UTILIZATION OF GEOTHERMAL RESOURCES OF KAMCRATKA, PROGNOSTIC ASSESSMENT AND FUTURE DEVELOPMENT

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ABSTRACT

The geothermal resources of high-temperature systems calculated by the volume method constitute a power potential of about 1130 MW_e for 100 years arid geothermal resources potential of the geothermal prospects with reservoir temperature blow 150 °C is about 1345 MW_t for 100 years. Four high-temperature geothermal fields have been partially evaluated. The Pauzhetka field is tho only one now used fot electric generatiori. The installed capacity of the geothermal power plant is 11 MW_e. The construction of the Mutnovskaya plant (the first phase about 80 MW_e) is in progress as well as the construction of hot water pipe line 80 km in length. Among 8 prospected geothermal fields with temperature below 150 °C, four are now used. The heat output relative to 35 °C is in average about 2×10^{15} J/year.

Key wurds: geothermal fields, geothermal resources, hydrothermal systems, heat discharge, Kamchatka

INTRODUCTION

Various types of geothermal resource's occur in the volcanic regions of Karnchatka. The most intense investigations of geothermal resources were carried out during the last thirty years. This is related to their possible utilization Fur heat or electric power supply as an alternative for fossil field consumption.

In Kamchatka, electrical power from geothermal energy was first produced in the region of the Pauzhetka hot springs where 5 MW_e (presently 11 MW_e) geothermal electricity generating plant has been operating since 1967.

Geothermal energy has found wide application in balneological treatment. A large demand for geothermal heat supply appeared in 1970, when the exploitation of hot waters From the Paratunka field began. 'This field of Kamchatka provided thermal energy for operation of greenhouses covering a total of 60,000 m^2 area.

In order to start production of electrical power, investigations were carried out on the large temperature anomalies, which received the names of related hydrothermal systems. Spatially restricted parts of such systems within which the commercial reserves of natural heat-carrying water or steam arc found and which meet consumer requirements are regarded as geothermal fields.

Studies of surface thermal manifestations and geological and geothermic features served as a basis for an assessment of geothermal resources potential. Our studies of the geothermal fields in Kamchatka made it possible to trace the relationship between the superficial heat and geochemical anomalies and the spatial position of geothermal reservoirs. This paper presents the results of an appraisal of the magnitude of geothermal resources, an evaluation of exploitable reserves (identified economic reserves proven hy boreholes) of various geothermal fields, data on utilization of the resources, and an estimate of the geothermal resource's base of Kanichatka. Data collected by the Institute of Volcanology, Kamchatgeolrigia and Kamchatburgeothermia Corporations were used for this study.

THF HEAT DISCHARGE OF NATURAL THERMAL ACTIVITY

It is known that in volcanic regions hot springs and other superficial therrrial manifestations are indicators fur the existence of geothermal reservoirs. The value of heat discharge bv superficial thermal manifestations (natural heat losses) defines the minimum, continuously supplied geothermal energy. The natural heat discharge of any hydrothermal system is determined by the sum of heat discharged by various types of thermal manifestations including heat discharged into surface waters, heat discharged from the surface of steaming ground and hot water pools and conductive heat losses through the covering rocks, which overlie a geothermal reservoir. The heat discharge is calculated with respect to the average annual surface temperature (0°C for Kamchatka).

Nearly all well-known hydrothermal systems and thermal manifestations are located in the East Kamchatka and Central Kamchatka volcanic belts. Approximately 150 groups of hot springs with different temperatures arid different chemical composition of water, including 11 high temperature hydrothermal systems, are grouped together in four geothermal provinces (Fig. 1). The genthermal provinces are based on geological, structural and hydrogeological criteria. Main groups of hot springs and single hot springs are shown in Fig. 1.

There are 16 groups of hot springs in the North Karnchatka geothermal province. The maximum temperature of water (75 to 95 °C) has been observed in the Palanskiye and Rusakovskiye springs. Springs discharge nitrogen rich water containing predominantly calcium sulphate and sodium. The total mineralization is up to 1.2 g/l. The total heat discharge is 81.3 MW_t.

Twenty-six groups of hot springs, including two groups of boiling springs (Kireunskiye, Apapelskiye), are located in the Middle Kamchatka province. These springs discharge hydrocarbonate-sulphate waters, the boiling springs discharge chloride-sodium waters; the total mineralization is 1-2.5 g/l. The total heat discharge is 62.3 MW_t.

There are 52 groups of thermal springs in the East Kamchatka geothermal province. The majority are located in the East Kamchatka volcanic belt. Among them are the boiling springs and steam vents of superficial manifestations of large hydrothermal systems such as Uzon, Geysernaya and Semyachinskaya, each discharging 268, 321 and 314 MW_t, respectively (Fig.1). Boiling spring waters have sodium-chloride composition: the total mineralization is 2-2.5 g/l. Hot and warm springs with a temperature of 20-75 °C discharge sulphate or hydrocarbonate-sulphate-chloride waters with a

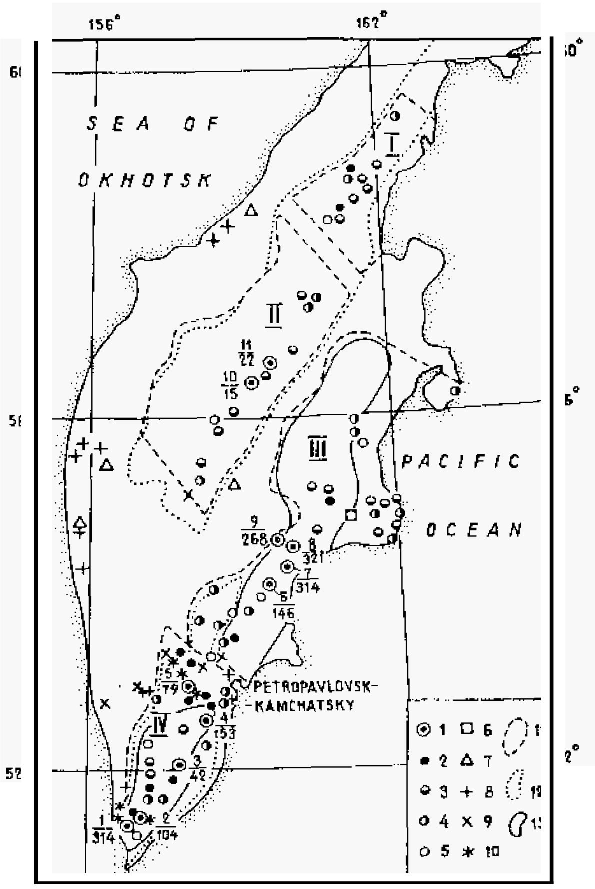

Fig.1. Map showing the location of the main groups of hot springs and hydrothermal systems of Kamchatka.
1 - high-temperature hydrothermal systems, digits in numerator designate the number in Table 2, except.ing Semyachinskaya - 7, Geysernaya - 8, Uzon - 9; digits in denominator designate natural heat discharge (MW_t): 2 tu 5 - temperature: 2 - 75 to 100 °C, 3 - 50 to 75 °C, 4 - 30 to 50 °C, 5 - below 30 °C; 6 to 10 - heat flow data (in Mw/m^2; Smirnov et al., 1991): 6 - less than 40, 7 - 40 to 60, 8 - 60 to 80, 9 - 80 to 100, 10 - 100 to 120; 11 - geothermal provinces: I - North Kamchatka, II - Middle Kamchatka, III - East Kamchatka, IV - South Kamchatka; 12 - Central Kamchatsky volcanic belt.; 13 - East Kamchatsky volcanic belt.

total mineralization of 0.8-7.0 g/1. The heat discharge reaches about. 1247 MW_t.

In tho South Kamchatka geothermal province there are 55 various hot springs, including those related to the high temperature hydrothermal systems such as Mutnovskaya, Bolshe-Bannaya, Pauzhetskaya, and Koshelevskaya. Most hot springs with temperatures of up to 100 °C art characterized by sulphate and chloride-sulphate waters with a total mineralization of 0.8-1.2 g/1. The Pauzhetka and Khodutka hot waters have chloride-sodium composition. The total hot water heat discharge is 923 MW_t.

The surface thermal manifestation of Kamchatka discharge a total of 2314 MW_t of which 1782 MW, (77 %) is discharged by high temperature systems. Most of these (9 of 11 identified) are confined to the East Kamchatsky volcanic belt.

ESTIMATION OF GEOTHERMAL RESOURCES

Geothermal resources represent the heat which is encompassed in the crust and which is contained in rocks and thermal waters heated by conductive and convective heat transfer. In Russian its appropriate name is natural or geological resources. Previously White and Williams (1975) and Muffler and Cataldi (1978) defined it as geothermal resources base.

In this paper we consider mainly the geothermal resources of high temperature hydrothermal systems, which are now actually utilized or may be utilized in heat-energetic installations.

To assess geothermal resources, hydrothermal convection systems were conventionally divided into high temperature (reservoir temperature is above 150 °C) and low temperature systems having reservoir temperature below 150 °C. Geothermal fields associated with hydrothermal systems were classified correspondingly. Assessment of the potential of geothermal resources of hydrothermal convection systems (prognostic resources in Russian terminology) defined by Muffler and Cataldi (1978) in terms of an accessible resources base was made predominantly from surface survey data, therefore their quantity are defined as probable resources.

Geothermal resources, the assessment of which is made from drilling data and from data on exploitation of geothermal prospects are considered as exploitable reserves (in Russian terminology) depending on the present state of study and represent part of the potential of hydrothermal convection systems. Muffler and Cataldi (1978) call them identified economic reserves; they apparently correspond to proven reserves and in part to inferred reserves in Donaldson and Grant's (1978) definition.

The geothermal resources derived from prospecting and exploitation of geothermal fields (exploitable reserves) and their utilization is given table 1. Pauzhetka geothermal field is given as an example assessment of geothermal resources. During 1958-1963, 21 wells were drilled in a 0.7 km^2 large discharge ares of the Pauzhetka boiling springs located in the valley of the Pauzhetka River(Figs. 1 and 2). The total withdrawal of 124 kg/s of steam-water mixture at pressures of 0.8 MPag and mean enthalpy of 710 kJ/kg was validated as exploitable (proven) reserve. This flow ensures operation of a geothermal power plant with a capacity of at least 5 MW_e. A geothermal power plant with an installed capacity of 5 MW_e has been operating here since 1967. During the reconnaissance studies the natural heat discharge was estimated. The total discharge of fluids proved to be 100 kg/s and the natural heat discharge was 62.8 MW_t (Piip, 1965). Natural heat losses of 42 MW_t were determined for thermal manifestations of the Kambalny Ridge, which belong to the Pauzhetka hydrothermal system. Thus, the overall natural heat losses in the Pauzhetka geothermal system were estimated to be about 104 MW_t. In 1970, prospecting drilling of deeper wells was continued in the southeastern part to increase the capacity of the geothermal power plant. 57 wells, including 24 production and 12 reinjection wells, have been drilled (Table 1)

Experimental output at the flow rate of about 330 kg/s and enthalpy of 778 Kj/kg can be regarded as a new exploitable reserve of the field. On the basis of these data, the installed capacity of the Pauzhetka geothermal power plant was increased to 11 MW_e. Using data from additional reconnaissance and exploitation of the *Pauzhetka geothermal field, the mass flow potential according to modeling data obtained* during a 30-year period of exploitation, was determined to be 400 kg/s of fluid. These reserves will maintain operation of a geothermal plant with a maximum capacity of 17 MW_e (Kiryukhin and Sugrobov, 1987).

Table 1. The geothermal resources obtained during prospecting and exploitation of geothermal fields in Kamchatka (exploitation reserves) and their utilization

No. in Fig. 2	Geothermal field	Temperature measured at different depths in production wells (°C)	Dissolved solids of fluid at wellhead (g/l)	Wellhead pressure (MPag)	Sum of mass flow (kg/s) / enthalpy (kJ/kg) or wellhead temperature (°C)	Exploitation reserves (kg/s) / enthalpy (kJ/kg) or wellhead temperature (°C)	Mean yearly heat output relative to 35° (1.10^{15} J)	Number of drilled wells / depth range (m)	Number of production wells / depth range (m)
High-temperature fields (reservoir temperature above 150 °C)									
1	[1]Nizhne-Koshelevskoe	231-240	0.05	0.1-1.6	24.4 / 2800	-	-	13 / 170-1530	5 / 170-1000
2	[2]Pauzhetka	170-220	2.67-3.47	0.05-0.8	600 / 760-800	330 / 790	-	79 / 220-1205	7 / 405-1205
4	[3]Severo-Mutnovskoe	228-310		0.1-1.6	311 / 1000-2760	107 / 2760	-	56 / 255-2100	17 / 466-2100
5	[4]Bolshe-Bannoe	148-171	0.8-1.5	0.02-0.35	285 / 661	6157 / 661		50 / 33-1015	15 / 51-1015
Geothermal prospects with a reservoir temperature below 150°C									
15	[5x]Anavgaiskoe	68-78	1.6	-	-	39 / 76	0.18	14 / 285-1228	6 / 336-1228
16	[5]Esso	52-78	1.6	-	-	240 / 75	0.78	14 / 258-1015	9 / 258-1015
17	[4]Pushchinskoe	-	6.0	-	-	33 / 63	-	8 / 502-1004	1 / 796
19	[4]Malkinskoe	78-88	0.7-1.0	-	28 / 80	-	-	10 / 201-603	-
21	[6]Nachikinskoe	8.0-84.5	1.2	-	-	13.6 / 73	-	4 / 90-320	4 / 90-320
22	[4]Yuzhno-Berezhnoe	-	-	-	14.2 / 42-72	2.1 / 70	-	14 / 1015-1572	1 / 1452
23	[7]Paratunskoe	70-106	0.9-2.1	-	/ 83-97	270 / 75	1.29	72 / 154-1504	41 / 154-1504
24	[4]Verkhne-Paratunskoe	70-106	0.9-2.1	-	/ 95	250 / 80	1.37[8]	48 / 307-1757	-

Note: Data obtained by "Kamchatgeologia" and "Kamchatskburgeotermia" Corporation are used. 1 - Geothermal resources are not used the project of hot water (26 Gcal/h) and steam (7.2 t/h) popeline about 22 km to settlement Ozernovsky is in progress (Company KAMES; 2- 11 MW_e generating plant is in operation. Heating of village; 3 - geothermal power plant with a capacity of 80 MW under construction; 4 - geothermal resources are not used; 5 - heating of dwellings and greenhouses; 6 - heating of health resort., balneological treatment; 7 - heating of village, 3 ha of greenhouses, health resort; 8 - Planned heat extraction.

PROGNOSTIC GEOTHERMAL RESOURCES (POTENTIAL RESOURCES)

Geothermal resources related to heat stored in rocks and based on conductive transport of heat (Diment et al., 1975) are defined as a geothermal resources base (Muffler and Cataldi, 1978). Of most interest are the regions of active volcanism, since the large thermal anomalies (hydrothermal systems and magma chambers) existing here may provide a wide development of geothermal power plants and systems of geothermal heat supply. The possible magnitude of geothermal energy was deduced previously on the basis of heat evaluation within the first, 10 km thick layer (Sugrobov, 1982). The total heat energy stored in rucks war found to be of the order of 5.2×10^{23} J.

Heat generated by shallow magma chambers is regarded by the author (Sugrobov, 1982) following Smith and Shaw (1975) as a geothermal resource potential. Since the problem of extraction of stored heat from rocks and magma chambers is poorly understood, our assessment will be only an order of magnitude estimate. Of all the magma chambers of Kamchatka lying at a depth down to 10 km (these objects are of interest from the point of view of possible heat energy recovery), those most appropriate for heat energy extraction are shown in Fig. 2. Only the intermediate chamber of the Avachinsky volcano has been studied by geophysical methods in detail (Fedotov et al., 1975). The volume of the Avachinsky magma chamber reaches 50 km^3. Its stored thermal energy is 1.2×10^{20} J, if we take the heat liberated to be 2.4×10^{18} J/km^3 caused by the decrease of the temperature of the chamber from 850 °C to 300 °C (Smith and Shaw, 1975). In calculating the stored thermal energy of other volcanoes (21 in total), the volume of

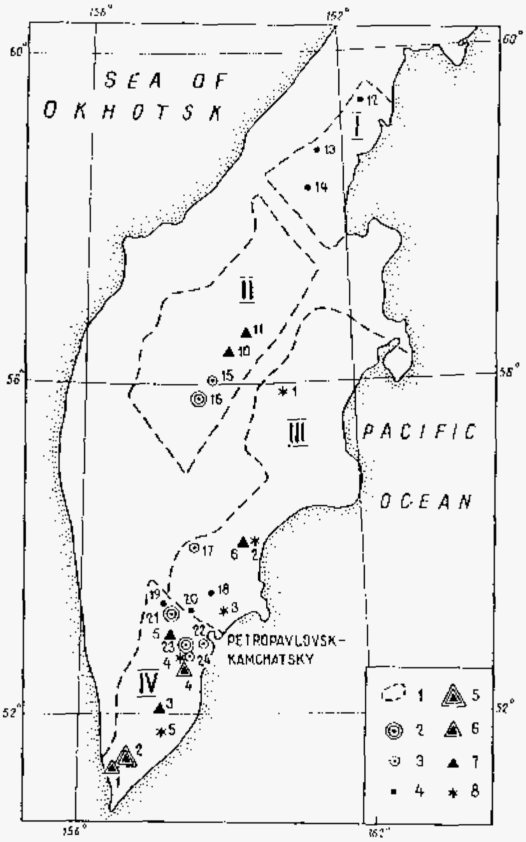

Figure 2. Map showing the location of the geothermal fields of Kamchatka considered for further prospecting and exploitation (see Table 1-2).
1 - geothermal provinces (same as in Fig.1). Symbols 2 to 4 - low-temperature geothermal fields (with temperature below 150 °C); 2 - operated; 3 - studied; 4 - considered €or prospecting: 12 - Tumlatskoye, 13 - Palanskoye, 14 - Rusakovskoyc, 15 - Anavgaiskoye, 16 - Esso, 17 - Pushchinskoye, 18 - Nalychevskoye, 19 - Malkinskoye, 20 - Pinachevskoye, 21 - Nachikinskoye, 22 - Yuzhnoberczhnoye, 23 - Paratunskoye, 24 - Verkhne-Paratunskoye: symbols 5 to 7 - high-temperature fields: 5 - operated, 6 - studied, 7 - considered for prospecting (numbers of fields marked by symbols 2 tu 7 correspond to the number of each prospect in Table 1-2); 8 - volcanoes and calderas with near-surface magma chamber: 1 - volcanic rift in the region of Tolbachik volcano, 2 - Maly Semyachik, 3 - Avachinsky, 4 - Gorely, 5 - Ksudach caldera.

their magma chambers was taken to he 20 km^3, excluding the volcanic rift of the Tolbachik volcano. The order of magnitude of stored thermal energy of the Kamchatka magma chambers is estimated to be 1.2×10^{21} J.

The minimum value of geothermal resource potential of high-temperature hydrothermal systems can be determined from the value of natural heat supplied to the surface. Table 2 provides the measured values of the natural discharged for a rough assessment, of geothermal resources of high-temperature hydrothermal systems. The actual extractable resources, as was established from prospecting data obtained in the Pauzhetka and Bolshe-Bannoe geothermal fields, exceed the natural heat discharge more than three times.

Geothermal resource potential calculated using the value of natural heat discharge with Increasing empirical coefficient 4 gives only an idea of the order of magnitude. This assessment was obtained at earlier stages of study before drilling.

The geothermal resources potential calculated for high-temperature systems, excluding Ceysernaya, Semyachinskaya and Uzon located in the Kronotsky Preserve, was equivalent to an electrical power potential of 550 MW,.

Assessments of geothermal resource potential calculated by the volume method (Muffler and Cataldi, 1978) are probably more reliable. In order to make assessments by this method it is necessary to evaluate the heat energy contained in the reservoir rocks saturated with fluid. volumes of the block, layer or reservoir of heated rocks, their temperature and volumetric specific heat of rock plus water.

Data required for evaluation of reservoir thermal energy were taken from Muffler (1979). Tn determining the volume of the reservoir, its thickness was assumed to be the same (2.5 km) for all systems, proceeding from data that roof lies at a depth of 0.5 km and that the economic base depth of a system is 3 km. Therefore the volume of the reservoir was calculated using the area of the reservoir. The temperature in the interior of the systems, using data of heat flow measurements, data from measurements in wells, and geothermometer data, varied from 150 °C to 220 °C for hot water systems and from 200 °C to 310 °C €or vapor-dominated or two-phase systems. However, The distribution of temperatures within a geothermal reservoir for most of the systems is not yet known. We have taken the temperature of 200 °C for all hot water systems and 220 °C €or vapor-dominated or two-phase systems as the calculation temperature.

Specific heat capacity rocks, chiefly volcanics and volcanic-sedimentary rocks. saturated with water and steam was taken to be 2.7 J/cm^3 K (Muffler, 1979). Also a5 in Muffler (1979), the reservoir heat eneryy extraction coefficient was assumed to 25 % and the ratio of the reservoir heat energy to utilization was such as 0.057 and 0.061 for reservoirs with mean temperatures of 200 °C and 220 °C, respectively. Utilization factor was assumed to be 0.4 for hot water- systems and 0.5 for vapor-dominated systems.

Data for calculation of power potential for the high-temperature systems are shown in Table 2. The heat potential of all high-temperature geothermal fields, except fnr the Semyachinskaya, Uzonand Geysernaya hydrothermal systems which are located in the Kronotsky Preserve are equivalent to an electrical power potential of the order of 1130 MW for 100 years. The prognostic capacities calculated with the natural heat losses have the same order of magnitude.

The chemical and gas composition of the fluids can be seen from the real fluids compostion from fields with discharging wells and not springs, which approximately reflect the composition of geothermal reservoir fluids. Heat energetic parameters of hydrothermal systems and geothermal fields studied through drilling were determined using actual measurements (see Table 1). Large geothermal fields with temperature at depth of below 150 °C also are the areas of low-temperature systems. Numerous thermal springs with temperature of 20-95 °C point to their existence (Fig.1). Assessment of their potential was based on heat energy stored in rocks of the reservoirs. Volumes were chosen by analogy with the prospected fields and regard to the character of distribution of the superficial thermal manifestations, their thickness and characteristic features of geological structure, Data used for assessing the geothermal resources potential, which are promising fur utilization

Table 2. The geothermal resources of high-temperature hydrothermal systems and geothermal fields of Knmchatka

No (see Fig. 2)	Hydrothermal system and fields	state of thermal fluids at the surface	Natural heat discharge (MW$_t$)	Inferred area of thermal manifestations (km^2)	Inferred reservoir volume (km^3)	Inferred mean temperature in reservoir, maximum temperature in well* (°C)	Mean reservoir thermal energy (10^{18} J)	Electrical energy potential (MW$_e$ for 100 yr)
1	Koshelevskaya system	Superheated and saturated steam	314[1)]	15±4.5	37.5±11.2	220	22.27±6.7	215±64
	Nizhne-Koshelevskoe		104[1)]	7±2.1	17.5±5.2	220-240*	10.39±3.11	100±30
2	Pauzhetka system	Saturated steam and water	104[1)]	18±5.4	45±13.5	200-220	25.78±7.73	186±56
	Pauzhetka field		62.8[1)]	7±2.1	17.5±5.2	200-218*	9.45±2.83	68±20
3	Khodutkinskaya system	Hot, water, springs 88°C	42[2)]	12.0±3.6	30±9	200	16.2±4.8	117±i35
4	Mutnovskaya system[6)]	Superheated and saturated steam	546[1)]	32±9.6	80±24	220	47.52±14.2	460±138
	North-Mutnovskoye field		129[1)]	12±3.6	30+9	220-301*	17.82±€5.3	172±52
5	Bolshe-Bannoe	Water (boiling)	79[2)]	6±1.8	15±4.5	171-200'	8.1±2.43	58±17
6	Karymskaya system	Water (boiling)	146[3)]	15±4.5	37.5±11.2	200	20.25±6.1	146±44
10	Apapelskaya system	Water (boiling)	16[4)]			200		
11	Kireunskaya system	Water (boiling)	24.5[5)]	7±2.1	17.5±5.2	200	9.45±2.83	h8±20

Notes: The data were taken from: 1 - Sugrobov, 1976; 2 - Kirsanova and Melekestsev, 1984; 3 - Pilipenko, 1989; 4 - Piip, 1937; 5 - Kirsanova, 1971; 6 - The natural heat discharge (546 MW$_t$) includes the discharge from north crater of Mutnovsky volcano (393 MW$_t$) and those from Nizhnezhirovskie and Voinovskie not springs (24 MW$_t$).

of geothernial prospects with reservoir temperature of below 150 °C is shown in Fig.2. Calculation of heat stored in rocks and of recoverable heat was made according Lo Muffler (19791. Assuming that the therrial waters are used directly, the beneficial heat of prognostic natural resources may be calculated by introducing the beneficial heat. utilization factor, which is equal to 0.24. Assessment of geothermal resources of all prospects showed in Fig.2 giver: a value of 1.718 x 10^{18} J, which during a 100-year period of utilization constitutes a thermal power potential of 545 MW$_t$. The total heat discharged by superficial thermal manifestations of these fields is 137 MW$_t$.

In total, 43 hydrothermal systems are recognized within four geothermal provinces. They are poorly studied, therefore assessment of heat energy and geothermal resource potential were based on approximate parameters. By analogy with the Paratunskoye prospect (Table 1), a rather large volume of reservoir was defined for the four hydrothermal systems. By analogy with the Malkinskoye prospect (Table 1) 26 systems were found to have a reservoir volume of about 3.7 km^3 each. The mean temperature was taken tu be 100 °C for all systems. The value of beneficial heat of these systems is 2.53 x 10^{16} J, whir-h, over a 100-year period of utilization, is 800 MW$_t$. The geothermal resources of prospects with temperature of below 150 °C are determined thereby to be 1345 MW$_t$.

CONCLUSIONS

Assessment of geothermal resource?; of Kamchatka and of hydrothermal convection systems were based on the material published before 1990. More valid are our assessment of geothermal resources of high-temperature hydrothermal systems; they are brtter studied as they are feasible electrical energy sources. Four fields, Pauzhetka, Bolshe-Bannoye, Nizhne-Koshelevskoye and Mutnovskoye, have been studied by drilling. The state and assessment of the resources of these fields are given in Tables 1 and 2.

Various information obtained at different. times beginning from the 1960's have been used in this paper. Assessment of geothermal resources and methods of study changed with time. At, first, our assessment. of the potential of geothermal resources based on natural heat discharge was 350 MW, for 30-100 years.

In the present paper, the geothermal resource potential of hydrothermal systems was calculated mainly by the volume method (Muffler and Cataldi, 1978). Mean reservoir thermal energy of high-temperature systems ($150x10^{18}$ J), not takiny into account the Semyachinskaya, Uzon and Geysernaya systems located in the Kronotsky Preserve, can probably support operation of geothermal power plants uith a total rapacity of the order of 1130 MW_e for 100 years. The geothermal resource potential of hydrothermal systems and prospects uith reservoir temperature below 150°C is about. $4.2x10^{18}$ J (beneficial heat), which is equal to 1345 MW_t, for 100 years.

Geothermal resources of high-temperature systems, calculated from natural heat loss data, except for three systems located in the Kronotsky Preserve. are estimated to be 550 MW_e. It should be emphasized that assessments of geothermal resources of hydrothermal systems yield only order of magnitude estimates because of lack of geological data, that makes it impossible to precisely determine the main characteristics of geothermal reservoir::. Revised assessment of geothermal resources can he made €or two prospects, Pauzhetka and Mutnovskoye, using exploratory data. It is obvious that. the capacity of the Pauzhetka prospect (Kiryukhin and Sugrobov,1987; Tables 1 and 2) is *less* than the geothermal resource potential. Since the Pauzhetka prospect is part. of the Pauzhetka system, not studied by drilling ax yet, the assessment of its geothermal resource potential is taken as the base. It is also premature to estimate the geothermal resource potential of the Mutnovskaya system before completion of on-going prospecting. Greater uncertainty is associated with assessing a geothermal resource potential for prospects with temperature below 150°C because of a greater variety in the types of prospects.

Based on heat flow measurements, the geothermal resource base of Kamchatka, calculated for depth intervals of 1-10 km is $5.2x10^{23}$ J, and stored thermal energy of Kamchatka magma chambers is $1.2x10^{21}$ J.

Now only a small part of the geothermal resources is used. Four high-temperature geothermal fields namely Pauzhetka, Mutnovskoye, Bolshe-Bannoye and Nizhne-Koshelevskoye were already evaluated. The Pauzhetka field is the only one now used for electric generation. The installed capacity of the plant is 11 MW. The construction of the Mutnovskaya plant (the first phase, about 80 MW_e) is in progress as well as the construction of hot water pipe line about 80 km in length from the plant to the town of Elizovo . The project of hot water 125 Gcal/h) and steam (7.2 t/h) pipe-line about 22 km from Nizhne-Koshelevskoye field to settlement. of Ozernovsky is in progress. Among 8 prospected geothermal fields with temperature below 150°C, the Paratunskoye, Nachikinskoye, Esso and Anavgaiskoye ones are now used. The heat output relative to 35°C is on average about $2x10^{15}$ J/year, . The known and new opened high-temperature geothermal fields are the best objects for electric power generation and the construction of the heat supply systems. The other fields producing the fluids with T<150°C can used *for* supplying heat €or greenhouses and for construction of small binary-cycle installations, €or example the unexplored Palanskoye and Rusakovskoye fields in the Northern Kamchatka.

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