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CONTENTS

FOREWORD ....(1)

INFORMATIONS

Geothermal Operating Experience, Geysers Power Plant (Paul Mathew) ....(3)
Geothermics in Indonesia .... Djajadi HADIKUSUMO, L. PARDYANTO ..(9)

REPORTS

Mathematical Models for Thermal Structure in Toyoha Mine Area .... Ken-ichi NOMURA ..(13)
Exploration of Ōnuma Geothermal Field, Northeastern Japan .... Mitsuo YORA, Kenji WAKITA, Sakurô HONDA ..(27)

INTRODUCTION OF TECHNICAL PAPERS

Geothermal Resources (L.G.P. MUFFLER) ....(45)

SUMMARIES ....(55)

MISCELLANEA ....(58)

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JAPAN GEOTHERMAL ENERGY ASSOCIATION

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海外情報

Geothermics in Indonesia[*]

Djajadi HADIKUSUMO[**] and L. PARDYANTO[**]

The demand for electric power in Indonesia is increasing and consumption is expected to reach 5,100 MW by 1990[1]. Some new hydro-electric power stations have recently been completed, such as Jatiluhur, Karangkates, Riam Kanan, etc., and others are now under construction. Some oil-fired (thermal) power stations are operating at present (Jakarta, Surabaya, Semarang).

Research on invested capital in the U.S.A., New Zealand, Italy, and Japan proved that the application of geothermal energy for generating electric power is much less costly if compared to conventional methods. According to Facca and Ten Dam (in Kappelmeyer[2]) the cost for production of electricity in mills/kWh using natural steam is 2-3, water 5.0-11.36, and thermal 5.47-7.75. On that account the Indonesian Government begins to investigate the use of natural steam for electricity. The First Five-Year Development Plan, REPELITA I, offers an opportunity in a broader sense to carry out research in the field of geothermal resources. Preliminary explorations have been made by the Geological Survey of Indonesia (G.S.I.) for the purpose of collecting basic data, viz. making an inventory of geothermal indications or phenomena visible at the surface, such as hot springs, hot water- and hot mud pools, solfataras and fumaroles. Included in the activities will be plotting of geothermal indications on topographic map, temperature measurements, pH readings, calculation or estimation of discharge, sampling of water for chemical analyses, and based on them computation of their energy potentials. The local geological setting will be studied in order to be able to interpret the probable existence of geothermal phenomena.

Part of the data have been collected from existing literature and where possible substantialed with new findings and records. Those inventory will be carried out over the whole of Indonesia, giving priority to areas where electric power will be developed by State Electrical Company.

During 1969-1970 G.S.I. started to collect data on 45 localities in West- and Central Jawa having geothermal indications. At about the same time the Power Research Institute, Ministry of Public Works and Power undertook geothermal investigations on Flores Island and in the areas of Pinrang, Sidenreng, Pangkajene, etc. in South Sulawesi[3].

During the second year, of REPELITA I, 1970-1971, a number of 63 localities in Central- and West Java and Bali with geothermal indications were made inventory. In the same year an evaluation was made of the geothermal resources of the Dieng highlands. This work, which was performed by Muffler or the United States Geological Survey under a US grant to Indonesia was based on recommendations as put forward in earlier reports[4,5,6,7]. He had also to make suggestions concerning follow-up activities for their development. Investigations were concentrated on the Dieng plateau, not only for the fact that it is recommended in earlier reports, but also because of it is located between two power distribution systems in Central Java. As a result of his investigation and recommenda-

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[*] Lembaga Ilmu Pengetahuan Indonesia and National Academy of Sciences, U.S.A. WORKSHOP ON NATURAL RESOURCES Jakarta, 11-16 September 1972, Background paper.

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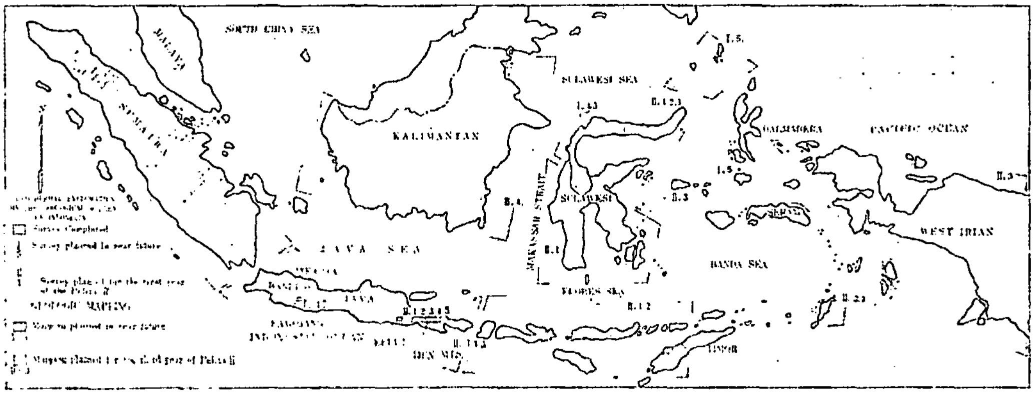
地熱 Vol. 10 No. 4 (Ser. No. 39) 1973

tion, a Project Agreement was signed on May 1970 between the Government of Indonesia and USAID outlining that geophysical survey, water geochemistry and interpretation of aerial photographs should be done. The Indonesian Government then organized a counterpart team, which was composed of G.S.I. and P.R.I. officials. A geophysical survey, consisting of resistivity measurements, was conducted by Group Seven, Inc. from USA. Also G.S.I. performed geophysical surveys consisting of gravity measurements. The results shown that two low resistivity anomalies (5 ohm-meter) exist along a strip between Siglagah and Sikidang. Within that strip a lower resistivity anomaly of less than 5 ohm-meter exist which includes the areas of Pagerkandang, Sikidang and Dieng Kulon[8]. Geochemical investigations were carried out by USGS, G.S.I. and P.R.I. at 55 localities in the Dieng highlands and surrounding areas (Pekalongan and Karangkobar). From samples of hot water and gas the ions of Cl, SO_4, SiO_2, Na and K have been calculated. The conclusion of this survey are, among others, as follows[9]: the geothermal system of the Dieng plateau will probably produce a mixture of hot water and steam rather than steam only; the subsurface temperatures indicated by critical chemical constituents are 203°C (critical) and approximately 200°C (alkali ratios). Interpretation of aerial photographs was done by the G.S.I. assisted by USGS specialists attached to the G.S.I. Geologic features of perticular significance are shown on a map, among other, the numerous young flows that radiate from the volcanoes around G. Pakuwaja, a zone of volcanic lineaments extending NW from G. Butak to Pagerkandang crater, N. 10 W. structural lineaments in the vicinity of the Dieng-Batur road between Batur and G. Nagasari[10]. Evaluation of those initial investigations resulted in the recommendation of exploratory drillings in the Dieng geothermal fields[11]. If successful this will be first geothermal power plant in Indonesia.

In the third year of REPELITA I, 1971–1972, inventory of geothermal phenomena were carried out in West Java, Central Sulawesi, West Sumatra and Lampung to a number of 106 localities. For the benefit of the geothermal exploration in the Dieng highlands, geologic mapping was performed in the surrounding areas.

In September to December 1971, K.E. Seal and J. Healy made a pre-feasibility study on geothermal resources in Indonesia under New Zealand technical assistance program. G.S.I. and P.R.I. functionaries acted as the counterpart. Hot springs and solfatara-fumarole fields in Java and Lumpung were visited. Healy[12] has come to conclusion, among others, that Kawah Kamojang is recommended for further investigation and development. As second and third alternatives Kawah Cibeureum and Cisolok are recommended, both subject to additional preliminary investigation to be carried out by local personnel; the thermal springs of Bali have relatively low temperatures, and although the existence



of geothermal resources in Central Bali cannot be ruled out, it is considered unlikely, so they should not be regarded as a possible source of power by 1975. Those pre-feasibility study will be followed by a preliminary survey in Kawah Kamojang in particular which is scheduled from September 1972 on or somewhat later this year.

Inventory of geothermal indications in the fourth year of REPELITA I, 1972-1973, is planned for the whole island of Sumatra, North and Central Sulawesi. The investigation is now under way. The G.S.I. has also organize a counterpart team to work with the New Zealand's specialists in the Kawah Kamojang and other areas.

Basic geothermal data collection in the future will be carried out over the whole of Indonesia. The detailed program can be seen on the attached map. Along with the survey, geologic mapping of volcanic regions will also be done, i.e. in Minahasa, the Ijen Mts. G. Kelut, etc. Preliminary geothermal investigation in particular areas will be held in congruent with the national program of electricity development of the Ministry of Public Works and Power.

At the beginning of REPELITA I the G.S.I. had only one assistant geologist involved in making the inventory of geothermal indications. One geologist and one surveyer were added in the second year and five more assistant geologists join until the fourth year. It is planned to add about four more geologists and about eight assistant geologists for the next REPELITA.

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74. *Terrestrial Heat Flow in Lake Biwa, Central Japan*

Preliminary Report

By Seiya Uyeda,[*] Teruhiko Watanabe,[*] Nobuyo Mizushima,[*]
Masashi Yasui,[**] and Shoji Horie[***]

(Comm. by Chuji Tsuboi, M. J. A., May 22, 1973)

During the past decade, the number of terrestrial heat flow measurements in and around the Japanese Island Arc has increased up to 500 (Uyeda and Vacquier, 1968; Watanabe *et al.*, 1971; Yasui *et al.*, 1971). As a result, the Japanese region has become one of the areas in the world that are most densely surveyed geothermally. The measurements have revealed that heat flow is low in the trench zone and uniformly subnormal in the Pacific Ocean basin in front of the trench zone, while it is high in the continent-ward zone of the arc and the marginal seas, such as Japan Sea, Okhotsk Sea and Okinawa Trough. Such a distribution of low and high heat flows is probably characteristic to certain active island arcs and provides a clue to understanding the tectonics associated with plate subduction (Hasebe *et al.*, 1971; Matsuda and Uyeda, 1971). In order to investigate the thermal processes under island arcs more thoroughly, it is desirable to make more detailed heat flow surveys in the transitional zone between high heat flow and low heat flow zones, which lies along the axis of an island arc. Most heat flow measurements on the land area have been made utilizing suitable deep mines or boreholes which are not available easily. One possibility for obtaining more additional data for land heat flow is to utilize lakes of which the bottom has a relatively stable temperature. In fact, such an attempt has been made in some lakes recently, utilizing the techniques of oceanic measurements (Diment and Werre, 1965; Hart and Steinhart, 1965; Lubimova and Shelyagin, 1966; Sclater *et al.*, 1970; Hänel, 1970, Herzen *et al.*, 1972). When the lake or the sea is shallow, however, the bottom temperature varies with time considerably, so that the temperature in the bottom sediments is suspected to change with time also. In such a case conventional Bullard-type oceanic heat flow probes are not suitable for measuring the true geothermal gradient. We, like

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some of the above authors, have also been trying to develop a technique of heat flow measurement at shallow waters by utilizing longer probes so that the effects of time variations of bottom temperature may be eliminated. So far in the Japanese area, however, we have had no reliable heat flow value in shallow waters against which our modified "oceanic" measurement could be checked.

Recently a group headed by one of the authors (SH) drilled a borehole in the central part of Lake Biwa, Central Japan, to sample a long core of bottom sediments. This borehole reached a depth of 197.2 m below the lake bottom or of 262.4 m below the lake surface, and provided a good opportunity for determining the reliable heat flow value in the lake. Present paper reports the heat flow measured in this hole by the conventional land heat flow technique.

The temperature gradient was measured by a thermistor thermometer with a 500 m insulated cable and the thermal conductivity of the sediment cores by von Herzen-Maxwell type needle probe method. The temperature measurement in the borehole was conducted six times during the drilling period from November 1 through December 19, 1971 as shown in Table I, the results being summarized in Fig. 1, together with the results of thermal conductivity measurements of the cores. The water temperature at the bottom varied within a range of about 0.4°C during this period. This range of temperature variation was much smaller than that at the surface. The temperature variation in the upper 50 meter layer of the sediment, however, was greater than that at the lake bottom. During drilling, the lake water at a depth of about 10 m was circulated inside the casing of the borehole. Apparently the variation in the temperature of this circulating water affected the temperature in the upper-most part of the borehole. The temperature gradient in the upper 20 meter layer of the sediment is larger than that in the deeper part (Fig. 1). This is partly due to the thermal disturbance by the water circulated during drilling, and partly to the smaller thermal conductivity of the upper layer. It is also possible that the temperature of the lake bottom at the time of measurement was lower than its annual mean. However, the temperature gradient in the sediment layer deeper than 150 meter from the lake surface was fairly stable. The mean value of the gradient in the layer between 150 meters and 250 meters from the lake surface is 5.5 $\times 10^{-4}$°C/cm.

Thermal conductivity measurement was made on Dec. 31, 1971 on the cores which had been stored in a freezer. The cores were thawed before the measurements. Since the effect of freezing and thawing of sediments on their thermal conductivity is not known, this way of measurement was probably not satisfying. The thermal con-

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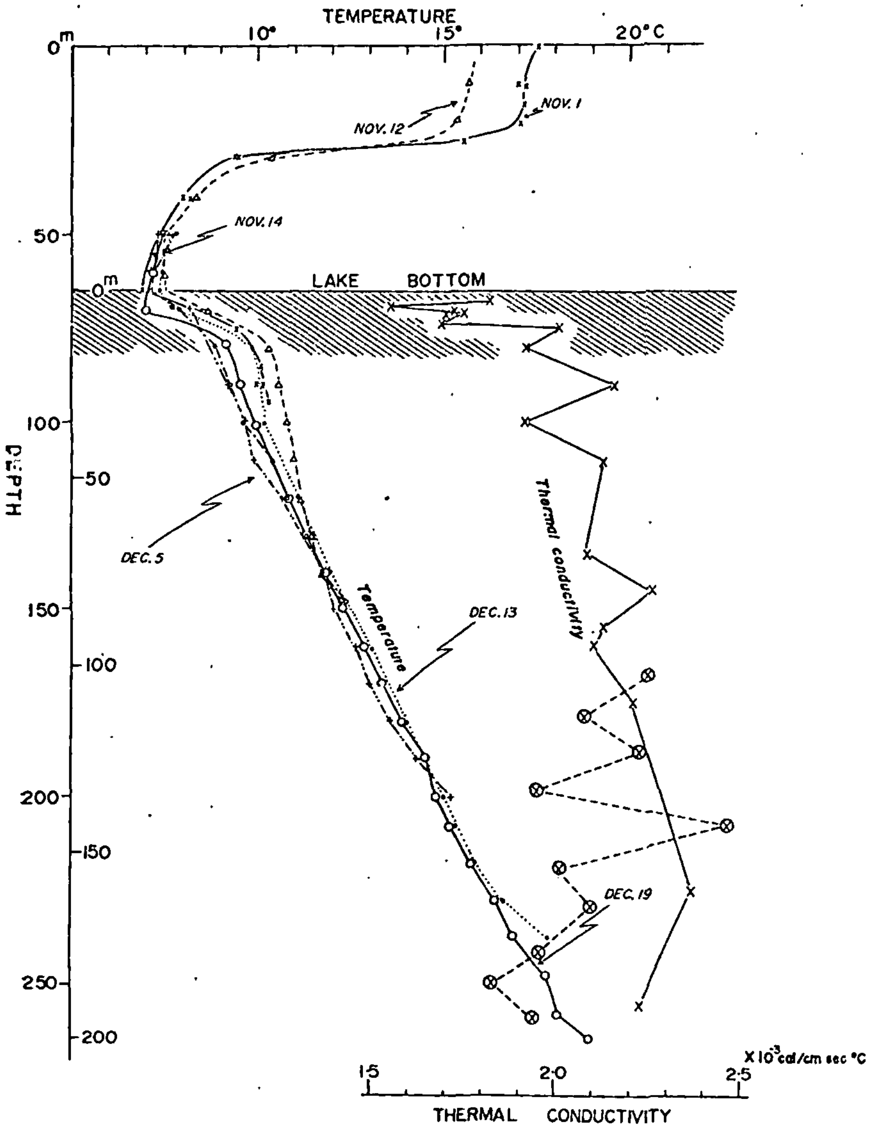

Fig. 1. Vertical profile of temperature and thermal conductivity in Lake Biwa.

ductivity of the sediments thus measured, however, appeared to have a systematic increase with depth (Fig. 1) ; especially in the uppermost layer, which may be less consolidated than the deeper layer. The mean thermal conductivity in the layer where the temperature gradient was established, i.e. the layer from 150 meter to 250 meter depths from the lake surface, is $2.20\pm0.09\times10^{-3}$ cal/cm sec°C. From these values, it was concluded that the magnitude of the heat flow value in Lake Biwa is 1.2×10^{-6} cal/cm^2 sec.

Table I. Temperature measurements in the borehole of Lake Biwa

Date	Depth of the borehole bottom		Time of measurements after cessation of drilling operation
	From the lake bottom	From the lake surface	
November 11	30 meters	95 meters	less than 1 hours
12	83	148	,,
14	83	148	2 days
December 5	143	208	1 day
13	174	239	20 hour
19	197.2	262.4	

Thermal conductivity measurement on the more cores was made on Dec. 13, 1972, i.e. about a year after the first measurement. The results of the later measurement are plotted in Fig. 1 by encircled crosses. For heat flow assessment, we used only the values obtained by the first measurement and included the later values only for reference, since the core specimens stored in a freezer for a year, during which an unwanted thawing and re-freezing took place, appeared to have changed their properties considerably: loss of water, for example, was apparent.

The value of heat flow might be affected by the existence of the lake itself (Lachenbruch, 1957, Johnson and Likens, 1967; Hänel, 1970). In the case of a circular lake, the following formula was derived for the steady-state anomaly (*dt/dz*) at the center (Lachenbruch, 1957).

$$dt/dz = -\frac{\Delta t}{R}\,\frac{1}{[1+(z/R)^2]^{3/2}}$$

where R is the radius of the lake, z is the depth below the lake bottom and Δt is the temperature difference between the lake and its surroundings at $z=0$. Though Lake Biwa can scarcely be considered to be circular in shape, the order of magnitude of the effect of temperature contrast between the lake bottom and its surroundings may be estimated by this formula as a first approximation. Putting $R=10^6$ cm, $\Delta t=10°C$ and $z=10^4$ cm, we obtain a magnitude of 10^{-5}°C/cm for the anomalous temperature gradient which is negligibly small compared with the measured temperature gradient.

The observed thermal gradient might be disturbed by the effect of drilling also. This problem is to be studied by comparing the gradient measured so far with what will be measured after the steady state is attained in future. For this purpose, a thermistor chain was put inside the borehole at the termination of the boring project.

Despite the possible disturbances caused by drilling and the uncertainty about the thermal conductivity as mentioned above, the magnitude of 1.2×10^{-6} cal/cm^2 sec is consistent with the heat flow distribution of the Japanese region obtained so far. Fig. 2 is the most up-date heat flow distribution taken from the Japanese UMP-Monograph (1972). Although final conclusion must await the steady-state data from the burried thermistor chain, it seems that the heat flow contour needs only a slight modification as indicated by the dotted curve in Fig. 2.

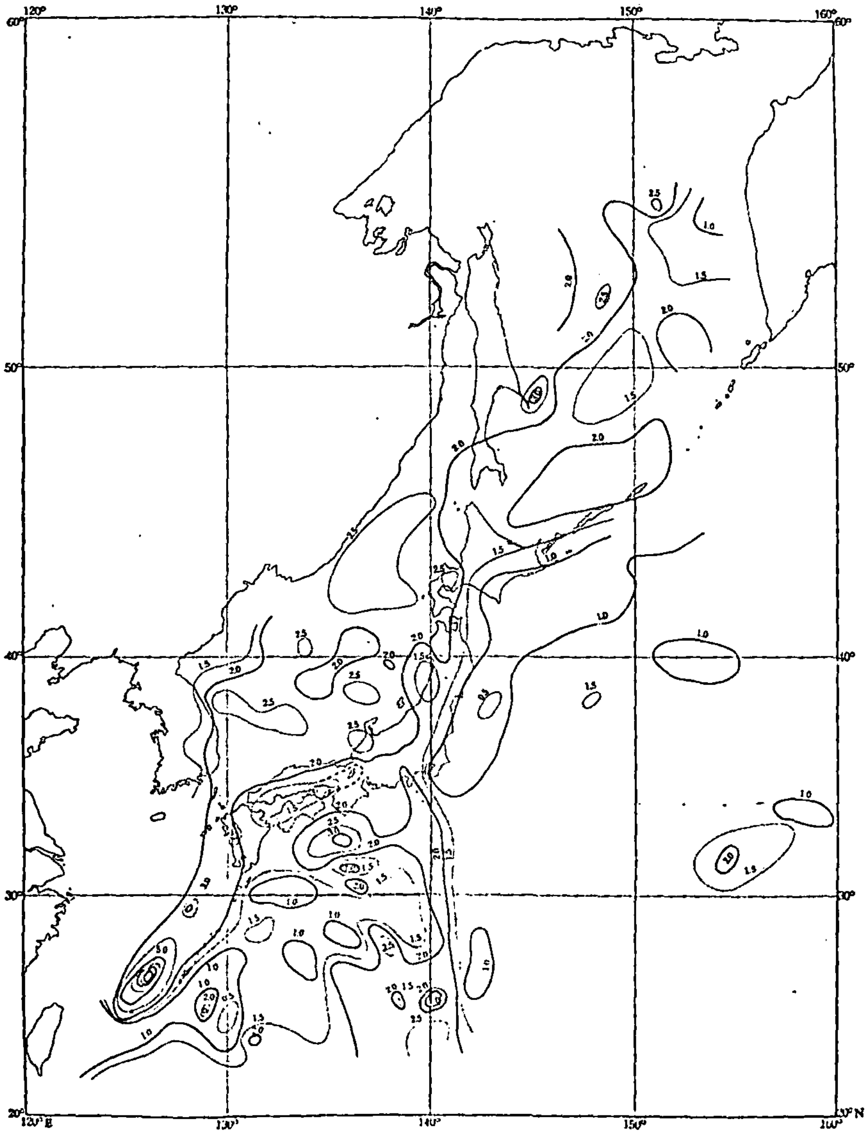

Fig. 2. Smoothed heat flow distribution in and around Japan derived from values averaged in one degree grid in the latitude and longitude.

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