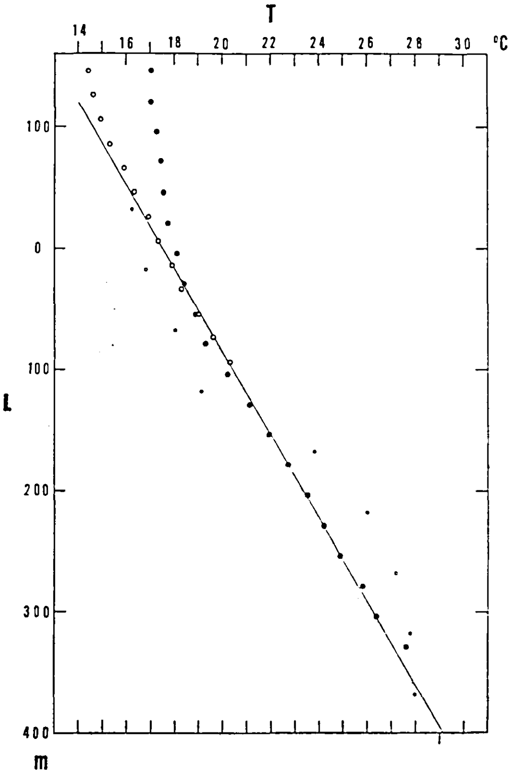

Fig. 3a. Underground temperature distribution in Taishu Mine, Izuhara.

Full circles	: Oita deep bore No. 1.
Hollow circles	: Shirotake No. 4.
Small hollow circles	: Himi deep bore No. 5.

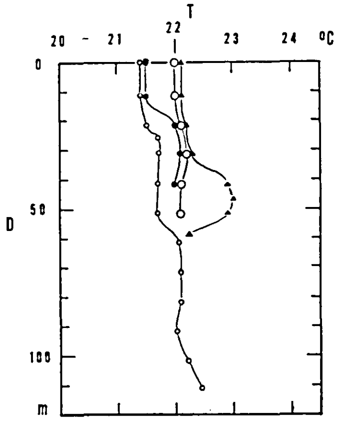

Fig. 3b. Temperature-depth relations in boreholes in the drifts of Taishu Mine.

Small hollow circles:	Himi −140 mL No. 5 1-A.
Small full circles:	Himi −140 mL No. 5 1-B.
Large hollow circles:	Himi −140 mL No. 28 1-C.
Solid triangles:	Himi −140 mL No. 28 1-B.

The geology of the mine is described by Uehara in detail.[4] Rocks cut through the boreholes are shale and sandstone of Palaeogene age partly altered by the intruded granite, and the dikes of quartz porphyry formed at the time of that intrusion. Thermal conductivity was measured on the rock samples collected from the boring cores. The results are listed in Table 1. Mean thermal conductivity is $7.41\times10^{-3}\ (\frac{R}{2}=2.33\times10^{-3})\ cal/cm\ sec\ {}^\circ C$.

From the data mentioned above, heat flow is calculated as $2.18\times10^{-6}\ cal/cm^2\ sec$.

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4) 上原幸雄 鉱山地質 No. 37, **9** (1959), 265.

Table 1.

Specimen	Rock type	Thermal conductivity ($10^{-3} cal/cm\ sec\ ^\circ C$)	Temperature during measurement ($^\circ C$)	Density (gr/cm^3)
IH I	Sandstone	9.10	25.4	2.62
II	Sandstone	11.29	25.2	2.68
III	Quartz-porphyry	6.56	25.4	2.53
IV	Quartz-porphyry	8.32	25.3	2.66
V	Quartz-porphyry	7.94	25.7	2.54
VI	Shale	5.03	25.5	2.71
VII	Shale	4.64	25.3	2.70
VIII	Shale	6.94	25.7	2.71

3. Takamatsu

In Takamatsu Coal Mine (Fig. 1, Fig. 4), owned by the Nihon Tanko Co., underground temperature has been thoroughly surveyed by Mr. Y. Kitamura and Mr. M. Hotta of the company. The temperature was measured at 10 places in the drifts of the mine ranging from 500 *m* to 1000 *m* below sea level as indicated in Table 2. In Fig. 4, the place where temperature was measured are indicated. A temperature distribution diagram is reproduced in Fig. 5, with the kind permission of the Nihon Tanko Co. Thermal gradient was calculated as $3.06 \pm 0.14^\circ C/$

Table 2. Temperature stations in Takamatsu Coal Mine.
(by Y. Kitamura and M. Hotta)

Name of site	Altitude of site (*m* above sea level)	Rock temperature ($^\circ C$)
A	−598	32.3
B	−603	33.6
C	−628	33.8
D	−672	34.1
E	−700	34.6
F	−731	36.0
G	−838	39.5
H	−891	41.5
I	−924	42.5
J	−982	44.5
P*	−450	30.0

* see text.

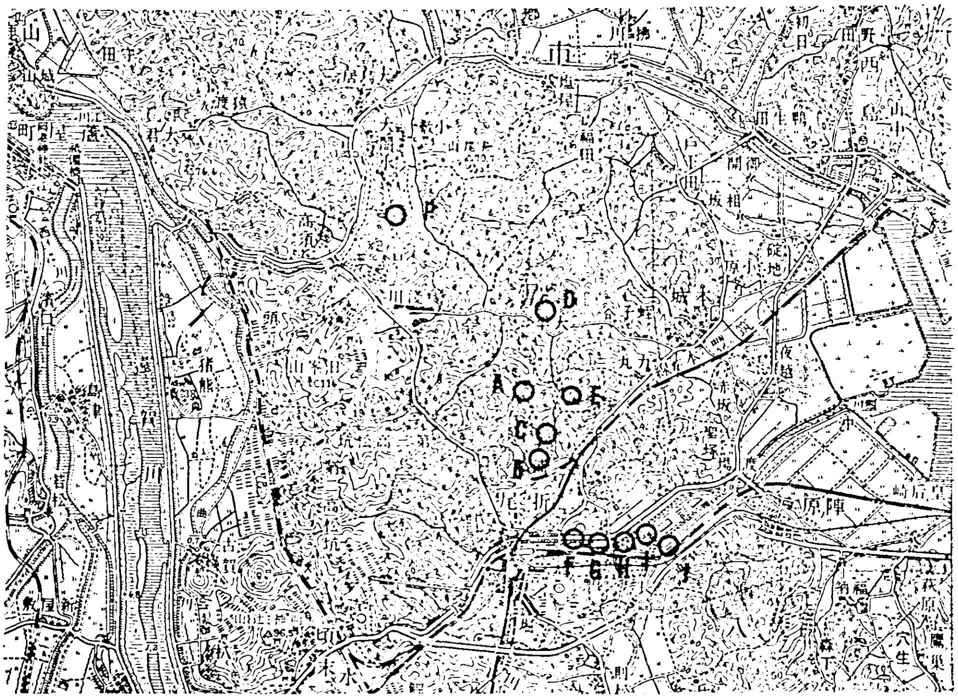

Fig. 4. Localities of temperature stations in Takamatsu Coal Mine. The map covers the area from 33°51′ N to 33°54′ N in latitude and 130°40′10″4 E to 130°45′10″4 E in longitude.

A to J: Stations by Kitamura and Hotta, Nihon Tanko Co.
P : Station by Hôrai and Uyeda.

100 *m* applying the least square method to their data. In the figure an additional datum of temperature measurement, obtained by Dr. Uyeda and the author in cooperation with Mr. Kitamura, Mr. Wada and Mr. Hotta of Takamatsu Mine, is also marked for comparison.

Geology of the area[5] belongs to the old Tertiary formation composed of interbeds of sandstone and shale. Samples of sandstone and shale were collected from the walls of the drifts and their thermal conductivity was measured. Considering the porosity of the sandstone samples they are saturated with water before measurement. The result is tabulated in Table 3. Mean thermal conductivity was assessed as $6.27\times10^{-3}\,cal/cm\,sec°C$ taking a weighted mean of conductivities of sandstone and shale $(\frac{R}{2}=1.59\times10^{-3}\,cal/cm\,sec\,°C)$. The weights were taken as proportional to their respective abundance in the column. The abundance ratio of sandstone to shale was assessed to be 800 : 204 based on the geological logging along the main shaft No. 3, which was cut

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[5] Y. KITAMURA, Private Communication.

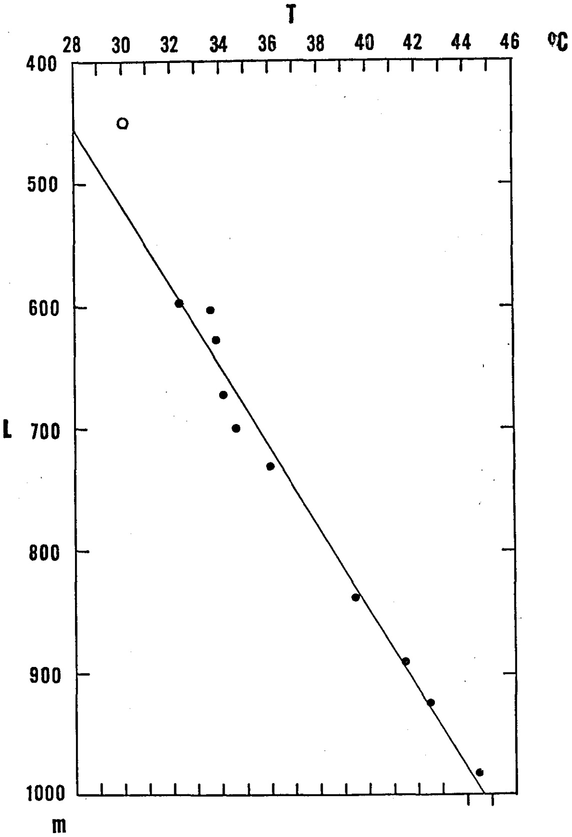

Fig. 5. Temperature-altitude (below sea level) relation in Takamatsu Coal Mine.

Full circles : After Kitamura and Hotta, Nihon Tanko Co.
Hollow circle: After Hôrai and Uyeda.

Table 3.

Specimen	Rock type	Thermal conductivity (10^{-3} *cal/cm sec °C*)	Temperature during measurement (°*C*)	Density (*gr/cm*^{3})
TM I	Sandstone (400m)	6.75*	33.4	2.19*′
II	Shale (400m)	3.74	31.3	2.49
III	Sandstone (700m)	9.47*	32.3	2.23*′
IV	Sandstone (700m)	5.82*	32.6	2.30*′
V	Sandstone (700m)	7.19*	31.0	2.25*′
VI	Sandstone (850m)	6.02*	29.2	2.31*′
VII	Sandstone (1000m)	6.98*	29.3	2.33*′
VIII	Sandstone (1000m)	6.20*	29.2	2.29*′

* Measured in water saturated state.
*′ Measured in desiccated state.

through in the central part of the mine extending vertically from the surface down to $-1000\,m$ level.

Heat flow in this area was calculated as $1.92 \times 10^{-6}\, cal/cm^2\, sec$, from the above mentioned data.

4. Taio

Rock temperature was measured at 39 places (33°07–08′N, 130°52′E) in the drifts of Taio Mine (Fig. 1, Fig. 6), Oita Prefecture. The drifts extend from the surface down to a depth of $550\,m$ near the summit of Sarugakeyama, $968\,m$ high. The approximate position of the area under investigation is indicated in Fig. 6. The results of measurements are listed in Table 4 and shown in Fig. 7. In Fig. 7, measured temperatures are plotted against the depth from the surface. It is observed in the figure that the temperature measured in the central part of the mine (W 14 to W 21 according to the classification of the mine) shows only a scattered pattern, while in the eastern part (W 9 to W 5) and the western part (W 27 to W 30) of the mine an increase of temperature with depth was observed. The reason for the scattered temperature in the central part of the mine is not clear, but effect of

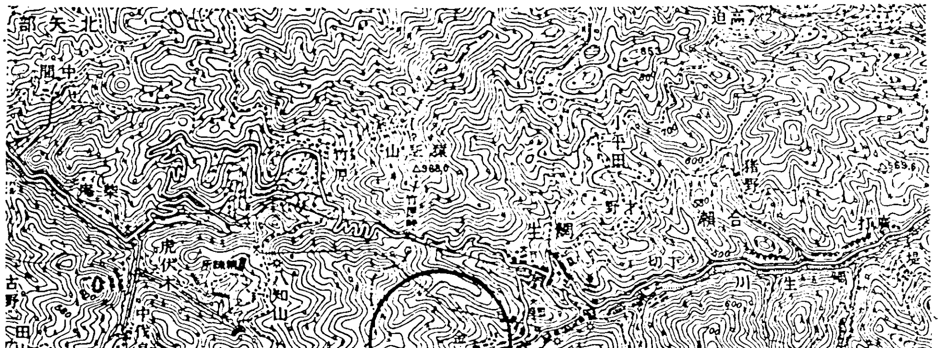

Fig. 6. Area under investigation in Taio Mine. The map covers from 33°06′ N to 33°09′ N in latitude and from 130°50′10″4 E to 130°55′10″3 E in longitude.

Table 4. Temperature stations in Taio Mine.

Name of site	Depth of site (*m*)	Rock temperature (°*C*)	Class in Fig. 7
3V 4L W 1	134	17.1	I
3V 5L E 2	158	19.2	I
4V 5L W 5	197	15.9	I
4V 5L W 5	197	15.9	I
5V 5L W 5	197	14.8	I
4V 6L W 3	188	16.6	I
4V 6L W 3	188	16.4	I
4V 7L W 1	220	17.2	I
4V 7L W 1	220	17.2	I
7V 7L W 3	220	17.6	I
7V 7L W 3	220	17.5	I
7V 7L W 4	241	17.6	I
2V 9L E 3	270	19.3	I
2V 9L E 3	270	19.3	I
2V 9L E 4	252	19.5	I
3V10L E 9	263	22.2	I
3V10L E 9	263	20.1	I
3V10L E 2	304	18.0	I
3V10L E 2	304	18.2	I
4V 8L W 4	276	17.7	I
3V 8L W 4	276	17.5	I
3V 8L W 4	276	17.4	I
4V 8L W14	517	18.1	
3V 8L W14	517	17.3	
3V 8L W15	538	17.8	
3V 8L W15	538	17.8	
3V 8L W19	495	19.9	
3V 8L W19	495	20.0	
3V 8L W21	502	19.1	
3V 8L W21	502	19.2	
3V 5L W19	407	19.3	
3V 5L W20	425	18.8	
4V 5L W21	414	21.1	
3V 5L W17	424	17.7	
3V 0L	25	15.2	I
4V 0L W28	294	17.2	II
4V 0L W29	286	17.9	II
12Vup 8LW30	454	21.5	II
12V 9L W30	487	21.4	II
12V 9L W29	512	21.7	II
12V 9L W28	522	21.3	II
12V 9L W38	346	23.9	
12V 9L W28	522	21.3	II
2V 2L W 2	77	16.0	I
3V 2L W 2	77	15.0	I
3V 2L W 2	77	15.1	I
3V 2L W 2	77	15.0	I
3V 4L W 2	137	15.9	I
3V 4L W 2	137	15.5	I
3V 4L W 3	135	15.0	I
3V 4L W 3	135	15.0	I
4V 5L W17	425	17.7	
4V 7L W18	459	20.2	
4V 7L W18	459	20.3	
4V10L W21	560	22.0	
4V10L W21	560	21.9	
12V10L W27	549	21.4	

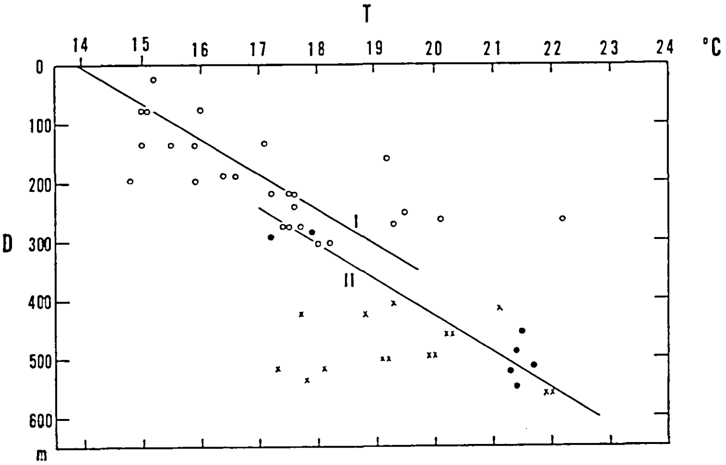

Fig. 7. Temperature-depth relation in Taio Mine.
Hollow circles (I): E 9-W 5.
Full circles (II): W27-W30.
Crosses : W14-W21.

underground water is suspected. The thermal gradient calculated from the temperatures in these two good parts applying the least squares method is $1.66\pm0.31°C/100\ m$ and $1.75\pm0.01°C/100\ m$ respectively.

Rocks around the area are mainly composed of propylites of Tertiary ages. Thermal conductivity was measured on 11 samples of propylite. The results are indicated in Table 5. In Table 5, classification of the propylite according to the geologists of the Taio Mine, Mr. Ito, Mr. Yatsuji and Mr. Ueki[6] is also mentioned. Mean thermal conductivity of propylite is $6.16\times10^{-3}\ cal/cm\ sec°C$ ($\frac{R}{2}=1.95\times10^{-3}\ cal/cm\ sec\ °C$). Thus, the heat flow is $1.05\times10^{-6}\ cal/cm^2\ sec$, taking the average thermal gradient in this area to be $1.71\ °C/100\ m$.

Table 5.

Specimen	Rock type	Thermal conductivity ($10^{-3}\ cal/cm\ sec\ °C$)	Temperature during measurement (°C)	Density (gr/cm^3)
TO I	Propylite WG	5.56	33.5	2.57
II	Propylite G	5.53	33.6	2.68
III	Propylite B	5.15	33.5	2.70
IV	Propylite A-Br-Wvi	5.71	33.4	2.60
V	Propylite S	6.81	33.4	2.52
VI	Propylite A-Br-Ch	6.14	33.5	2.66
VII	Propylite A-Wvi	4.65	33.4	2.52
VIII	Propylite A-Br-Vi	6.77	33.5	2.67
IX	Propylite Br-WG	6.37	33.6	2.66
X	Propylite Br-Vi	8.55	33.6	2.58
XI	Propylite Br-Wvi	6.52	32.9	2.61

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[6] T. ITÔ, A. YATSUJI and Y. UEKI, *Kyushu Kozan Gakkaishi*, **29** (1961), 87.

5. Makimine

Underground temperature was measured in the drifts of the Makimine Mine (32°38′N, 131°26–27′E) (Fig. 1, Fig. 8), Miyazaki Prefecture. Due to the distribution of ore bodies, the mine is separated into two parts, *i.e.*, the eastern part and the western part. Temperature was measured using the boreholes drilled in the drifts at various depths ranging from 100 *m* above sea level to 600 *m* below sea level. The results are summarized in Table 6. In Fig. 9, rock temperatures are plotted against the altitude of the location where temperature was measured. Temperature shows a linear increase with depth without any notable departure between the temperatures in the eastern and the western parts. The observed gradient was 2.57±0.07°*C*/100 *m*.

Geology around the area belongs to the unclassified Mesozoic formation composed of phyllite, sandstone, slate and green rocks

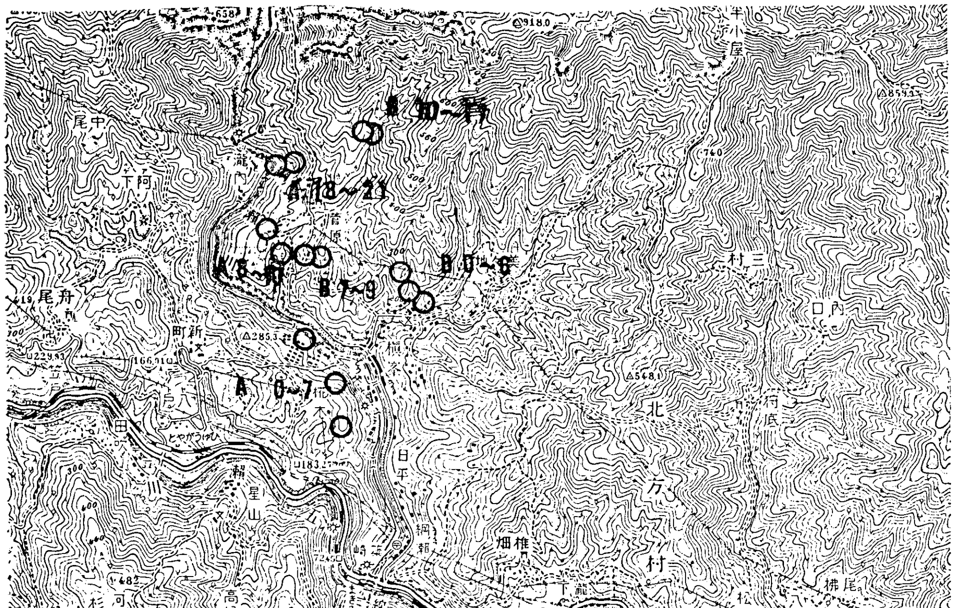

Fig. 8. Localities of boreholes used in Makimine Mine. The map covers the area from 32°36′ N to 32°39′ N in latitude and from 131°25′10″4 E to 131°30′10″4 E in longitude.

B: Eastern part of mine, see Table 6.
A: Western part of mine.

Table 6. Temperature stations in Makimine Mine.

Name of site	No.	Altitude of site (m above sea level)	Depth of site (m)	Rock temperature (°C)
West adit	A0	120	115	18.7
	A1	121	114	18.3
	A2	117	118	18.4
W. No. 4 drift	A3	10	200	21.3
	A4	17	193	21.4
	A5	18	192	21.2
W, 8L	A6	−116	271	24.1
	A7	−115	270	24.2
W, 12L	A8	−283	518	28.4
	A9	−283	518	28.5
	A10	−283	518	28.3
	A11	−278	513	28.3
W, 14L	A12	−384	564	30.9
	A13	−384	564	30.7
	A14	−384	564	30.7
W, 16L	A15	−493	698	36.1
	A16	−492	697	36.9
	A17	−493	693	36.4
W, 18L	A18	−595	705	35.9
	A19	−593	703	35.8
	A20	−593	703	35.0
	A21	−593	703	35.2
East adit	B0	116	104	18.0
	B1	113	107	17.9
E, No. 4 drift	B2	25	155	20.1
	B3	17	163	20.9
	B4	17	163	21.0
E, 6L	B5	−16	286	23.1
	B6	−15	285	23.3
W, 10L	B7	−193	438	27.9
	B8	−193	438	27.8
	B9	−189	439	27.4
E, 12L	B10	−288	678	29.9
	B11	−297	687	29.6
	B12	−303	693	29.9
E, 13 L	B13	−333	713	30.2
	B14	−330	710	30.2
	B15	−345	725	30.6
E, 14L	B16	−388	843	32.7
	B17	−390	845	32.7

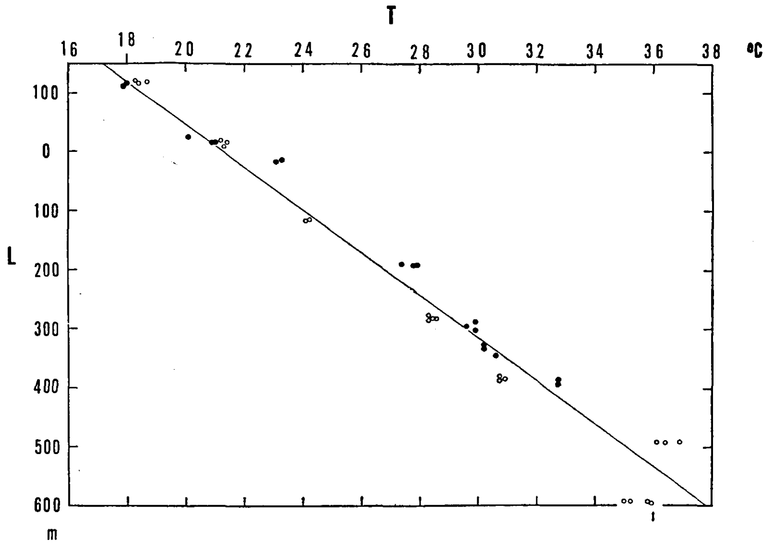

Fig. 9 Temperature-altitude relation in Makimine Mine.
Full circles : Eastern Part.
Hollow circles: Western Part.

(metamorphosed basic volcanic rocks)[7]. Thermal conductivity was measured on the samples of these rocks. The results are shown in Table 7, giving the mean thermal conductivity as 6.95×10^{-3} ($\frac{R}{2}=1.97\times10^{-3}$) *cal/cm sec°C*. Combining the thermal gradient with the thermal conductivity, the heat flow can be obtained, as 1.79×10^{-6} *cal/cm²sec.*

Table 7.

Specimen	Rock type	Thermal conductivity (10^{-3}*cal/cm sec °C*)	Temperature during measurement (°*C*)	Density (*gr/cm*³)
MM I	Black phyllite	5.17	34.8	2.71
II	Black phyllite	8.54	34.8	2.77
III	Sandstone	7.38	34.8	2.68
IV	Sandstone	10.29	34.8	2.65
V	Metamorphosed basic volcanic rocks	5.40	34.7	2.95
VI	Metamorphosed basic volcanic rocks	4.89	34.7	2.84

6. Kushikino

A terrestrial heat flow survey was made at Kushikino Mine, (Fig. 1, Fig. 10), Kagoshima Prefecture. Rocks distributed in and around the mine are composed of andesitic rocks of Miocene age and tuffaceous

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[7] T. Tatsumi, *Sci. Pap. Coll. Gen. Educ. Univ, Tokyo.*, 81, **3** (1953), 201.

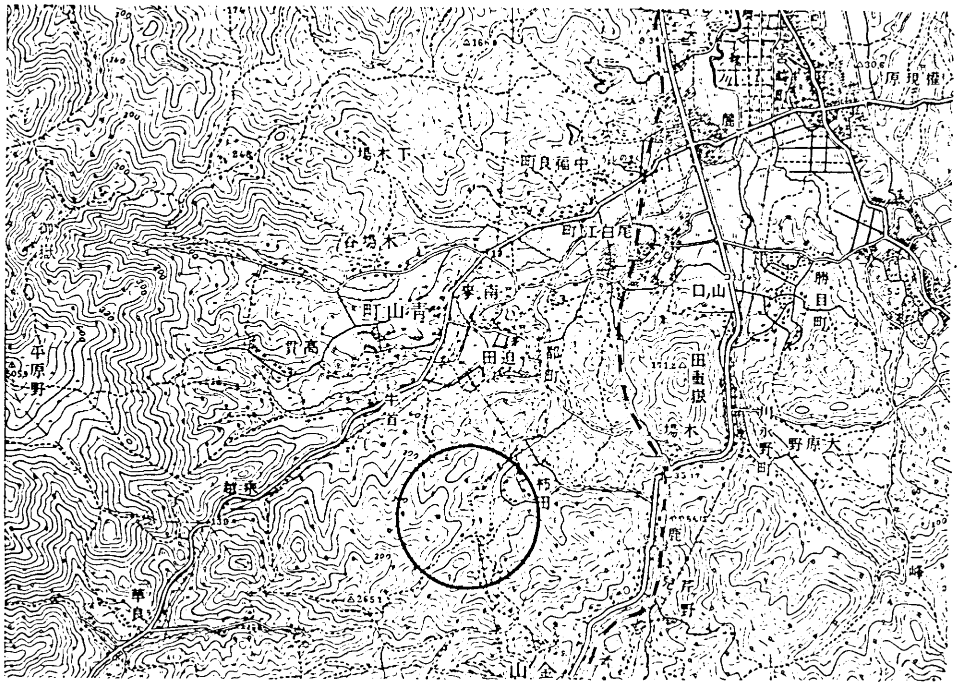

Fig. 10. Area under investigation in Kushikino Mine. The map covers the area from 31°45′ N to 31°48′ N in latitude and from 130°15′10″4 E to 130°20′10″4 E in longitude.

sandstone presumably belonging to the Pliocene age[8]. The andesitic rocks are partly altered. Thermal conductivity was measured on the samples of tuff breccia, andesite, pyrite and propylite and the result is tabulated in Table 8. In Table 8, it is observed that, apart from pyrite, thermal conductivity shows no large difference from one type to another. Mean thermal conductivity is 5.23×10^{-3} *cal/cm sec°C*.

Table 8.

Specimen	Rock type	Thermal conductivity (10^{-3} *cal/cm sec °C*)	Temperature during measurement (°*C*)	Density (*gr/cm*^{3})
KKN I	Tuff breccia	4.20	34.8	2.29
II	Propylite	5.24	34.7	2.62
III	Propylite	4.49	34.6	2.43
IV	Andesite	4.67	34.5	2.70
V	Propylite	5.57	34.7	2.57
VI	Pyrite	7.22	34.8	2.66

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[8] T. WATANABE, Ed., *Progress in Economic Geology* (Fuzanbo, Tokyo. 1956).

Underground temperature was measured using boreholes drilled from the land surface and those cut in the drifts of the mine. In Fig. 10, the area in which these boreholes are distributed is shown. Measured temperatures are plotted in Fig. 11 against the depth of temperature stations. It may be observed in the figure that the dependence of the temperature on the depth is not definite indicating that the underground temperature distribution is complicated in this area. The nature of the disturbance which causes this complicated distribution is not known. Composite structure of different rock type would not be responsible for this. Mere application of the least squares method produces a gradient 1.36°*C*/100 *m* giving a heat flow of 0.71 $\times 10^{-6}$ *cal/cm*^{2} *sec*. This value, however, has little reliability. To get a more reliable thermal gradient it would be necessary to extend the measurement to the deeper part or to make another measurement in the vicinity of the area where the disturbance is less.

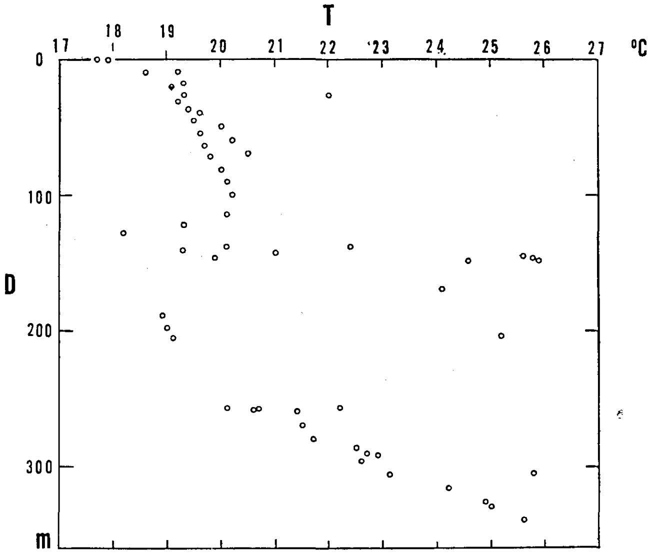

Fig. 11. Plot of measured underground temperatures in Kushikino Mine.

7. Conclusion

Data on heat flow in Kyushu District is summarized in Table 9. The table indicates the following when reference is made to Fig. 1; a) Heat flow in Tsushima Island in the Japan Sea is high ($Q = 2.18 \times 10^{-6}$

Table 9. Terrestrial Heat Flow in Kyushu District.

Locality	Abbreviation	Site	Latitude (N)	Longitude (E)	Geothermal gradient ($^\circ C/100m$)	Thermal conductivity ($10^{-3} cal/cm\ sec^\circ C$)	Terrestrial heat flow ($10^{-6} cal/cm^2 sec$)	Remarks
Izuhara	IH	Pb, Zn mine	34°13′	129°14′	2.93	7.41	2.18	
Takamatsu	TM	Coal mine	33°52′	130°43′	3.06	6.27	1.92	
Taio	TO	Au, Ag mine	33°07′	130°52′	1.71	6.16	1.05	
Makimine	MM	Cu mine	32°38′	131°27′	2.57	6.95	1.79	
Kushikino	KKN	Au, Ag mine	31°44′	130°16′	(1.36)	5.23	(0.71)	not reliable

cal/cm^2 *sec*); this is in agreement with our observation in other parts of Japan. b) In the other part of the District also *i.e.* the main island of Kyushu, the heat flow seems to be high (Q is almost 2×10^{-6} *cal/cm*^{2} *sec*), but not very high. Even a relatively low value is observed in the central part ($Q=1.05\times10^{-6}$ *cal/cm*^{2} *sec* in Taio). Obviously, more measurements are needed before further discussion of the distribution of heat flow in this District.

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10. 地球熱学 第11報 九州地方に於ける地殼熱流量測定結果

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1. 九州地方の5地点で地殼熱流量の測定を行ない，この地方の地殼熱流量分布について基本的な傾向を知ることができた．個々の測定点に関する要点を以下に述べる．

2. 厳原（いずはら）　長崎県下県(あがた)郡厳原町の東邦亜鉛株式会社対州鉱業所において，探査用ボーリング数本を用いて地下温度分布の測定を行なつた．測定点の概略の位置は北緯 34°13′，東経 129°14′ で対島下島の西海岸側に当る．温度測定値にもとづいて深さ対温度曲線を描いてみると，地下坑道に近接するボーリングには曲線に著しい屈曲があり，これは坑道からの排水に伴なう地下水の強制循環の影響ではないかと考えられる．地下坑道から隔つた位置にあるボーリングでは深さ対温度の関係は直線に近く，地下温度増加率は 2.93°*C*/100 *m* であつた（本文第3図参照）．測定点付近の地質は古第三紀層に属する砂岩・頁岩を花崗岩体が貫入し，周囲の水成岩を接触変成するとともに石英斑岩の岩脈を形成したといわれる．ボーリング柱状図を参照しつつ，頁岩・砂岩・石英斑岩等の試料を採集し，その熱伝導率を測定した．平均の熱伝導率は 7.41×10^{-3} *cal/cm sec°C*．地殼熱流量は 2.18×10^{-6} *cal/cm*^{2} *sec* である．調査に当つて対州鉱業所採鉱課の神出福吉課長，上原幸雄氏はじめ各位の御協力を得た．

3. 高松　福岡県遠賀郡水巻町の日本炭砿高松砿業所では，同所の北村義夫氏らの手によつて坑道内岩盤温度の測定がなされている．測定地の概略の位置は北緯 33°52′，東経 130°43′ である．温度

測定の行なわれた坑道のうち，最深のものは地表からの深さ約 900 m に達し，岩盤温度は地表からの深さとともに増加することがみとめられる．この温度測定資料にもとづいて地下温度増加率を求めると $3.06°C/100\,m$ になる．付近の地質は古第三紀に属する砂岩・頁岩の互層から成つている．坑道内の露頭からこれらの岩石の試料を採集し，砂岩は岩質が porous であることを考慮して水で飽和させた状態で熱伝導率を測定した．砂岩と頁岩の存在比を用いて地層の平均の熱伝導率を求めると，$6.27\times10^{-3}\,cal/cm\ sec°C$，地殼熱流量は $1.92\times10^{-6}\,cal/cm^2\,sec$ となる，当地の地殼熱流量調査に際して，温度測定資料の提供，岩石試料の採集等，同鉱業所の北村義夫課長・勝田湊次課長他各位の御配慮にあずかつた．

4．鯛生　大分県日田郡中津江村の鯛生鉱業株式会社鯛生鉱業所の地下坑道内数 10 点で地下温度の測定を行なつた．測定地の概略の位置は北緯 33°07′，東経 130°52′ である．温度測定点が広範囲にわたつたために鉱山全体としての深さ対温度の関係がやや不明瞭であるが，鉱山の東部，中部．西部の各々についてみると，東部．西部では深さ対温度の関係が比較的明瞭になり，地下温度増加率は $1.66°C/100\,m$ および $1.75\ °C/100\,m$ となつた．鉱山を構成する主な岩石は第三紀に生成したと考えられる変朽安山岩で，これらの試料 11 個について熱伝導率を測定し，平均値 $6.16\times10^{-3}\,cal/cm\ sec°C$ を得た．地殼熱流量は $1.05\times10^{-6}\,cal/cm^2\,sec$ となる．測定実施に際して同鉱業所鉱務課の伊藤虎雄課長，植木保吉氏他各位の御協力を得た．

5．槇峰　宮崎県東臼杵郡北方村の三菱金属鉱業株式会社槇峰鉱業所の地下坑道内数 10 点で温度測定を行ない，地下温度増加率 $2.57°C/100\,m$ をえた．測定地の概略の位置は北緯 32°38′，東経 131°27′，利用した坑道の高低差は約 700 m である．付近の地質は時代未詳中生層に属する千枚岩，砂岩，粘板岩等と緑色岩類（変成した塩基性火山岩類）から成つている．それらの岩石の試料を用いて熱伝導率の測定を行ない，平均値 $6.95\times10^{-3}\,cal/cm\ sec°C$ をえた，地殼熱流量は $1.79\times10^{-6}\,cal/cm^2\,sec$ である．調査にあたつて同鉱業所地質課の城戸満課長．長井俊秀氏，石崎秀司氏はじめ各位のお世話になつた．

6．串木野　鹿児島県串木野市の三井金属鉱業株式会社串木野鉱業所において，地下坑道内数 10 点で地中温度を測定した．付近の地質は第三紀中新世に属すると考えられる安山岩類と，鮮新世に属すると考えられる凝灰岩質砂岩などからなり，安山岩類は変質をうけている．凝灰岩，安山岩，変朽安山岩，珪化変質安山岩等の試料について熱伝導率を測定して平均値を求めると $5.23\times10^{-3}\,cal/cm\ sec°C$ となる．しかし温度測定結果にもとづいて深さ対温度図を作つてみると（本文第 11 図参照）地下温度分布は相当に不規則で，信頼すべき地下温度増加率を求めることは不可能であつた．地下の温度分布がこのように不規則なことの原因としては地下水の運動等が考えられる．調査にあたつて串木野鉱業所採鉱課の大倉長喜課長，武田達也氏はじめ各位のお世話になつた．

7．以上の結果を要約すると，九州地方においては対馬（厳原）で地殼熱流量が $2\times10^{-6}\,cal/cm^2\,sec$ を超えるが，その他の地域では $1\times10^{-6}\,cal/cm^2\,sec$ 台の地殼熱流量であつた．この地方の詳細な地殼熱流量分布を知るためには現在の資料だけでは不充分であつて更に多数の測定を行なう必要があると考えられる．

以上の研究調査を行なうにあたつて，上記の各鉱山会社，鉱業所の多くの方々に必要な便宜の提供をうけ，研究に協力していただいた．ここに心から感謝の意を表したい．