GEOTHERMAL RESOURCES OF RUSSIA

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ABSTRACT

The report is a work of creative collectives a SPSMI (TU) and FSUE "Entrailses" during more than 30 years. The offered classification of geothermal resources. It contain the conceptual device and their differentiation by principles of industrial development and technology of developmentworks. The features of geothermal resources, as one of sources of energy, their basic advantages and lacks are allocated. The techniques of a geology - economic rating and districtses potential (common) and separately rock and hydrogeothermal resources for different stages and directions of their development are briefly described. The quantitative rating of geothermal resources of the allocated categories, their districts and drawing up of maps in territories of Russia and its perspective regions (outside the report - for all others countries, wich formed USSR) is executed. In the report are tables and maps summing results of this geology - economic rating and allowing to administrations, businessmen and investors are submitted to have the resource, technological and economic characteristics of a geothermal source of energy in any area and for any consumer not from Russia's territory. The basic emphasis is naturally made of needs of a heat supply. All offers, wich state in the report, technique both the development have a world and domestic priority.

1. INTRODUCTION

The traditional sources of energy have the limited and not renewed stocks. During 20-30 last years actively grow rates of manufacture in the world and use of nonconventional power resources: geothermal, solar, wind, bioweight etc. The forecast of their development shows, that in world's balance of consumption of energy by 2030 their share can make up to 15 % and it will be increased progressive. A practical inexhaustibility, distribution in all territories, ecological cleanliness and other advantages allow to consider, that the future of mankind is these sources.

The special place is borrowed by geothermal resources. They exceed in 10 times total resources of organic fuel in the world. On the Russia's territory the prognosis geothermal resources on accessible depths (up to 5-6 km) in 4-6 times exceed resources of hydrocarbons and by a rating a SPMI (TU) and a FSUE "Entrailses" for needs of a heat supply are 57 bills. t o.e., including for heating are 31 bills. t o.e. [1,2].

2. CLASSIFICATION AND SPECIFICITY OF GEOTHERMAL RESOURCES

2.1. Classification and conceptual device of a rating of geothermal resources

Considering a thermal energy of entrailses, as useful mineral, it is necessary to determine quantitative, qualitative, economic and its social importance. The geothermal resources, in connection with the specificity, and main, their alternative, for the foreseeable period, purpose require obligatory realization of an economic rating. As against existing domestic and foreign methods of expert quantitative ratings, in the St.-Petersburg state mining institute (Technical university) - SPSMI (TU), former LIE, the basic concepts were developed and the first technique of a geology - economic rating of geothermal resources is created [1-7]. The progress in this direction achieves as a result of joint researches a SPSMI (TU) and FSUE «Entrailses». In development of former sight the classification and technique of a rating of geothermal resources were change [8-10].
Concept «geothermal resources » during a long years was debatable. Offered on start [1-5, 11] the definition: "*is a quantity of heats, wich contain in a lithosphere or its sites, up to depth, technically by achievable means of drilling for the prognosis period* ", for past 30 years has not caused the proved radical objections and, apparently, can be considered recognized.
According to the developed classification *potential* (**P)** geothermal resources, in view of mining - geological conditions, degree of industrial development, technology of production and use of heat of entrailses, it is possible to divide into two groups (fig. 1):

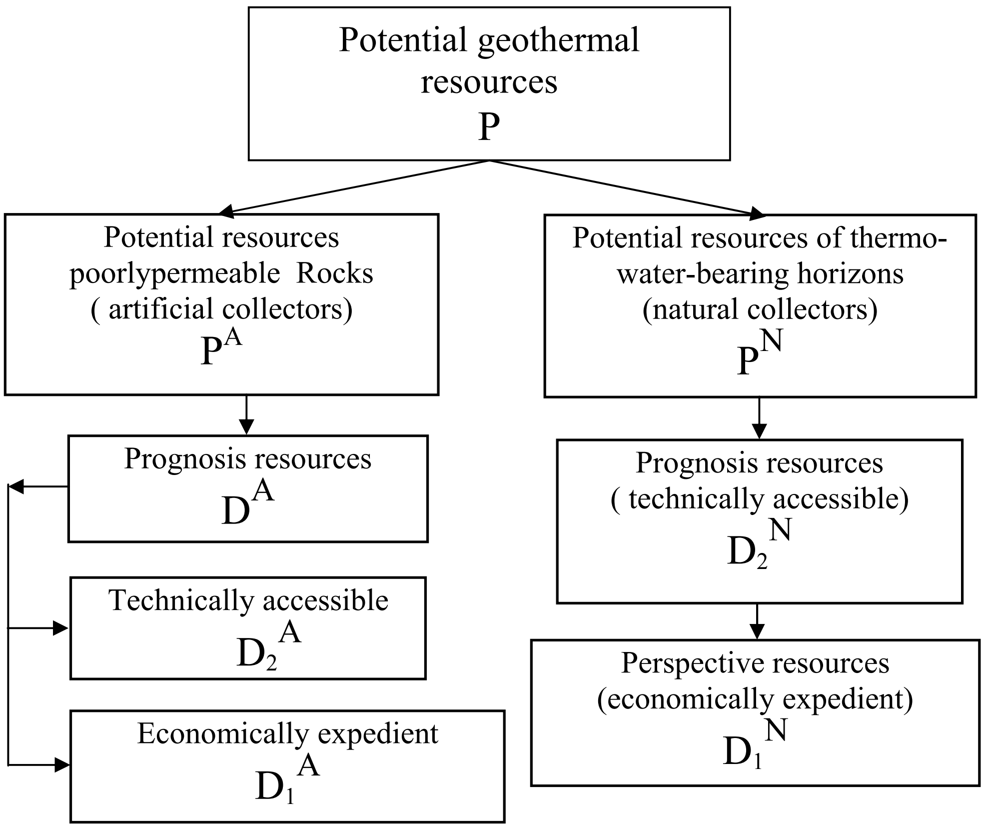


Figure 1. Classification of geothermal resources in view of an industrial opening up of technology of their development.

a) Geothermal resources of poorlypermeable mining rocks - rockgeothermal ($\mathbf{P}^A$). Their common potential is determined as the contents of heat in a thickness of a lithosphere on limiting depth of drilling (10 km) with cooling of rocks up to temperature of an environment of the consumer. The technology of their extraction is at an experimental level, the skilled circulating systems with artificial collectors are created only.

б) Geothermal resources of natural collectors - *hydrogeothermal* ($\mathbf{P}^N$). Their potential is determined as the contents of heat in total capacity of permeable layers on depth of sedimentary rocks of a cover (with the heat conductivity additive from containing rocks) within the limits of opportunities of chisel engineering, at cooling them up to temperature of an environment. They are industrially maintained by circulating systems (France, USA, Germany, Denmark, Ukraine, Poland, Switzerland, Russia etc.).

The *prognosis* geothermal resources are a part of *potential rockgeothermal* or *hydrogeothermal* resources. The *prognosis rockgeothermal* resources of poorlypermeable mining rocks ($\mathbf{D}^A$) are divided into two groups:

1) *Technically accessible rockgeothermal resources* ($\mathbf{D}_2^A$) - are estimated as the contents of heat in thicknesses of rocks up to depth of industrial drilling (6 km), in view of factor of extraction. They are limited in the given temperatures of the consumed and fulfilled heat-carrier (for needs of a heat supply: 70/20 - for hot water supply, 90/40 - for heating), i.e. are characterized not only quantitatively, but also is qualitative.

2) The *economically expedient rockgeothermal resources* ($\mathbf{D}_1^{\mathbf{H}}$) - are estimated in view of a competition to manufacture of heat of boiler-house on organic fuel: the top border of a resource interval pays off in view of a heatting additional in peak boiler-house or thermal pumps, and bottom - on economic comparison with alternative boiler-house. Additional heating

Prognosis (technically accessible) the hydrogeothermal resources of natural collectors ($\mathbf{D}_2^N$) are estimated as the contents of heat in thermo-water-bearing layers limited in temperature of an environment and factor of temperature extraction. The heat conductivity inflow of heat from spreading and above laying rocks is in taken into account.

The *perspective (economically expedient) hydrogeothermal resources* of natural collectors ($\mathbf{D}_1^N$) are estimated as a part prognosis, which can be economically expediently extracted and is used at a modern technological level of development of a thermal energy of entrailses.

2.2. Specificity of geothermal resources

By comparison to traditional sources of energy wih geothermal resources are obvious *advantages*: an inexhaustibility, breadth of distribution, affinity to the consumer, localization of complete maintenance of the consumer by heat and electric power, regional belonging to local resources, complete automation, production of geothermal energy is safety and practical absense of people , economic competitiveness, opportunity and expediency of construction of low-power installations, ecological cleanliness.

But specificity of geothermal resources includes some *lacks*: low temperature potential of the heat-carrier on an exit from installation, No-transportable, difficulties of warehousing, dispersal of structures, limitation of industrial experience.

3. TECHNIQUE OF A RATING AND DISTRICTS OF GEOTHERMAL RESOURCES

3.1. Potential geothermal resources (P)

They characterize thermal potential of a thickness of rocks on prognosis depth up to 10 km. Density of distribution of resources ($\mathbf{Q}^{\mathbf{P}}$) is determined (1) proceeding from the precondition, that the file can be cooled up to temperature of an environment.

$Q^P = k\,c_v (H_{пр} - h_{нс})(T_{из} - t_{ос})$, t o.e. / m² (1)

Where k - factor of transition from a thermal energy to relative fuel, t o.e.. / J; c_v - volumetric heat capacity of rocks, J/m^3 0C; $H_{пр}$ - prognosis depth of drilling, m (10 km); $h_{нс}$ - capacity of a neutral layer, m; $t_{ос}$ - temperature of an environment; $T_{из}$ - average temperature of a file, ^{0}C:

$$T_{из} = 0{,}5\,(T_{пр} + t_{нс});\ \ T_{пр} = G\,(H_{пр} - h_{нс}) + t_{нс};$$

$t_{нс}$ - temperature of a neutral layer, ^{0}C; $T_{пр}$ - temperature of rocks on prognosis depth, ^{0}C; G - geothermal gradient, ^{0}C/m.

3.2. Rockgeothermal resources. A rating and districts

Prognosis rockgeothermal technically accessible resources of a geothermal heat supply $\mathbf{D}_2^A$ pay off in two modes determined by a consumer: a mode 70/20 ^{0}C - for a heat supply and 90/40 ^{0}C - for heating.
For a mode 70/20 ^{0}C density of resources of geothermal energy of a category $\mathbf{D}_2^A$ is defined:

$Q(D_2{}^u) = k\,\xi\,c_v\,(H_н - H_в)(T'_{из} - 20)$, t o.e. / m^2; (2)

Where ξ - factor of temperature extraction (ξ = 0,125); $H_н$ - bottom border of a resource interval, m ($H_н$ = 6000 m); $H_в$ - top border of a resource interval, m;
$H_в = (T_в - t_{нс})/G + h_{нс}$; $T'_{из} = 0{,}5(T_в + T_н)$, $T_в$ - temperature on the top border of a resource interval, ^{0}C. In a mode 70/20 ^{0}C for reception of the heat-carrier with temperature not less than 70 ^{0}C average temperature of a file ($T'_{из}$), in view of losses at transportation, should be not less than 80 ^{0}C. $T_н$ - temperature on the bottom border of a file of a resource interval. Proceeding from a rule(situation) $T'_{из} \geq$ 80 ^{0}C: $T_в = 2T_{из} - T_н$, then the minimal value $T_в = 160 - T_н$. At high values $T_н$ the restriction $T_в \geq 30$ ^{0}C is entered. Temperature on the bottom border ($T_н$) pays off under the formula: $T_н = G\,(H_н - h_{нс}) + t_{нс}$.
Density of resources of geothermal energy for a mode 90/40 ^{0}C of a category $\mathbf{D}_2^A$:

$Q(D_2{}^u) = k\,\xi\,c_v\,(H_н - H_в)(T'_{из} - 40)$, t o.e. / m^2 (3)

For maintenance of the heat-carrier with temperature 90 0C average a temperature of a file $T'_{из}$ should be not less than 100 ^{0}C. Given temperature on the top border of a resource interval ($T_в$) not less than 50 ^{0}C.
The *prognosis rockgeothermal economically expedient* resources of geothermal energy of a category $\mathbf{D}_1^A$ pay off in some stages. The depth of the top and bottom borders of a resource interval is determined on a level of expenses on reception of heat in fuel boiler-house. Therefore first stage of a technique is the definition of the given expenses on reception of the heat-carrier of the given quality in fuel boiler-house, the Heat productivity it as by base boiler-house in conditions of a heat supply of small areas is accepted equal 100 GJ/h.
The depth of the bottom border is economically caused by equality of one of the chosen economic criteria (further - given expenses) on reception of hot water in fuel boiler-house and production of

the geothermal heat-carrier, which quality (temperature) satisfies of the consumer. The given expenses for production of the geothermal heat-carrier are determined with the help received on the basis of economic-mathematical modeling the express train of a technique [12-14].
The depth of the top border of prognosis economically expedient resources is determined with equality of the given expenses on reception of hot water in fuel boiler-house and on production of the geothermal heat-carrier with a probable subsequent heatting additional it in peak boiler-house up to quality providing consumer.
Density of prognosis (economically expedient) resources of a category $\mathbf{D}_1^{A}$:

$$Q(D_1^{\,u}) = k\, k_u \xi\; c_v\, (H_э - H_в)(T_{из} - T_0),\ \text{т o.e. / m}^2 \qquad (4)$$

Where k_u - factor of extraction, pays off with the account Tи, and fuel heatting additional; $H_э$ and $H_в$ - economically justified depths of the bottom and top borders of a resource interval, m; T_0 - temperature of reset of the heat-carrier, ^{0}C.
The described logic and more than 60 dependences were formalized in economic-mathematical model of calculation of size of prognosis economically expedient resources. On the offered technique density was determined prognosis resources of a geothermal heat supply of two categories $\mathbf{D_2^И}$ and $\mathbf{D_1^И}$ of resources, for two temperature modes more than in 3000 items in territory of Russia. The received values for each item were born on a map of an actual material of scale 1: 10 000 000 and on the method of simple interpolation constructed system of isolines reflecting change of density of resources of a geothermal heat supply up to depth 6000 m.
The maps prognosis technically accessible (fig. 2) and economically expedient (fig. 3) resources of a geothermal heat supply are issued [15, 16].

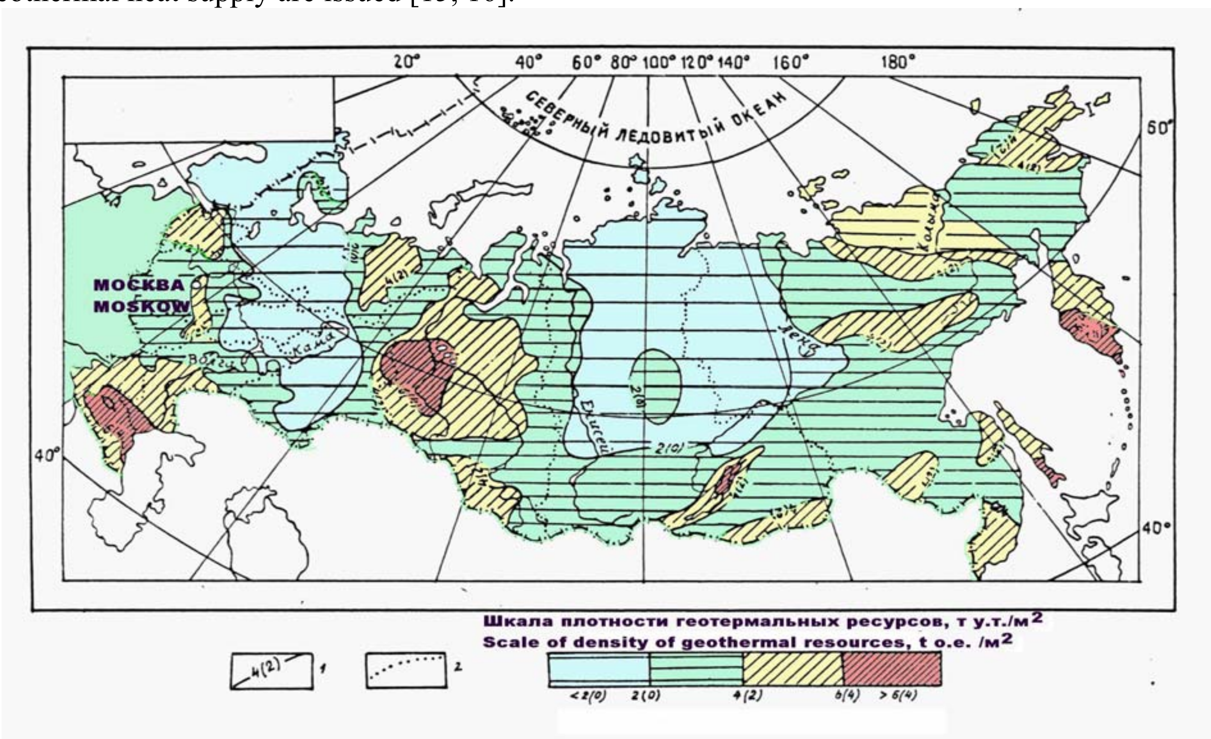


Figure 2. A schematic map prognosis, technically of accessible resources of a geothermal heat supply.

1. Isoline of density of resources of a geothermal heat supply, t o.e. /m^2. The designation - 4 (2) is deciphered: 4 - for a heat supply (mode 70/20 ^{0}C), 2 - for heating (mode 90/40 ^{0}C). 2. Border of economic regions of Russia.

The common potential resources of geothermal energy of a category **P** characterize raw base of geothermal power. Their common thermal potential is equivalent 1702 bills. t o.e. Counted up prognosis, technically accessible resources of geothermal energy of a category $\mathbf{D}_2^A$ have made for needs of a heat supply 70/20 ^{0}C - 56,9 bills. t o.e., including for needs of heating - 30,5 bills. t o.e. The energy potential technically of accessible, economically expedient and ecologically clean alternative source of energy for Russia makes 44,6 bills. t for needs of a heat supply (70/20 ^{0}C,) including for heating - 16,4 bills. t o.e. (tab. 1).

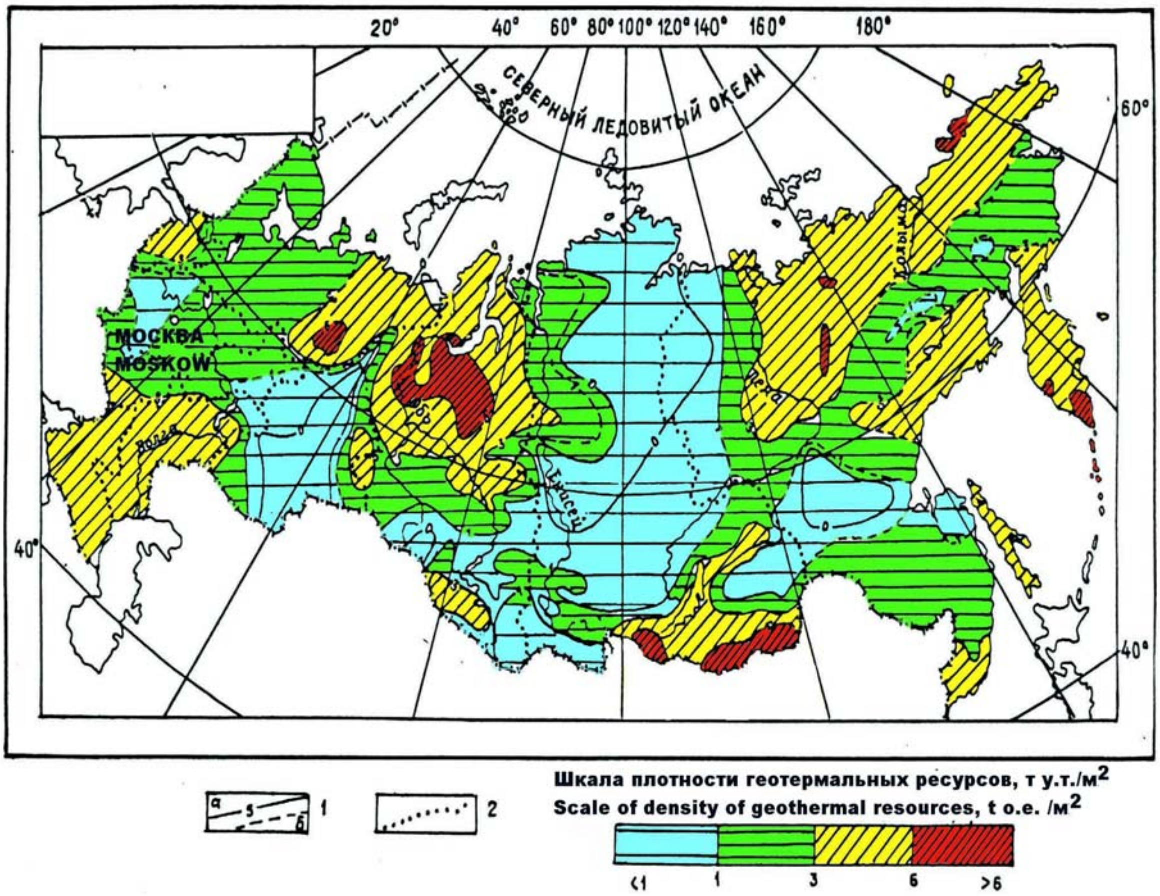


Figure 3. A schematic map prognosis economically expedient resources of a geothermal heat supply.

1. Isoline of density of resources of a geothermal heat supply, t o.e. /m^2 (mode 70/20 ^{O}C): a) authentic, б) assumed(prospective). 2. Borders of economic regions of Russia.

3.3. Hydrogeothermal resources. A rating and districts

The significant part of Russia's territory is characterized by presence low and mediumtemperature natural collectors. For their development the industrial circulating technology is created. However, even in scales of nonconventional power, its distribution extremely is limited.

As the basic obstacles of wide application of this technology it is possible to consider:

1) High requirements to the geology - geothermal characteristics of a natural collector - depth, temperature, capacity and permeability determining an economic feasibility of a geothermal heat supply;

2) Rather low temperatures of rocks of productive horizons causing of a peak heatting additional of the heat-carrier or at the expense of thermal pumps;
3) Ash value of distribution of geothermal resources under such technology.
In a SPSMI (TU) together with a FSUE «Entrailses» [4,5,9,13,17,18] the technique of a quantitative rating of geothermal resources of natural collectors is developed. The calculation of resources of a thermal energy of natural collectors is carried out for three categories of resources: potential – $\mathbf{P}^N$, prognosis - $\mathbf{D}_2^N$ and perspective - $\mathbf{D}_1^N$.
The potential hydrogeothermal resources – $\mathbf{P}^N$ are defined:

$$Q(P^e) = k \sum_{i=1}^{i=n} [c_{vi}\, m_i\, S_i\, (T_{пл\, i} - t_{oc})], \text{ t o.e.} \tag{5}$$

Where c_{vi} - volumetric heat capacity of rocks of each of productive layers, J / (m^3 ^{0}C); m_i - capacity of a layer № i, m; S_i - area of distribution of a layer, m^2; $T_{пл\, i}$ - average temperature of a layer № i, ^{0}C; t_{oc} - temperature of an environment, ^{0}C; n - quantity of thermo-water-bearing layers.
The prognosis hydrogeothermal resources - $\mathbf{D}_2^N$ are determined as the contents of heat in a layer by capacity - m, area - S, designed provided that the layer with average temperature $T_{пл}$ can be cooled up to temperature of an environment t_{oc}:

$$Q(D_2{}^e) = k\, \varepsilon_k\, \zeta_T\, c_v\, S\, m\, (T_{пл} - t_{oc}), \text{ t o.e.} \tag{6}$$

Where ε_k - factor of increase of resources at the expense of heat conductivity inflow of heat, wich dependent from capacity of a layer, temperature of rocks and other factors; ζ_T - factor of the temperature extraction determined in view of temperatures of the extracted and fulfilled heat-carrier; c_v - volumetric heat capacity of rocks average on capacity of a layer, J/(m^3 ^{0}C).
The rating of prognosis resources of geothermal energy of natural collectors ($\mathbf{D}_2^N$) enables to define the maximal security by geothermal resources by development of concrete layers, at circulating technology without account of expenses on reception of the geothermal heat-carrier.
The perspective hydrogeothermal resources - $\mathbf{D}_1^N$ are estimated in view of technological parameters of production of the geothermal heat-carrier, its economic parameters and conditions of the consumer. On the first evaluation stage of perspective resources their presence is determined. For this purpose on the basis of economic-mathematical modeling one of optimum general criteria pays off: the given expenses for production of heat by geothermal circulating systems $П_Г$, pure current cost NPV or other. It is compared to a parameter by alternative to fuel boiler-house, for example $П_А$. If $П_А > П_Г$, it is possible to speak about considered layers as a productive and pass to the further rating of resources of a category $\mathbf{D}_1^N$.
At the second stage temperature of the heat-carrier on an exit from system of a geothermal heat supply $t_{СГТ}$ and temperature given by the consumer - t is compared. If $t_{СГТ} > t$, the presence suitable to development of a geothermal deposit with a natural collector is ascertained and the calculation of resources of a category $\mathbf{D}_1^N$ follows. If $t_{СГТ} < t$, the efficiency of resources of a layer is estimated in view of a fuel heatting additional of the taken heat-carrier or its thermotransformation up to standard temperature.

In calculation of *perspective hydrogeothermal resources* $\mathbf{D}_1^N$ (7) factors of scope $k_{oxв}$, are characterized with distribution of filtration flows in a zone of selection of heat and degree of its cooling by the geothermal heat-carrier on the end of term of operation:

$$Q(D_1^e)=k\,\varepsilon_k\,\zeta_T\,k_{oxв}\,c_v\,S\,m(T_{пл}-t_{oc}),\ \text{t o.e.} \quad (7)$$

Table 1. Geothermal resources of territory of Russia

Regions	Potential, **P**, 1*10[12] t o.e.	Prognosis resources of a heat supply **D**, 1*10[12] t o.e..			
		Technically accessible, $\mathbf{D}_2$		Economically expedient, $\mathbf{D}_1$	
		70/20 ^{0}C	90/40 ^{0}C	70/20 ^{0}C	90/40 ^{0}C
Northern	132	3.7	1.1	3.4	0.95
Northwest	18	0.9	0.2	0.6	0.1
Central	35	1.5	-	0.99	-
Central-Chernozem	19	5.7	1.3	4.8	0.07
Volgo-Vjatsky	12	0.54	-	0.37	-
Povolgsky	59	2.7	1.49	2.1	1.37
North-Caucasian	45	1.86	1.35	1.6	0.97
Ural	64	1.2	0.36	0.6	0.18
Western-Siberian	258	9.8	7.4	8.2	3.8
East-Siberian	364	7.9	5.4	5.1	1.86
Fareast	696	21.1	11.9	16.8	6.15
Kaliningrad province	-	-	-	0.1	0.09
Total on Russia	1702	56.9	30.5	44.64	16.44

The executed rating of potential hydrogeothermal resources of Russia's territory (tab. 2) of a category $\mathbf{P}^N$ testifies to an opportunity of the essential contribution in fuel and energy base of the country.

4. THERMAL RESOURCES LOWTEMPERATURE NATURAL COLLECTORS OF THE MOSCOW SYNECLISE

As an example of a geology - economic rating of geothermal resources the geological formation - Moscow syneclise is considered. In its territory two basic thermo-water-bearing horizons are predicted: top - middle Devonian with depth of a bedding from 800 up to 1700 m and bottom - middle Cambrian on depth of 900-2300 m. At a rating of resources of geothermal energy of these thermo-water-bearing horizons as a basis the fact sheet received as a result of drilling and study more of 300 chinks in researched territory has served: temperature, depth, capacity and permeability of rocks of a collector:

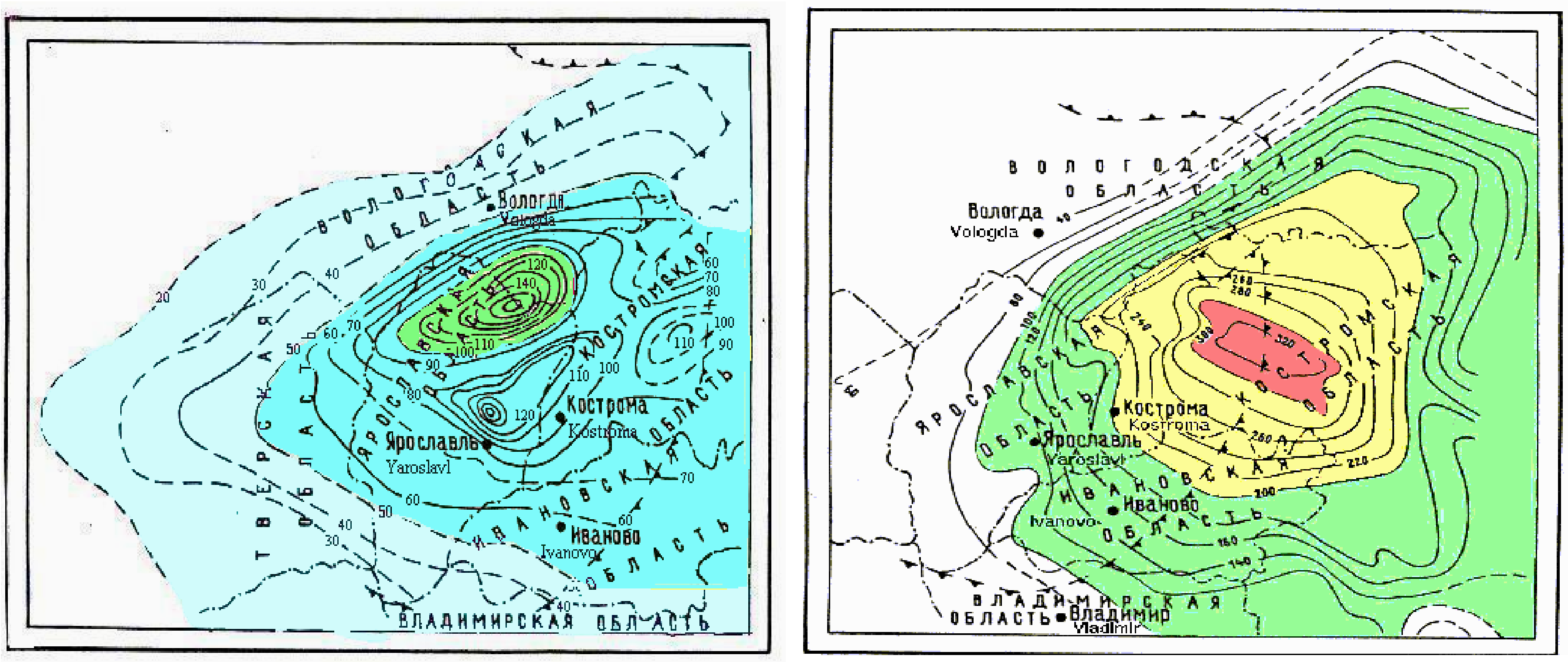
	Middle Devonian	*Middle Cambrian*
Temperature of a collector, °C	20 - 60	30 - 70
Effective power, m	70 - 250	20 - 65
Permeability, Dar	1,5 – 3,0	0,01 - 3,0

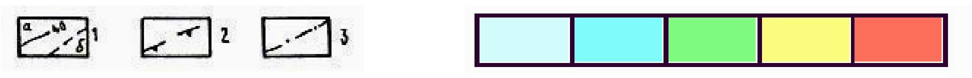
The resources of geothermal energy of middle Cambrian thermo-water-bearing horizon are located on 183,5 thousand km^2 of the area of the Moscow syneclise (fig. 4 a) and make 11 bill. t o.e., middle Devonian - on 221,7 thousand км2 (fig. 4 b) also is made by 33 bill. t o.e. (tab. 3). As the basic consumers of geothermal energy the systems of heating and hot water supply of urban, settlement and village objects were considered. Therefore accounts were carried out for three heats productivity of geothermal installations: 5; 25 and 100 GJ/h. The choice of temperatures of the heat-carrier directed to the customer, was determined from modes of operations of used heating devices. The set of settlement temperatures declared by the consumer, is accepted: 60; 70; 80 and 90 ^{0}C.

Table 2. Prognosis geothermal resources of natural collectors sedimentary pools of Russia.

№	Sedimentary pools	Scale of density of resources, t o.e. /m^2							
		0 - 2		2 - 4		4 - 6		Total	
		The area - S, thous. km^2; resources - Q, bill. t o.e.							
		S	Q	S	Q	S	Q	S	Q
1	Leningrad-Novgorod.	42	42	24	72			66	114
2	Moscow	23,4	23,4	12	36			35,4	59,4
3	Ryazan	80,1	80,1	14,4	43,2			94,5	123,3
4	Caspian	110,8	110,8	65,6	196,8	8	40	184,4	347,6
5	Before Caucasian	29,6	29,6	320	960	17,4	87	367	1076,6
6	Timano-Pechora	141,2	141,2	171,7	515,1	83,6	418	396,5	1074,3
7	Volga-Ural	225,2	225,2					225,2	225,2
8	Western-Siberian	671,7	671,7	542	1626	651,6	3258	1865	5555,7
9	Hatanga	64	64	72,7	218,1			136,7	282,1
10	Ust-Ilim	390,1	390,1	52,4	157,2			442,5	547,3
11	Viljuy	264,3	264,3	245,4	736,2			509,7	1000,5
12	Burein	70,8	70,8	20	60			90,8	130,8
13	Thukotka			56	168			56	168
14	Anadir			58,8	176,4			58,8	176,4
15	Sakhalin			60,8	182,4	7,6	38	68,4	220,4
	In total on Russia	2113	2113	1716	5147	768,2	3841	4597	11102

Temperature of the extracted geothermal heat-carrier 20-60 ^{0}C, that is obviously not enough for the consumer, installations with thermal pumps therefore are accepted. The results of accounts of technical and economic parameters executed, on the basis of economic-mathematical modeling, with 100 chinks, wich was chose in territory of the Moscow syneclise, were a basis of a comparative rating and construction of maps of an economic feasibility of development of geothermal resources of middle Devonian and middle Cambrian thermo-water-bearing horizons (fig. 5). These results of a geology - economic rating allow to compare geothermal and traditional resources, to consider prospects of a geothermal heat supply and to choose prime objects and sites of construction of geothermal circulating systems in territory of the Moscow syneclise. Besides the maps were constructed: the investments in construction of systems of a geothermal heat supply; the cost prices of manufacture of heat by geothermal stations; the relative profit (damage) by manufacture of heat of a SGH etc.





Density of geothermal resources, thousand t o.e. /км2

20-50 50-100 100-200 200-300

Figure 4. A schematic map of perspective geothermal resources a) Middle Devonian, b) middle Cambrian thermo-water-bearing horizons of the Moscow syneclise.

1. Isoline of density of perspective geothermal resources (thousand t o.e. /km^2): a - authentic, b - assumed(prospective).
2. Borders of distribution thermo-water-bearing horizons. 3. Borders of administrative areas.

5. HEAT SECURITY BY GEOTHERMAL RESOURCES THE CENTRAL REGIONS OF RUSSIA

The area of the Moscow syneclise consist of Vladimir, Vologda, Ivanovo, Kostroma, Nizhniy Novgorod, Novgorod, Tver and Yaroslavl areas. The thermal need of the population of these territories is divided in a place of residing: in cities, settlements of a urban type and in the village occupied items.

For the urban and village population the needs for heat for: of the industrial enterprises are allocated; dwelling-municipal services. As criterion of security the geothermal resources accept term of improvement of perspective geothermal resources with a total annual heat productivity satisfying need for heat for the inhabitants of this territory.

Table 3. Perspective hydrogeothermal resources middle Devonian and middle Cambrian thermo-water-bearing horizons of the Moscow syneclise

Areas	Territory having resources		Perspective resources, bill. t o.e.	Density, thous. t o.e./km^2
	thous. km^2	in % from general		
Vladimir	14.2 / 3.2	49.0 / 11.0	1.42 / 0.11	100 / 34
Vologda	62.1 / 51.4	42.6 / 35.3	8.24 / 2.51	130 / 49
Ivanovo	23.9 / 11.8	100.0 / 49.4	4.06 / 0.75	170 / 64
Kostroma	54.2 / 25.5	90.2 / 42.4	11.46 / 2.16	200 / 85
Nizhniy Novgor.	28.0 / -	37.0 / -	4.2 / -	150 / -
Novgorod	- / 4.2	- / 7.5	- / 0.11	- / 25
Tver	2.9 / 51.0	3.4 / 60.6	0.19 / 1.99	60 / 39
Yaroslavl	36.4 / 36.4	100.0 / 100.0	3.59 / 3.38	200 / 93
Total	221.7 / 183.5		33.16 / 11.01	

The note: numerator is middle Devonian horizon, denominator is middle Cambrian horizon.

The executed ratings show, that when specific density of geothermal resources in the central areas of Russia (tab. 3) choose from 25 up to 211 thousand t o.e. /km^2 on each of thermo-water-bearing horizons, and in common - up to 200-300 thousand t o.e. /km^2, the security by perspective geothermal resources at relative complete use of the areas and the deconcentration of thermal loadings up to a level of the village occupied items can make from 300 till 4200 years (tab. 4).

Table 4. Security by geothermal resources of administrative areas territories of the Moscow syneclise.

Area	Specific Heat Need (requirement) areas, t o.e. / km^2	Density geothermal Resources thousand t o.e. / km^2		Security by geothermal resources, years	
		Cambrian horizon	Devonian horizon	Cambrian horizon	Devonian horizon
Novgorod	66,9	25,3	-	380	-
Tver	72,5	39,2	65,2	540	910
Vologda	45,3	48,7	132,6	1080	2900
Yaroslavl	153,8	92,7	98,7	600	640
Ivanovo	209,0	63,7	170	300	800
Kostroma	49,9	84,9	211,4	1700	4200
Vladimir	210,3	34,5	99,9	160	470
Nizhniy Novgor.	248,6	-	150	-	600

The offered map (fig. 6) allows to make rough ratings of long term of use of a geothermal source of energy, need(requirement) for it(him) and quantity(amount) of this local fuel in administrative areas of the centre of Russia.

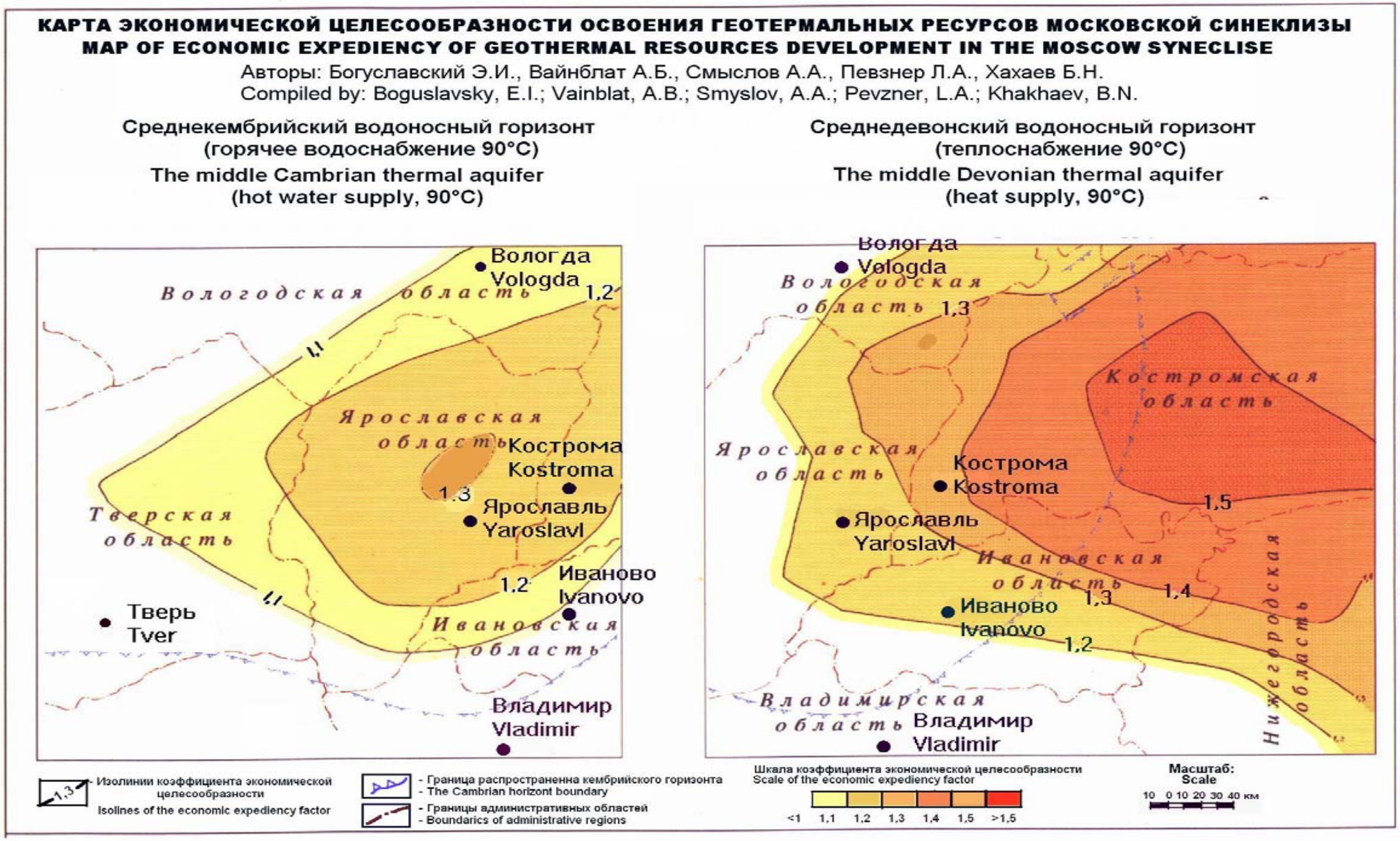


Figure 5. A schematic map of an economic feasibility of development perspective geothermal resources a) middle Devonian, b) Middle Cambrian thermo-water-bearing horizons of the Moscow syneclise (heat supply 90 ^{0}C).

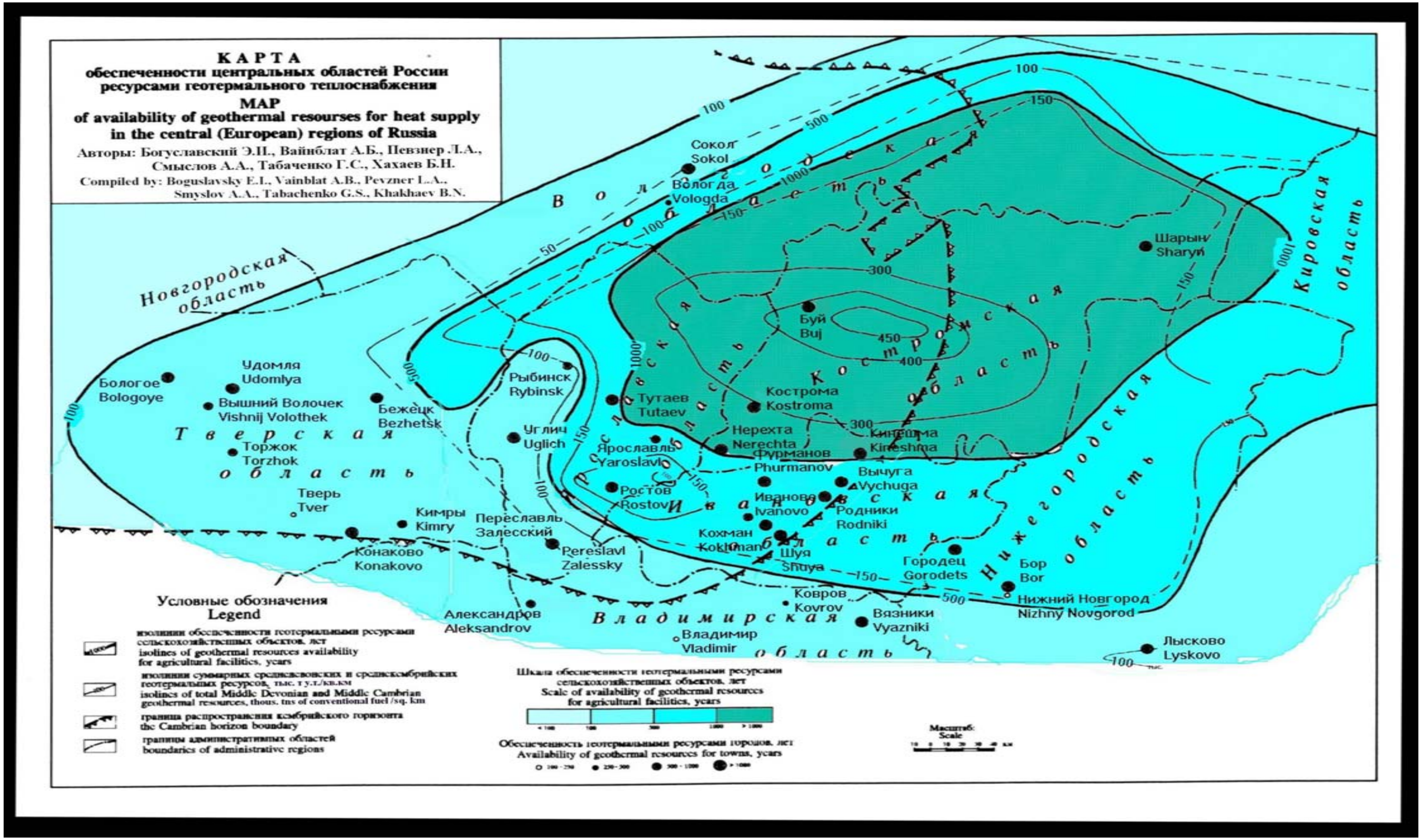


Figure 6. A schematic map of security of the central areas of Russia by resources of a geothermal heat supply.

1. Isoline of security by geothermal resources of a heat supply of agricultural objects, years. 2. Isolines of density of total middle Devonian and middle Cambrian geothermal resources, thousand t o.e./km^2. 3. Borders of distribution of middle Cambrian horizon. 4. Borders of the subjects of Federation.

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