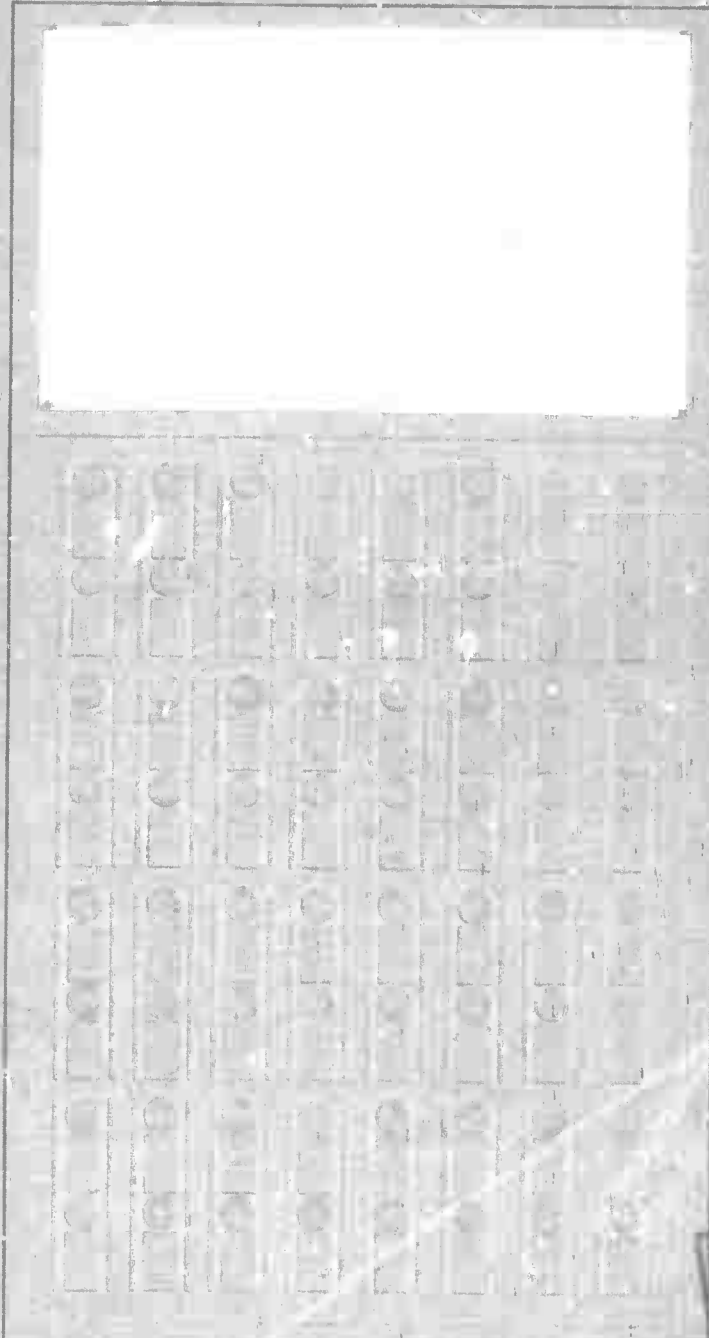


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13. ABSTRACT <p>This report presents the results obtained in an attempt to provide information on recent Soviet research on geothermy. Emphasis is on the identification and description of high-intensity heat flow areas in the USSR that have or might become potential sites for geothermal power or space heating developments. In general, the information provided consists of background data (geographical, geological and chemical) covering recently investigated areas. In some instances the data may be partially incomplete for some areas, i. e., may lack information on one or two of the above-mentioned three fields. Further search is required to close these gaps.</p> <p>With only a few exceptions, no attempt has been made in this first report to supply references to Soviet publications dealing with the engineering problems associated with the building or maintenance of geothermal plants. It is anticipated that these problems will be treated in the next report of this series.</p> <p>Details of Illustrations in this document may be better studied on microfiche</p>			

# RECENT SOVIET INVESTIGATIONS IN GEOTHERMY

Report 1 - May 1972

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## INTRODUCTION

This report presents the results obtained in an attempt to provide information on recent Soviet research on geothermy. Emphasis is on the identification and description of high-intensity heat flow areas in the USSR that have or might become potential sites for geothermal power or space heating developments. In general, the information provided consists of background data (geographical, geological and chemical) covering recently investigated areas. In some instances the data may be partially incomplete for some areas; i. e., may lack information on one or two of the above-mentioned three fields. Further search is required to close these gaps. Here, one might point out that a search for pertinent information on such areas as the Chukotka area (north of the Arctic Circle) might produce some interesting results.

With only a few exceptions, no attempt has been made in this first report to supply references to Soviet publications dealing with the engineering problems associated with the building or maintenance of geothermal plants. It is anticipated that these problems will be treated in the next report of this series.

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## PART I. MAJOR REFERENCE WORKS ON THE GEOTHERMY OF THE USSR

### HIGH-TEMPERATURE WATERS OF THE USSR

Bogoroditskiy, K. F. Vysokotermal'nyye vody SSSR (High-temperature waters of the USSR). Moskva, Izd-vo Nauka, 1968, 166 p.

The coverage below utilizes the large volume of illustrations in the book to provide pictorial and tabulated information on USSR geothermal areas, their water characteristics, etc., and to facilitate an "at-a-glance" assessment of the area development potential of the USSR as a whole.

Following the translated Table of Contents, the treatment of the book in this report is broken down into two major sections. Section A is an informative treatment of the most relevant information, which has been summarized in the illustrations and tables appearing in this section. Section B represents an indicative treatment of information which is either a detailed description of a specific small area (e. g., point-to-point geothermal sections - generalized on maps in Section A) or tabular data on chemical and mineralization aspects of geothermal sources. In both Sections, the original numeration of the maps and tables has been retained to facilitate reexploitation or relocation of the material in the event additional or more explicit information is required.

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References: Lists 54 items, 51 of Soviet Origin and 3 of Non-Soviet Origin

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Section A.

Water-Temperature Classification Used by the Author in this Book (p. 11)

<u>Cold Water</u>	<u>Temperature °C(°F)</u>
Supercooled	<0(32)
Very Cold	0 - 10(32 - 50)
Cold	10 - 20(50 - 68)
<u>Low-Temperature Waters</u>	<u>Temperature °C(°F)</u>
Warm	20 - 37(68 - 100)
Hot	37 - 50(100 - 122)
<u>High-Temperature Waters</u>	<u>Temperature °C(°F)</u>
Very Hot	50 - 100(122 - 212)
Superheated	>100(212)

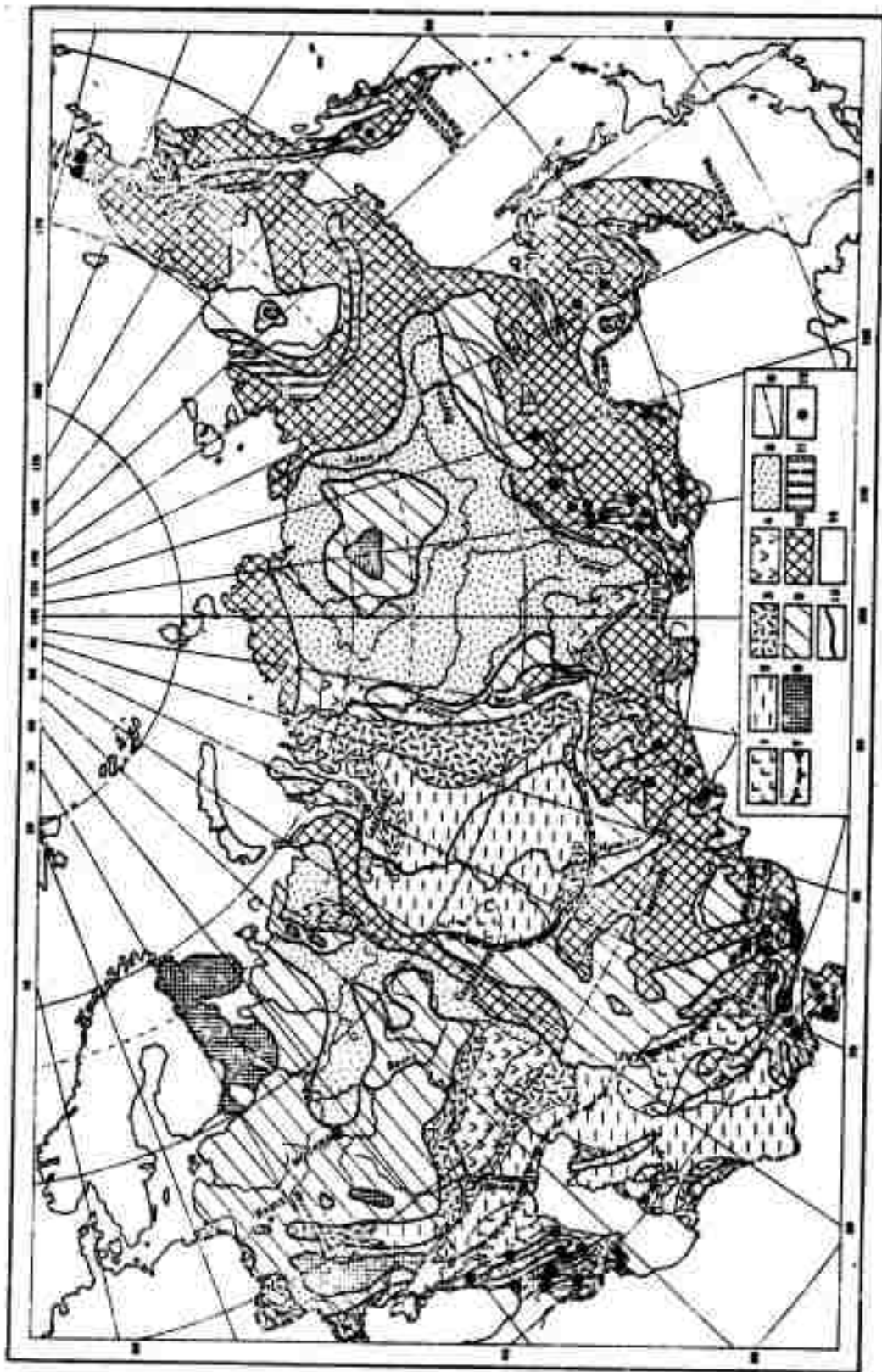


Fig. 1. Schematic Map Showing the Distribution and Depths of Occurrence of Hot Waters (50°C ± 10), i. e., 122°F ± 18° (pp. 14-15).

Stratum and Stratum-Interstitial Waters. Areas (1 - 5) in which the predominant depths of hot waters are: 1 - less than 1000 m, 2 - 1000 - 1500 m, 3 - 1500 - 2000 m, 4 - 2000 - 2500 m, 5 - deeper than 2500 m; 6 - boundaries of areas, determined and postulated; 7 - boundaries of regions with possible artesian hot waters. Interstitial and Interstitial-Vein Waters. 8 - crystalline shields with possible occurrence of hot waters at great depths; 9 - basements of artesian basins with possible occurrence of hot waters in the deepest (still not verified by drilling) depressions and tectonic fault zones; 10 - fold-mountain areas in which hot waters occur in tectonic fault zones; 11 - upper structural stages of fold-mountain areas in which interstitial waters occur in small artesian basins; 12 - springs having temperatures of 40 - 60°C; 13 - boundaries of areas in which stratum, stratum-interstitial and interstitial and interstitial-vein waters occur; 14 - regions for which information is unavailable.

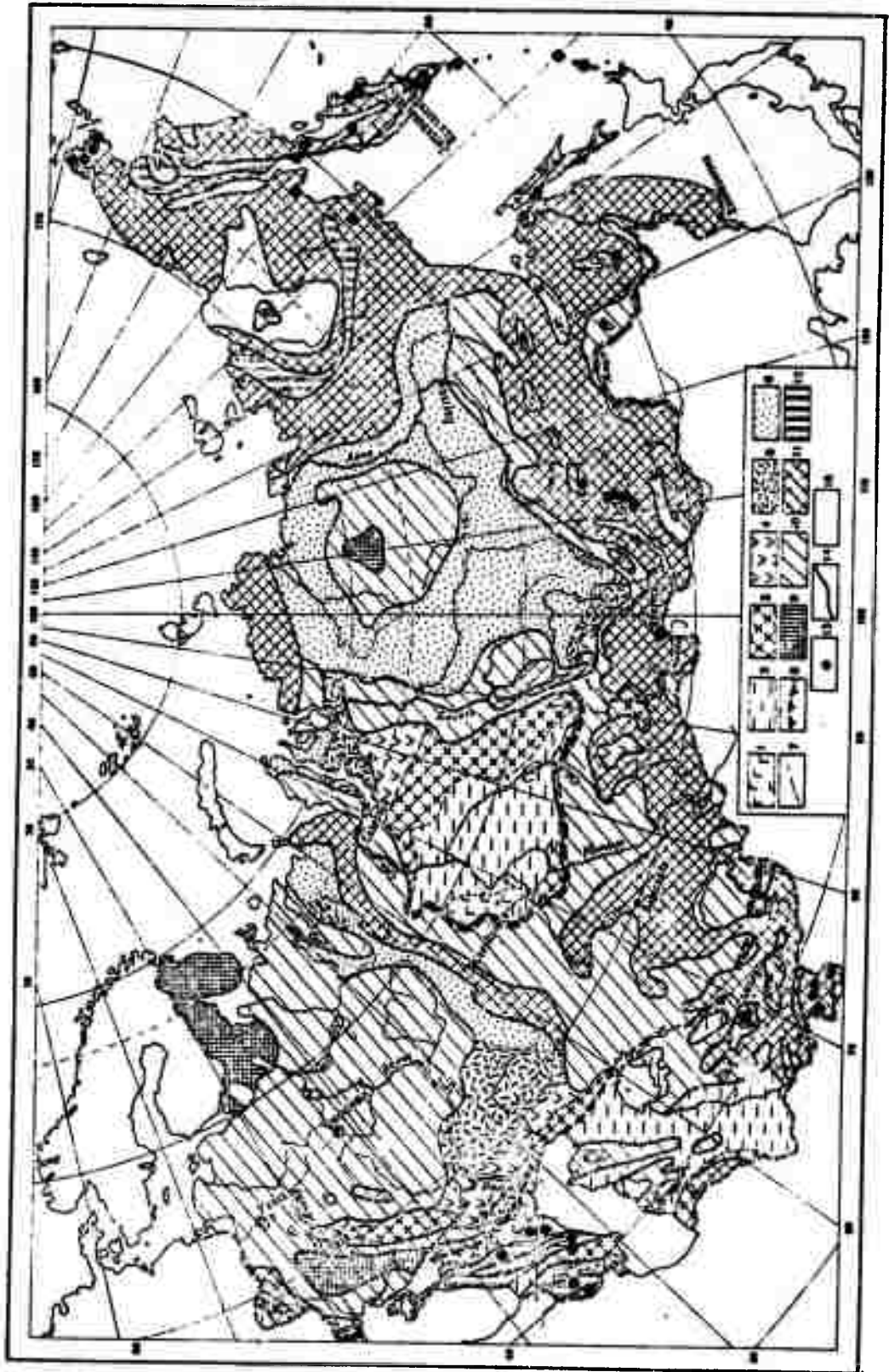


Fig. 2. Schematic Map Showing the Distribution and Depths of Occurrence of Very Hot Waters ( $75^{\circ}\text{C} \pm 10$ ), i. e.,  $167^{\circ}\text{F} \pm 18^{\circ}$  (compiled by K. F. Bogoroditskiy and Ya. B. Smirnov), (p. 18).

Stratum and Stratum-Interstitial Waters. Areas (1 - 6) in which the predominant depths of very hot waters are: 1 - less than 1500 m, 2 - 1500 - 2000 m, 3 - 2000 - 2500 m, 4 - 2500 - 3000 m, 5 - 3000 - 3500 m, 6 - deeper than 3500 m; 7 - boundaries of areas, determined and postulated; 8 - boundaries of regions within which very hot artesian waters are possible. Interstitial and Interstitial-Vein Waters: 9 - crystalline shields with possible occurrence of very hot waters at great depths; 10 - basements of artesian basins with possible occurrence of very hot waters in the deepest (still not verified by drilling) depressions and tectonic fault zones; 11 - fold-mountain areas in which very hot waters occur in tectonic fault zones; 12 - upper structural stages of fold-mountain areas in which artesian waters occur in small artesian basins; 13 - hot springs with temperatures ranging from  $60$  to  $90^{\circ}\text{C}$ ; 14 - boundaries of areas in which stratum, stratum-interstitial and interstitial and interstitial-vein waters occur; 15 - regions for which information is lacking.



Fig. 3. Schematic Map Showing the Distribution and Depths of Occurrence of Superheated Waters ( $100^{\circ}\text{C} \pm 10$ ), i. e.,  $212^{\circ}\text{F} \pm 18^{\circ}$  (compiled by K. F. B. Bogoroditskiy and Ya. B. Smirnov). (p. 22).

Stratum and Stratum-Interstitial Waters. Areas (1 - 4) in which the predominant depths of superheated waters are: 1 - less than 2000 m, 2 - 2000 - 3000 m, 3 - 3000 - 4000 m; 4 - more than 4000 m; 5 - boundaries of areas, determined and postulated; 6 - boundaries of regions in which superheated artesian waters are possible. Interstitial and Interstitial-Vein Waters. 7 - crystalline shields with possible occurrences of superheated waters at great depths; 8 - basements of artesian basins with possible occurrences of superheated waters at the greatest depths (still not verified by drilling) in depressions and tectonic fault zones; 9 - fold-mountain areas in which superheated waters occur in tectonic fault zones; 10 - upper structural stages of fold-mountain areas in which interstitial waters occur in small artesian basins; 11 - springs with water temperatures higher than  $90^{\circ}\text{C}$ ; 12 - boundaries of areas in which stratum, stratum-interstitial and interstitial and interstitial-vein waters occur; 13 - regions for which information is lacking.

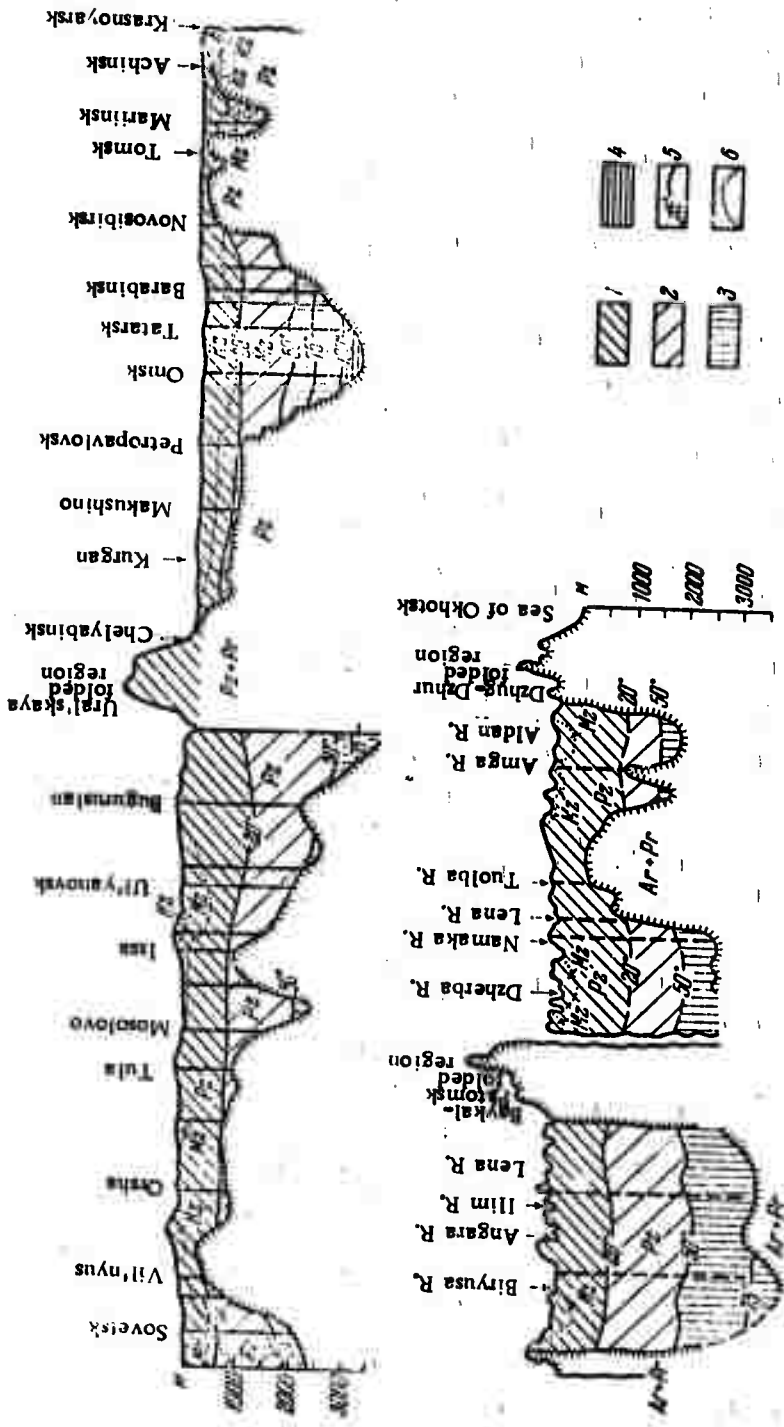


Fig. 10. Schematic Latitudinal Hydrothermal Section of the USSR (compiled by K. F. Bogoroditskiy and O. I. Grozdova on the geological base of the I. K. Zaytsev hydrochemical profile) (p. 49).

Zones (1 - 4) in which waters have temperatures of: 1 - lower than 20°C (cold water); 2 - from 20 to 50°C (warm and hot waters); 3 - from 50 to 100°C (very hot waters); 4 - above 100°C (superheated) waters; 5 - geoisotherms; 6 - stratigraphic contacts.

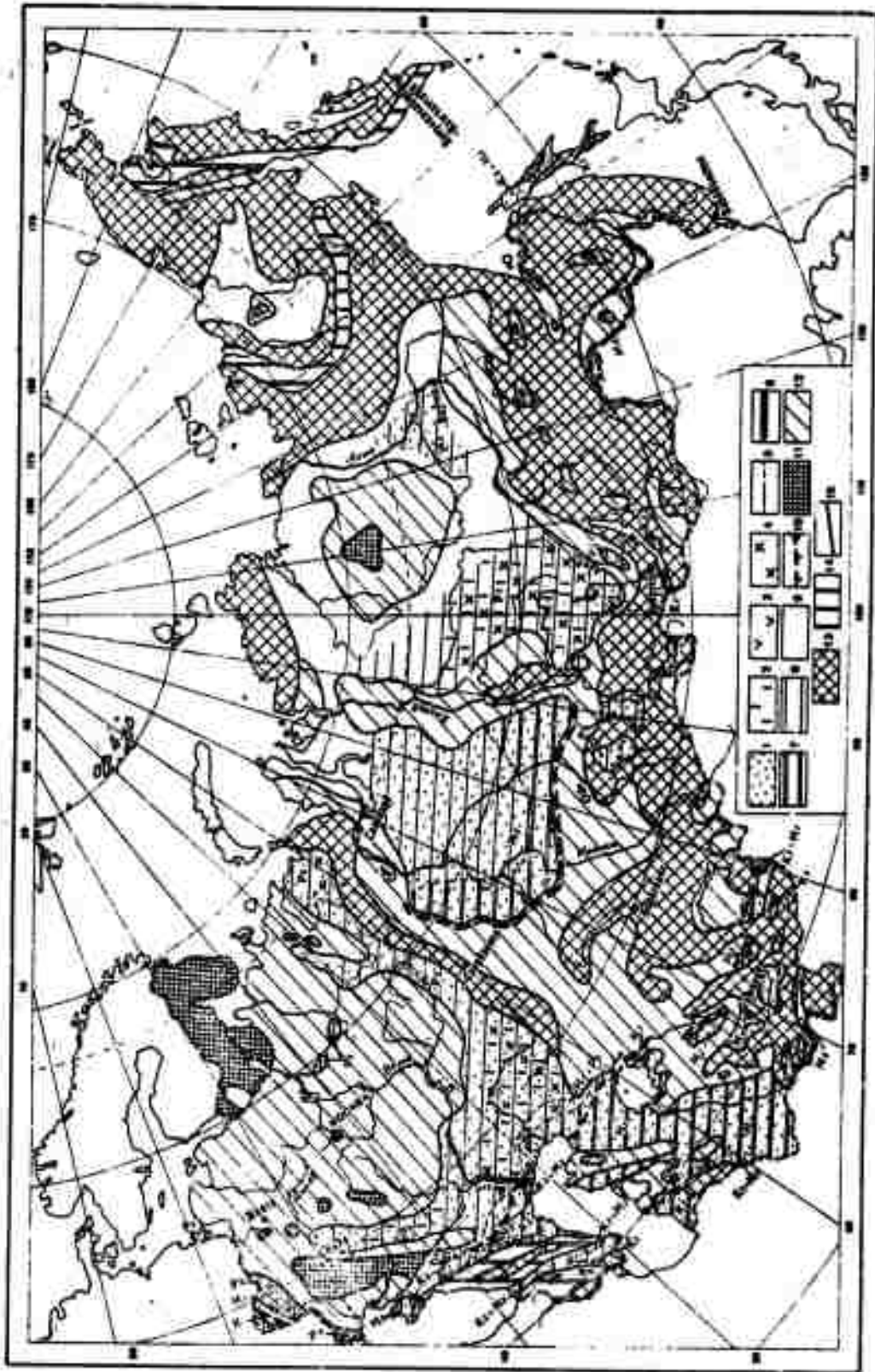


Fig. 12. Schematic Map Showing the Abundance of Water in Rocks Containing Very Hot Waters ( $75^{\circ}\text{C} \pm 10$ ) in the USSR. (pp. 56-57).

Areas of Stratum and Stratum-Interstitial Waters. Water-bearing rocks (1 - 4): 1 - terrigenous; 2 - carbonaceous; 3 - tufaceous; 4 - saliferous; 5 - contacts between rocks of different age. Water abundance (6 - 9) of rocks (expected well discharge, m<sup>3</sup>/day): 6 - exceedingly abundant water supply (mainly exceeding 1000); 7 - abundant supply (mainly from 250 to 1000); 8 - low-abundance (mainly up to 250); 9 - regions for which information is lacking; 10 - regions having possible artesian hot waters. Areas of Interstitial and Interstitial-Vein Waters: 11 - crystalline shields, occurrences of very hot water not recorded; 12 - basements of artesian basins, very hot waters encountered in individual wells in weathered-crust and tectonic fault zones; 13 - fold-mountain areas, occurrences of very hot waters noted in tectonically disrupted zones with discharges of wells and boreholes of the order of 1500, rarely 2500 m<sup>3</sup>/day or more; 14 - upper structural stage of fold<sub>3</sub>mountain areas, distribution of small artesian basin interstitial waters, well discharges to 1000 m<sup>3</sup>/day; 15 - boundaries of areas of stratum, stratum-interstitial and interstitial and interstitial-vein waters.

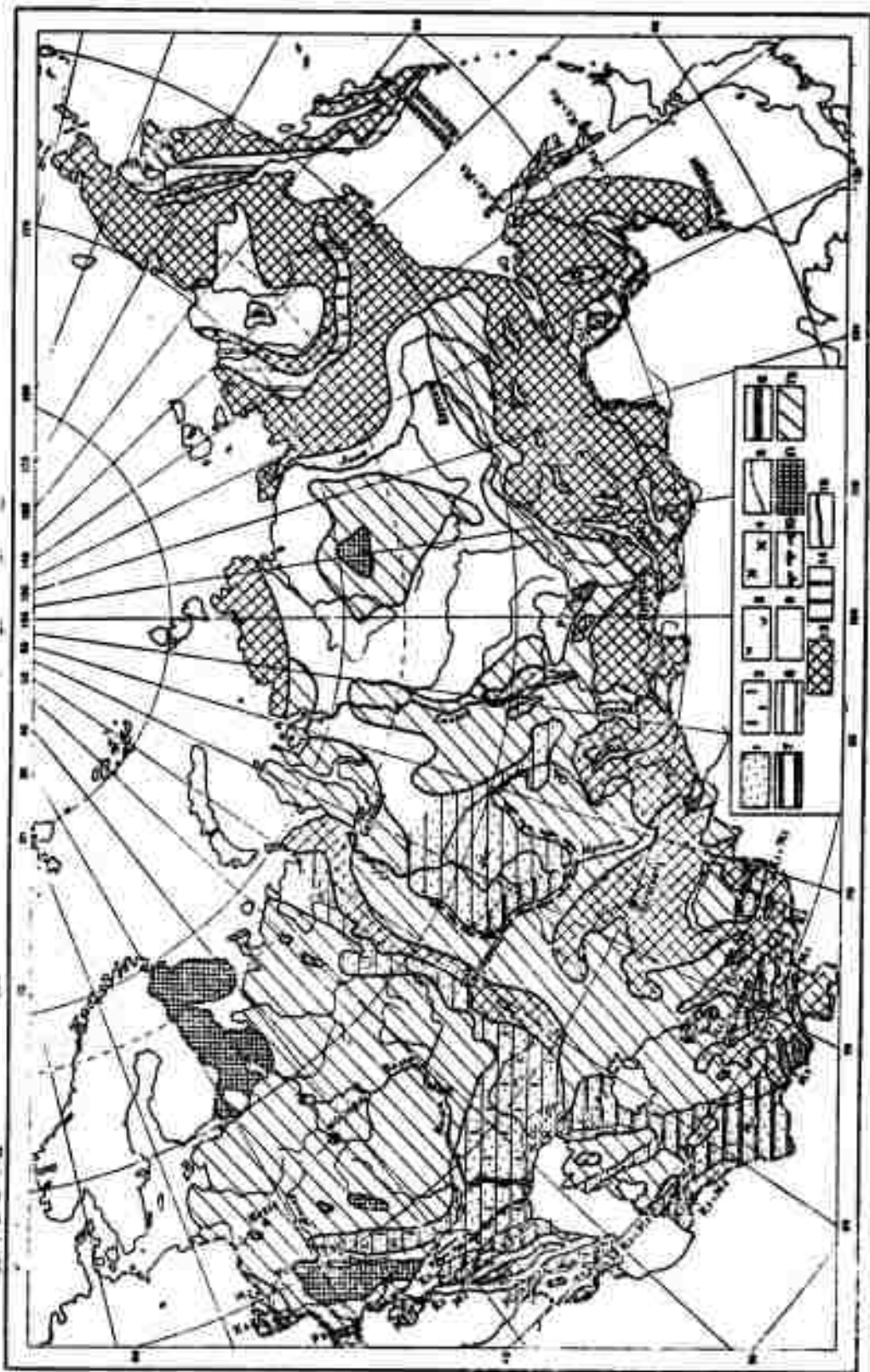


Fig. 16. Schematic Map Showing Water Abundance in Rocks Containing Superheated Water ( $100^{\circ}\text{C} \pm 10$ ), i. e.,  $212^{\circ}\text{F} \pm 18$ , in the USSR. (p. 72).

Areas of Stratum and Stratum-Interstitial Waters. Water-bearing rocks: (1 - 4): 1 - terrigenous; 2 - carbonaceous; 3 - tuffaceous; 4 - saliferous; 5 - contacts between water-bearing rocks of different ages. Water abundance (6 - 9) of rocks (expected well discharges, m/day): 6 - exceedingly abundant (mainly above 1000); 7 - abundant (mainly from 250 to 1000); 8 - low abundance (mainly to 250); 9 - regions for which information is lacking; 10 - boundaries of regions in which superheated artesian waters are possible. Areas of Interstitial and Interstitial-Vein Waters: 11 - crystalline shields (occurrence of superheated waters not found); 12 - basements of artesian basins (occurrence of superheated waters not found); 13 - fold-mountain areas (superheated waters found in tectonically disrupted zones with spring and well discharges of up to 1000, occasionally to 1500 m/day); 14 - upper structural stages of fold-mountain areas in which interstitial water may occur in small artesian basins (prevailing discharge of wells to 500 m/day); 15 - boundaries of areas in which stratum, stratum-interstitial and interstitial and interstitial-vein waters are possible.

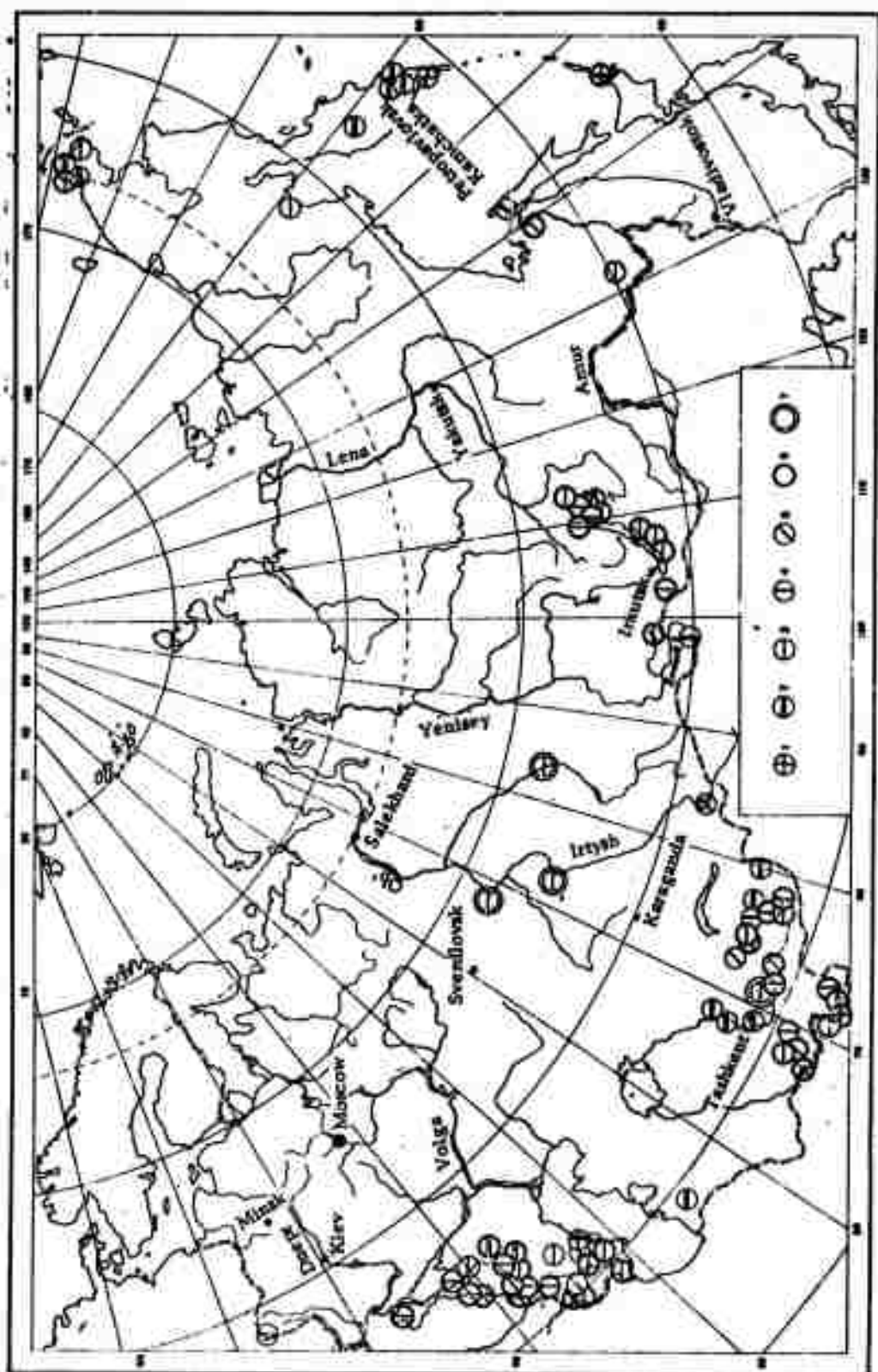


Fig. 37. Sketch Map Showing Regions of Potentially Useful High-Temperature Waters. (p. 164).

Practical utilization of high-temperature waters (according to hydrogeological indices): 1 - geothermal electric power station with subsequent utilization of recycled water for heating, hot-water supply or hothousing-greenhousing; 2 - thermal power installation (utilizing refrigerants) for heating, hot water supply hothousing-greenhousing; 3 - heating, hot-water supply, hothousing-greenhousing; 4 - heating-cooling supply, swimming pools, bath facilities, heating of soil, hot-spring irrigation; 5 - heating-cooling, swimming pools, heating of soil; 6 - thermal energy and balneology; 7 - thermal energy and chemicals manufacture.

Source discharges, m <sup>3</sup> /day	Number of Sources															
	Caucasus			Central Asia & Kazakhstan			Baykal Area			Northeastern Siberia			Kamchatka & Kurile Islands			
	Temp. ranges, °C	Temp. ranges, °C	Temp. ranges, °C	Temp. ranges, °C	Temp. ranges, °C	Temp. ranges, °C	Temp. ranges, °C	Temp. ranges, °C	Temp. ranges, °C	Temp. ranges, °C	Temp. ranges, °C	Temp. ranges, °C	Temp. ranges, °C	Temp. ranges, °C		
Less than 500	19	15	4	20	16	4	14	9	5	8	7	1	10	3	3	4
From 500 to 15000	9	8	1	4	3	1	6	6	—	4	2	2	8	1	5	2
From 1500 to 2500	—	—	—	1	1	—	3	1	2	1	—	—	—	—	—	—
More than 2500	—	—	—	—	—	—	2	1	1	2	—	1	4	—	—	4
Unknown	9	3	5	1	4	1	7	6	1	5	2	3	21	7	7	7

Table 2. Discharges of Hot Springs in the USSR. (p. 117).

Borehole site and its number	Depth of sampling, m	Water-bearing rocks		pH	Mineralization	Ca <sup>2+</sup>	Mg <sup>2+</sup>	SO <sub>4</sub> <sup>2-</sup>	HCO <sub>3</sub> <sup>-</sup>	Trace elements	Freely escaping gases
		Age	Composition								
Novaya Mamesta, T-2	2000	J	Limestones	38.3	26.9	1.37	0.37	0.004	0.59	J, Br, Si, Fe, Zn, Sr, F, B, Mn	H <sub>2</sub> S, CH <sub>4</sub>
Matevsta, T-2	1600-1700	•	Ditto	38.7	27.7	1.40	0.30	0.003	0.58		
Staraya Mamesta, T-2	2170	•	•	31.2	26.9	1.33	0.38	0.002	0.53		
Khozta, T-1	2300	•	•	45.5	23.0	1.15	0.34	0.01	0.59		
Gagra	2500	Cr+Js	•	42.0	2.3	0.06	0.15	1.37	0.23		
Sukhumi, 1	1800	Cr <sub>1</sub>	•	35.0	1.7	0.32	0.05	0.12	0.27	Br, J, B, Si, Fe	H <sub>2</sub> S, N <sub>2</sub>
Geshtek, SA	648	Cr <sub>2</sub>	•	62.0	4.3	1.51	0.03	0.34	3.44		H <sub>2</sub> SiN <sub>2</sub>
Dzhermuk	46	•	Limestones, marls	64.0	3.8	1.00	0.07	0.15	2.24		CO <sub>2</sub> , N <sub>2</sub>
Ankavan, 17	252	•	Limestones	39.0	6.9	0.11	0.63	0.22	3.64		
Iatsu	670	Pg	Tuffs	60.0	5.0	1.70	0.03	0.22	2.71	J, Br, Si, Mn, Fe, Al	CO <sub>2</sub>
Tbilisi, 5	1058	Pg <sub>2</sub>	Sandstones and deposits of volcanic origin	42.0	4.4	1.10	0.01	0.58	0.10		
Tbilisi, 8	1405	Pg	Argillaceous shales and sandstones	50.5	0.4	0.10	0.01	0.07	0.16	Si, Al, Zn, Fe, Ti, Pb, Cu, Ba, Mn	CH <sub>4</sub> , N <sub>2</sub> , H <sub>2</sub> S
Tbilisi, 9	1009	Pg <sub>2</sub>	Sandstones and volcanic deposits	56.0	0.3	0.09	0.01	0.07	0.10		
Borzhomi	194	Pg <sub>1</sub>	Flysch deposits	32.8	5.9	1.53	0.04	0.09	3.87	Sr, Ba, Fe, Al, Mn, Br, J	CO <sub>2</sub>
Bogchevskaya, 6-P	1771-1737	N <sub>1</sub>	Shales	70.0	7.3	1.35	0.02	1.02	2.45		

\*Data of L. N. Berabnov (1961), I. M. Buschidze and S. S. Chikhalidze (1961) were used in compiling the table.

Table 8. Results of Hydrogeological Samplings of Deep Boreholes Disclosing High-Temperature Waters in Small Artesian Basins (p. 123).

Table 15. Key Criteria for the Effective Utilization of High-Temperature Waters as Heat Transfer Agents in Various Branches of the Economy \* (p. 153).

Branches of economy	Temp. °C	Dis-charge, more than m <sup>3</sup> /day	Pres-sure, more than, atm	Depth of waterbearing stratum not exceeding, m	Impurity content not ex-ceeding, mg/l	Mineral-ization not ex-ceeding, g/l	Hardness not ex-ceeding, mg/eqv	pH	O <sub>2</sub> not ex-ceeding, mg/l	CO <sub>2</sub> (free) not ex-ceeding, mg/l	H <sub>2</sub> S (free) not ex-ceeding, mg/l	Period of exploitation not less than, yrs.
<b>THERMAL ENERGY</b>												
Geothermal electric power station	above 100	10000	2,5	5000	5	2-4(50)**	3(9)	5,5-9,5	0,1(0,5)	10(250)	1(10)	25-30
Geothermal energy, utilizing refrigerants	60-90	2500	1,0	2500	5	50	9	9	0,5	50	10	9
<b>MUNICIPAL SERVICES</b>												
Heating	70-90	1000	1,5	2500	5	2(50)	3(9)	9	0,1(0,5)	10(250)	1(10)	9
Hot water supply	40-60	1000	1,5	1500	5	2(50)	3(9)	9	0,1(0,5)	10(250)	1(10)	9
Heating-cooling supply	25-50	500	1,0	1500	5	50	9	9	0,5(0,5)	0	10	9
Swimming pools and baths	25-40	250	1,0	1000	10	50	9(12)	9	-	50(500)	1(10)	9
<b>AGRICULTURE</b>												
Hothouse, greenhouse, conservatory heating	40-70	500	1,0	1500	5	10(50)	5(12)	9	0,5(0,5)	50(550)	1(10)	9
Heating of soils	25-50	500	1,0	1000	5	50	5	9	0,5	50	1	9
Hot-spring irrigation	25-40	250	2,0	1000	10	2	5	9	0,5	50	1	9

\*When concrete and reinforced concrete are used, it is necessary to take into account sulfate and magnesium aggressive waters (SN 249-63).  
 \*\*The limiting values of heat exchange in geothermal installations are given in parentheses.

Table 16. Regions of Potential Utilization of High-Temperature Stratum- and Fracture-Waters (pp. 156-160).

BASIC DATA ON HIGH-TEMPERATURE WATERS									
Argesian basins	Regions	Waters-bearing formations	Depth of occurrence, m	Wellhead pressure, atm	Well discharge, m <sup>3</sup> /day	Wellhead pressure, atm	Mineralization, g/l	Chemical type	Possible kinds of utilization
Transcarpathian area	Transcarpathian area	Sarmatian Neogene	450-600 350-500	35-40 25-30	1000-1500 400-500	Flowing well Ditto	0.5-2.0 0.8-1.5	HCO <sub>3</sub> -Na Ditto	Heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
Black Sea area	Crimea area	Lower Cretaceous	800-1000	35-45	500-2000	* *	1-10	Cl-Na, HCO <sub>3</sub> -Na	Bainology, heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
Azov-Kuban	Krasnodar area	Lower Cretaceous	400-600	35-40	500-1000	* *	0.8-1.2	HCO <sub>3</sub> -Na	Heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
	Krasnodar and population centers westward along Kuban' R. valley	Paleo-alluvial, Pustian and Kimmeridgian	To 1000	35-40	500-1000	* *	0.5-0.6	HCO <sub>3</sub> -Ca	
	Maykop, Kizilshipskaya, Kuzhonskaya, and Tul'skaya stations	Oligocene Lower Cretaceous (Albian)	1200-1500 2500-2800	40-70 70-80	500-2000 To 500	To 20 Flowing well	25-30 5-7	Cl-Na Ditto	Thermal energy utilizing refrigerants, heating, hot water supply, hot-dousing greenhouses
	Apteronok Armavir and environs	Lower Cretaceous Eocene-Paleocene	2200-2500 2600-1700	75-80 40-50	300-500 500-300	To 10 Flowing well	25-30 To 20	Ditto * *	Flowing well Heating, hot water supply, hot-dousing greenhouses
	Labinsk	Lower Cretaceous	2500-2600	65-80	500-600	Ditto	10-12	* *	Thermal energy utilizing refrigerants, heating, hot water supply, hot-dousing greenhouses

Table 16 (con't)

Azov- Kuban Terko- Kurnskiy	Belorechenskaya stanitsa, Vellitsy Dagestan ASSR	Choktraktian	1100-1200	50-60	400-600	Flowing well	3-5	HCO <sub>3</sub> -Na	Heating, hot-water supply, greenhousing
	Makhachkala, Karman, Kizlyar, Khasar'yurt	Karagantian Choktraktian	2500-3000	100-120	1500-3000	5-10 or more	2,5	Ditto	Geothermal electric power station with recycling of water for heating, hot-water supply and hot-housing greenhousing
	Ish-erzaf, Katslyk, and nearby population centers	Karagantian	1000-1500	40-60	300-500	1-3	2-5	"	Heating-cooling supply, swimming pools and bath facilities, heating of soils
	Chercheno-Ingushskaya ASSR								
	Gronyy, Gushermes, Gergash	Karagantian Choktraktian	2000-2500	65-85	To 1500	10 or more	1-3	Cl-Na	Heating, hot-water supply, hot-housing greenhousing
	Dzaryk, Karabulak, Achalaki	Upper Cretaceous	1200-1700	60-80	To 5000	To 20	To 50	Ditto	
	Kabardino-Balkarskaya ASSR								
	Mal'chik and environs	Lower Cretaceous	2200-2300	80-85	600-800	17-20	18-20	Ditto	
	Starropol'skiy kray								
	Cenoglyevsk and nearby population centers	Miocene-Oligocene	1200-1800	65-90	2000-3000	25-75	To 30	"	Thermal energy utilizing refrigerants, heating, hot-water supply, hot-housing greenhousing
	Nevisomnyak, Melitensk, and nearby population centers	Lower Cretaceous	3000-3200	100-120	500-1000	12-35	20-50	"	Ditto
	Nigulskaya stanitsa	Lower Cretaceous	1300-1400	50-55	300-500	40-50	0,8-0,9	HCO <sub>3</sub> -Na	Hot-water supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation

Table 16 (cont)

BASIC DATA ON HIGH-TEMPERATURE WATERS									
Artesian basins	Regions	Water-bearing formations	Depth of occurrence, m	Wellhead water temp., °C	Well discharge, m <sup>3</sup> /day	Pressure at wellhead, atm	Mineralization, g/l	Chemical type	Possible kinds of utilization
Blonno-Kurinskoye	Cherkassk and environs	Lower Cretaceous	1500—2500	60—90	300—1000	10—20	1—3	HCO <sub>3</sub> -Na	Heating, hot water supply, hothousing-greenhousing
	Pyatigorsk, Yessentuki and their environs	Paleocene	1000—1500	35—40	500—2000	15—35	1—8	HCO <sub>3</sub> -Na	Balneology, heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
	Oruzinskaya SSR Zaglad, Tsishinskaya, Tshakaya, Nakhshivri, Kvaloni, Poti	Upper Cretaceous	2000—3000	75—80	To 600	2—5	1.5—2.5	SO <sub>4</sub> -Ca, Cl-Na	Balneology, heating, hot water supply, hothousing-greenhousing
	Azərbaycanın SSR Mts. Bashir and nearby population centers	Maykopian	1000—1500	35—40	To 500	Flowing well	12—15	Cl-Na	Heating-cooling supply, bath facilities, heating of soils
Syrdaryinskoye	Kazakhstan and Uzbekistan SSR	Upper Cretaceous	1400—1600	50—70	To 5000	3—5	0.5—1.5	HCO <sub>3</sub> -Na, SO <sub>4</sub> -Na, Cl-Na	Thermal energy utilizing refrigerants, heating, hot water supply, hothousing-greenhousing
	Tashkent, Arystan-Sary-Agach, Tashkent, Kibray, Izbeyan-Kurgan and nearby population centers	Pliocene (red beds)	1500—1800	70—80	800—1000	5—10	20—30	Cl-Na	Thermal energy utilizing refrigerants, heating, hot water supply, hothousing-greenhousing, chemical manufacturing
Western Turkmenistan	Turkmenistan SSR Chelakhen peninsula, Nebiti-Dag, Krasnovodsk	Pliocene (red beds)	1500—1800	70—80	800—1000	5—10	20—30	Cl-Na	Thermal energy utilizing refrigerants, heating, hot water supply, hothousing-greenhousing, chemical manufacturing

Table 16 (con't)

Ferganskiy	Uzbekskaya SSR Fergana, Chirchik, Gur-Tepe and near- by population cen- ters	Neogene (Mangysh- tan stage)	2000—2500	60—70	400—1200	To 12	30—50	Cl—Na	Heating, hothousing-greenhousing, chemical manufacturing
South Tadjik	Fergana, Ishtabent, Vansovskaya sta., Margilan and near- by population cen- ters	Neogene (Bakhtian stage)	1000—1200	40—45	800—1000	To 10	0,7—0,8	HCO <sub>3</sub> —Na	Balneology, heating-cooling supply, swimming pool and bath facilities, heating of soils, hot-spring irrigation
	Tadjikskaya SSR Dunlomb, Shuam- bary zar' nearby population centers	Neogene	500—1000	40—45	400—500	1—5	1—15	SO <sub>4</sub> —Na	Balneology, heating-cooling supply, bath facilities, heating of soils
Ilyiski	Kazakhskaya SSR Pantfloy and near- by population cen- ters	Paleocene	1000—1500	40—45	400—500	1—5	5—15	Ditto	Balneology, heating-cooling supply, bath facilities, heating of soils
Issykul'skiy	Kazakhskaya SSR Pantfloy and near- by population cen- ters	Cretaceous	2000—2500	80—90	500—1000	To 10	2—5	HCO <sub>3</sub> —Na	Thermal energy utilizing refrigerants, heating, hot water supply, hothousing- greenhousing
Issykul'skiy	Alma-Ata and en- vironments	Cretaceous	2500—3000	70—80	500—1000	To 10	2—5	Ditto	Thermal energy utilizing refrigerants, heating, hot water supply, hothousing- greenhousing
Chuykiy	Kirgizskaya SSR Frukhval'skiy (Dzhargalan R. val- ley)	Neogene	1500—1600	40—45	2000—2500	5—10	0,8—1,0	Cl—Na	Balneology, heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
Chuykiy	Kazakhskaya SSR Frunsa, Lugovkaya sta. and nearby population centers	Neogene- Paleocene	800—1000	30—40	1000—1500	2—5	1—5	HCO <sub>3</sub> —Na	Heating-cooling supply, bath facilities, heating of soil.
Zaysanskiy	Kazakhskaya SSR Zaysan and nearby population centers	Neogene and Paleo- cene	1200—1500	40—45	To 1000	0—5	1—5	SO <sub>4</sub> —Na	Ditto
West Siberian	Western Siberia Omsk, Tyumen', Tobol'sk and near- by population cen- ters	Lower Cretaceous	1800—2200	65—85	200—800	To 7	To 30	Cl—Na	Heating, hothousing-greenhousing, chemical manufacturing

BASIC DATA ON HIGH-TEMPERATURE WATERS

Artesian basins	Regions	Water-bearing formations	Depth of occurrence, m	Wellhead water temp., °C	Well discharge, m <sup>3</sup> /day	Pressure at wellhead, atm	Mineralization, g/l	Chemical type	Possible kinds of utilization
Tunkinskiy	Buryatskaya ASSR Arshan spa and near- by population cen- ters	Neogene	800—1000	35—40	400—600	Flowing well	0.8—1.0	HCO <sub>3</sub> —Na	Balneology, heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
Selenginskiy	Buryatskaya ASSR Population centers of Selenga r. delta	Neogene	2200—2800	50—60	400—600	Ditto	To 3	HCO <sub>3</sub> —Na, Cl—Na	Balneology, heating, hot water supply, hothousing-greenhousing
North Sakhalin	Sakhalinskaya Oblast' Okha, Mukhto and nearby population centers	Neogene	1500—2000	30—35	To 300	→ →	5—10	Cl—Na	Heating-cooling supply, bath facilities, heating of soils

BASIC DATA ON HIGH-TEMPERATURE WATERS

Artesian basins	Regions	Temp., °C	Discharge, m <sup>3</sup> /day	Mineralization, g/l	Chemical type	Gas components	Possible kinds of utilization
Tbilisskiy	Gruzinskaya SSR, Tbilisskiy	45—50	>5000	0.3—0.4	Cl—Na	NH <sub>4</sub>	Balneology, heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
Alpindzskiy	Adigenskiy	39—40	2000	0.5—0.9	Cl—Na	CO <sub>2</sub>	Balneology, heating-cooling supply, baths, heating of soils
Borzhomskiy	Borzhomi spa	36	600	6.0—7.0	HCO <sub>3</sub> —Na		
Sukhumo-Kodorskiy	Sukhumskiy (Besleti village)	39—42	2000	1.5—2.6	SO <sub>4</sub> —Na		
Gagrinako-Gudaurtskiy	Gagrinakiy (Novaya Gagra)	41	2500	2.0—3.0	SO <sub>4</sub> —Ca	N <sub>2</sub>	
Pambakskiy	Armenyanskaya SSR, Ankavanakiy	39	1800	6.9	HCO <sub>3</sub> —Na	CO <sub>2</sub>	
Arpinskiy	Dzhermuk spa	50—65	2000	3.0—4.0	HCO <sub>3</sub> —Na	CO <sub>2</sub>	Balneology, heating, hothousing-greenhousing
Kel'bedzhanskiy	Azerbaydzhanskaya SSR, Isti-Su spa and environs	40—64	4000—4500	4.5—7.0	HCO <sub>3</sub> —Na	CO <sub>2</sub>	
Lenkoranskiy	Gorny Talys	40—65	6000	2.0—17.0	Ditto	CH <sub>4</sub> , CO <sub>2</sub> , N <sub>2</sub>	

Table 17. Regions of Potential Utilization of Fracture High-Temperature Waters in Small Artesian Basins (p. 160)

Table 18. Regions of Potential Utilization of High Temperature Springs and Their "Parallel" Boreholes (pp. 161-163).

BASIC DATA ON HIGH-TEMPERATURE WATERS						
Wells	Temp., °C	Discharge m <sup>3</sup> /days	Mineralization, g/l	Chemical types	Gas components	Possible kinds of utilization
Azerbaydzhanskaya SSR						
Khaltanskiye	47	1200	1,7	HCO <sub>3</sub> - Na	H <sub>2</sub> S	Balneology, heating, hothousing-greenhousing
Tadzhikskaya SSR						
Khodzha-Obi- Garm	40-90	500	0,4-0,5	SO <sub>4</sub> - Na	N <sub>2</sub>	Balneology, heating, hot water supply, hothousing-greenhousing, heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
Obi- Garm	43-45	1500	0,5-0,6	Cl - Na	N <sub>2</sub>	
Chashma, Yamchin	43	630	0,8	SO <sub>4</sub> - Na	H <sub>2</sub> S	Balneology, heating, hothousing-greenhousing, heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
Dzhilandy	60	480	0,2	HCO <sub>3</sub> - Na	-	
Tokuz-Bulak	65	450	0,4	SO <sub>4</sub> - Na	CO <sub>2</sub>	
Garm-Chashma	64	650	1,8	HCO <sub>3</sub> - Na	Ditto	
Dzharty- Gumbez	63	260	1,8	HCO <sub>3</sub> - Na	H <sub>2</sub> S	
Issyk-Bulak	65	61	1,1	HCO <sub>3</sub> - Na	CO <sub>2</sub>	
Kirgizskaya SSR						
Dzhalal- Abad	43	500	1,6	SO <sub>4</sub> - Na	N <sub>2</sub>	Balneology, heating-cooling supply, baths, heating of soils
Issyk- Ata	56	1555	0,3	SO <sub>4</sub> - Na	Ditto	Heating, hot water supply, hothousing-greenhousing, heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
Ak-Su	41-56	1600	0,3-0,4	HCO <sub>3</sub> - Na	• •	
Dzhely-Su- Kadzhi	52	1280	0,9	SO <sub>4</sub> - Na	• •	
Dzhety-Oguz	44	500	13,0	Cl - Ca - Na	• •	Balneology, heating-cooling supply, baths, heating of soils
Kazakhskaya SSR						
Alma- Arasan	37	320	0,25	SO <sub>4</sub> - Na	N <sub>2</sub>	Balneology, heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
Tuvinskaya avtonomnaya oblast', Tayrys	47	600	0,4	SO <sub>4</sub> - Na	N <sub>2</sub>	Heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation

Table 18 (con't)

BASIC DATA ON HIGH-TEMPERATURE WATERS						Possible kinds of utilization
Wells	Temp, °C	Discharge m <sup>3</sup> /days	Mineralization, g/l	Chemical types	Gas components	
Yush-Bel'dyr (wells and holes)	80	500	0,4	SO <sub>4</sub> —Na	—	Balneology, heating, hot water supply, hothousing-greenhousing
Buryatskaya ASSR	82 78—82	7000	0,4	HCO <sub>3</sub> —Na	—	Thermal energy utilizing refrigerants, heating, hot water supply, hothousing-greenhousing
Mogoyanskiy Uakitskiy		7000	0,6	SO <sub>4</sub> —Na		
Hot springs and wells	56	2000	0,6	SO <sub>4</sub> —Na	N <sub>2</sub>	Balneology, heating, hot water supply, hothousing-greenhousing
Verkhneangarskiye	59	6000	0,3	HCO <sub>3</sub> —Na	Ditto	
Bauntovskiye	54	1200	0,35	HCO <sub>3</sub> —Na	» »	Balneology, heating, hot water supply, hothousing-greenhousing
Kotel'nikovskiye	62	1730	0,3	SO <sub>4</sub> —Na	» »	
Garginskiye	75	200	1,0	Ditto	» »	
Pitatelevskiye (wells, boreholes)	54—68	>1000	1,5—2,0	» »	» »	
Shurinda	40—60	1700	0,5	» »	» »	Balneology, heating, hot water supply, hothousing-greenhousing
Seyuyskiye	52—55	400	0,3	» »	» »	
Irkanskiye	37	900	0,3	SO <sub>4</sub> —Na	N <sub>2</sub>	Heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
Dzhilinda	42	—	0,2	Ditto	Ditto	
Korikeyskiye	44	1000	0,3	» »	» »	
Magadanskaya oblast'	58	865	15,0	Cl—Na	CH <sub>4</sub>	Balneology, heating, hot water supply, hothousing-greenhousing
Tavatumskiye	51	450	0,3	HCO <sub>3</sub> —Na	N <sub>2</sub>	
Kabarovskiy kray	72	1900	0,3	Cl—Na	—	Heating, hothousing-greenhousing
Annenskiye	61	3500	4,5	Cl—Na	CO <sub>2</sub> , N <sub>2</sub>	
Kul'dur	55	740	35,0	Ditto	CH <sub>4</sub>	
Chukotskiy national'nyy okrug	95	6500	3,9	» »	CO <sub>2</sub> , N <sub>2</sub>	
Kukun'skiye	79	1120	1,5	» »	—	Thermal power utilizing refrigerants, heating, hot water supply, hothousing-greenhousing
Neshkenskkiye	80	1280	18,0	» »	—	
Mechigmenskiye	85	4300	3,0	» »	—	
Senyavinskiye						
Chaplinskiye						
Gil'mimlineyskiye						

Table 18 (con't)

BASIC DATA ON HIGH-TEMPERATURE WATERS						
Wells	Temp., °C	Discharge m <sup>3</sup> /days	Mineral- ization, g/l	Chemical type	Gas com- ponents	Possible kinds of utilization
Kamchatskaya oblast'						Ditto
Zhirovskiy	99	2590	0,8	• •	N <sub>2</sub>	
Kireunskiy	100	3400	1,6	• •	N <sub>2</sub> , CO <sub>2</sub>	
Bannyye	97	3000	1,2-1,4	SO <sub>4</sub> - Na	N <sub>2</sub>	
Paratunskiy (springs and wells)	64 (spr.) 64-87 (wells)	200 7000	1,3-1,9	Ditto	Ditto	
Pauzhetskiye (springs and wells)	100-200	To 10000	2,7-3,4	Cl - Na	CO <sub>2</sub> , N <sub>2</sub>	Geothermal power station with re-use of recycled water for heating, hot water supply, and hothousing-greenhousing
Kurile Islands, Goryachiy Klyuch	100-130	Not pre- cisely deter- mined, having latent discharge of water and esca- ping dry air jets and steam	4,6	Cl - Na	N <sub>2</sub> , CO <sub>2</sub> , NH <sub>4</sub>	Ditto

## Section B.

Table 1. Classifications of Springs and Ground Water in Terms of Temperature (p. 10).

(Classifications proposed by 5 Soviet and 8 non-Soviet specialists, tabulated by terminology used, °C, and by author).

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\* While not stated in text, the implication here is that for some natural springs, an additional borehole is sunk to the deep source in an effort to increase the output.

**Fig. 31. Variation in Temperature in Various Areas of the Earth's Crust and the Temperature of Saturated Steam as a Function of Depth and Pressure. (p. 144).**

## HEAT REGIME OF THE EARTH'S INTERIOR IN THE USSR

Akademiya nauk SSSR. Geologicheskii institut. Teplovoy rezhim nedr SSSR (Heat regime of the Earth's interior in the USSR). Moscow, Izd-vo Nauka, 1970, 224 p. (ITS: Trudy, no. 218, 1970).

The above cited work, while structured as a monograph, is basically a collection of individually authored or coauthored chapters or sections. Following the translated table of contents, the book is grouped into informative and indicative sections and the original numeration has been retained. Worthy of special note are two large fold-in maps which show the geothermal gradient in the upper part of the earth's crust in the USSR (Fig. 12) and the distribution of temperature at the surfaces of the crystalline and folded basements in the USSR (Fig. 13). The large volume of map information on area geothermal gradients, contained on the map in Fig. 12 (scale-approximately 1:20,000,000) also shows permafrost isopachs (lines of equal permafrost thickness) for the 100-, 300-, and 500-meter thicknesses.

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Section A.

(continued with map on next page)

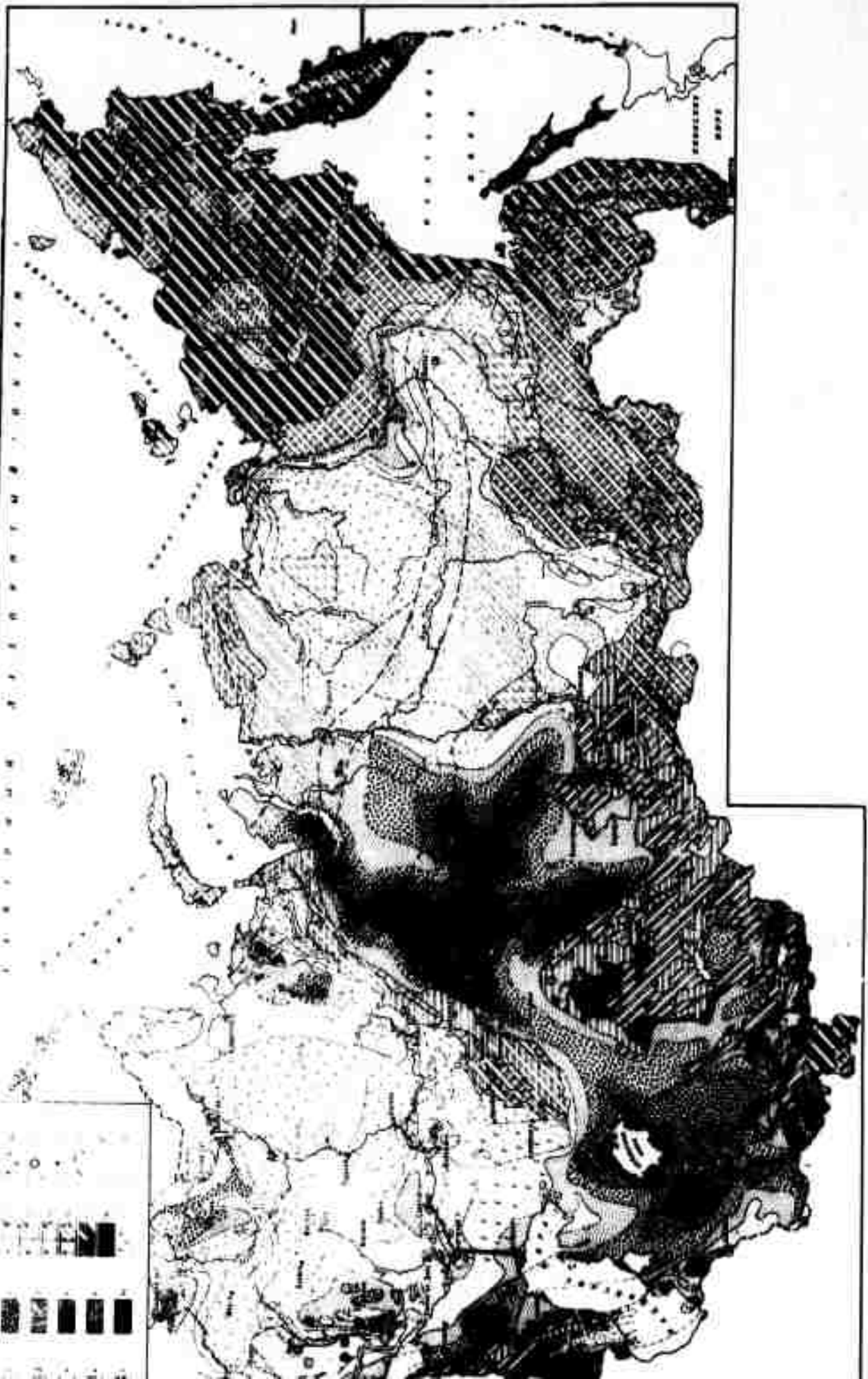


Fig. 12. Map of the Geothermal Gradient in the Upper Part of the Earth's Crust in the USSR Territory (Schematic map compiled by several authors and edited by F. A. Makarenko, B. G. Polyak and Ya. B. Smirnov, issued in 1965 and revised in 1967. Scale: approximately 1:20,000,000). (insert between pp. 76-77).

Zones in which the predominant gradients, in  $^{\circ}\text{C}/100\text{m}$ , in areas covered by platform and partially by orogenic formations within the boundaries of the sedimentary regolith down to a depth of 3000 m are: 1 - less than 1.5 (here a are determined values and b are postulated); 2 - 1.5 to 2.0; 3 - 2.0 to 2.5; 4 - 2.5 to 3.0; 5 - 3.0 to 3.5; 6 - 3.5 to 4.0; 7 - 4.0 to 4.5; 8 - 4.5 to 5.0; 9 - 5.0 to 6.0; 10 - more than 6.0. Zones in which the predominant gradients in  $^{\circ}\text{C}/100\text{m}$ , in areas covered by geosynclinal and partly orogenic formations within the boundaries of an identified structural stage are: 11 - less than 1.0; 12 - 1.0 to 1.5; 13 - 1.5 to 2.0; 14 - 2.0 to 2.5; 15 - 2.5 to 3.0; 16 - more than 3.0. Zones in which the geothermal gradient varies sharply are: 17 - areas of salt-dome tectonics; 18 - areas of Quaternary volcanism; 19 - determined values of the thermal gradient at the basement of platforms and geosynclinal areas; 20 - characteristic positive anomalies in the geotemperature field; 21 - permafrost isopachs; i. e., lines connecting points of equal permafrost thickness. Isogradients: 22 - determined; 23 - postulated.

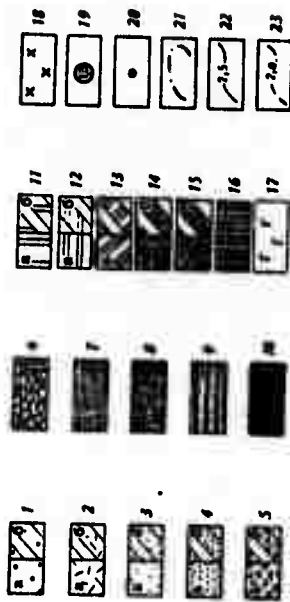




Fig. 13. Map Showing the Distribution of Temperatures at the Surfaces of the Crystalline and Folded Basements in USSR Territory (Schematic map compiled by several authors under the editorship of F. A. Makarenko, issued in 1963 and revised in 1967. Scale: approximately 1:15,000,000). (insert between pp. 76-77).

1 - eoisotherms at the surface of the crystalline and folded basements of platforms, plates and major marginal and intermontane troughs; 2 - 5 geothermal zones on the surface of crystalline and folded basements (a - determined, b - postulated); 2 - lower than 50°C; 3 - 50-100°C; 4 - 100 to 200°C; 5 - higher than 200°C; 6 - fold-mountain areas and crystalline massifs; 7 - boundaries of fold-mountain areas and crystalline massifs; 8 - temperature of the "neutral" layer in fold-mountain areas and crystalline massifs; 9 - faults.



Table 20. Distribution of Temperatures in the Sedimentary Regolith of Precambrian Platform (in the numerator - minimum and maximum values, in the denominator - average values). (pp. 86-87).

Region	Temperatures (°C) at depths (m)				Thick-ness of permafrost, m	Max. depth of basement, m	Temp. at these depths, °C	Average temp. gradient, °C/100m	Depth (m) of isotherm occurrence	
	500		1000						50°	100°
	min	max	min	max						
RUSSIAN PLATFORM										
Volga-Ural syncline	5-29 16	13-38 24	19-51 34	-	-	1050-2200	20-53	0.7-2.9 1.8	1470-1870	-
Moscow syncline	7-16 13	10-24 18	14-42 29	17-56 41	-	5000	50	0.7-2.7 1.6	1600-3630	-
Pechora syncline	7-22 14	14-38 27	20-54 38	34-74 55	47-111 64	7000	150	1.3-4.1 2.7	1330-3230	3000-3900
Carlian foreland depression	13-42 30	21-51 36	30-62 45	31-77 62	35-107 66	15500	200	0.5-3.7 2.0	970-3480	-
Pripet downwarp	10-21 15	17-35 22	24-47 31	30-54 37	40-67 51	5000	100	1.0-2.0 1.4	1720-4000	-
Dniepr-Donets downwarp	13-30 23	22-49 36	35-64 48	40-84 63	87-119 90	8000	200	1.4-3.5 2.7	1040-3040	2470-5400

Table 20 (cont)

SIBERIAN PLATFORM

North slope of Aldan shield	$\frac{3-4}{3,5}$	10,5	—	—	—	80—100	1500—2500	20—25	0,7—1,3	—
Tungus syncline	$\frac{4-13}{8}$	$\frac{15-25}{20}$	$\frac{27-37}{32}$	$\frac{38-48}{43}$	—	30—70	4500—5500	96—105	2,3	2100
		4	13	22	31	40	90	4500	76	1,8
Monocline of NE slope of E. Sayan and S. part of the Baykal foreland arched uplift area	$\frac{6-13}{11}$	$\frac{13-19}{15}$	$\frac{19-25}{22}$	$\frac{26-31}{28}$	$\frac{32-44}{39}$	—	2700—2800	38—47	1,4	—
		$\frac{13-19}{15}$	$\frac{21-28}{25}$	$\frac{28-31}{29}$	$\frac{32-36}{35}$	$\frac{39-42}{40}$	—	3800—4000	67—74	1,5
Kansko-Taseyev depression	16	$\frac{15-16,5}{16}$	$\frac{22-26}{24}$	$\frac{30-37}{34}$	$\frac{40-51}{45}$	$\frac{57-78}{62}$	5500—7000	100—135	1,7—2,5	$\frac{2750-2650}{2700}$
		16	28	39	51	62	—	2000—2500	>60	2,3
Rybinsk depression	$\frac{0-9}{3}$	$\frac{10-21}{14}$	$\frac{22-34}{28}$	$\frac{34-47}{42}$	$\frac{46-63}{55}$	$\frac{55-83}{68}$	6000—9000	150—250	1,6—4,0	$\frac{2200-2600}{2400}$
Vilyuy syncline	—	—	—	—	—	Д° 650	—	—	—	$\frac{3500-4100}{3800}$

Table 22. Distribution of Temperatures in the Sedimentary Regolith of Epi-Paleozoic Plates (in the numerator - minimum and maximum values, in the denominator - average values). (pp. 92-93).

Region	Temp. (°C) at depths (m)					Max. depth of basement, m	Temp. at these depths, °C	Average heat gradient, °C/100m	Depth of occurrence (m)	
	500	1000	1500	2000	2500				3000	500
WEST SIBERIAN PLATE										
Central part of plate	15-28 22	27-44 34	43-63 50	56-96 68	72-101 84	85-122 116	93-126	3,0-5,0	1200-1770 1500	2100-2500 2300
N. part of plate (Ob'-Tazov interfluvium)	7-16 11	17-34 25	36-52 42	50-69 53	63-71 67	77-84 80	100-125	2,5-3,0	1500-2000 1750	2600-3550 3400
E. Ural slope	17-40 21	31-54 42	54-80 64	75-93 86	-	-	80-116	4,0-6,0	700-1200 950	1500-2000 1750
	8-16 12	29-39 33	51-61 54	69-84 77	-	-	75-85	3,9-4,7	1140-1500 1330	-
N. Kazakhstan slope	23-33 27	43-53 52	63-85 77	-	-	-	82-102	3,5-6,0	810-1300 1050	1800-1900 1800
	20-21 20	32-40 33	-	-	-	-	53-55	2,4-3,8	-	-
Yenisey fore-land slope	6-14 10	17-25 22	33-38 35	-	-	-	33-39	2,2-3,0	-	-
	4-10 7	16-25 21	28-40 35	40-58 50	52-76 66	-	79-87	2,0-3,0	1770-2460 2100	-

Table 22 (con't)

		TURANSK PLATE									
Central Karakum area	Dome part	40-58	56-69	70-81	83-96	-		To 2500	110	3,1-4,1	300-500
		46	61	77	94	82-89	97-100				113-122
Aral area (E. Aral depression)	S. slope	35-40	51-56	66-72	82-89	97-100	113-122	3500	136	2,9-3,3	800-1100
		38	53	68	84	100	117				980
N. Ust'yurt-Chalkar zone of downwarp <sup>1</sup>		30-32	31-34	71-73	-	-	-	To 1500	72	3,3-4,3	920-950
		31	32	72	-	-	-	6000	>230	2,5-3,3	1200-1700
S. Mangyshlak downwarp		30-30	33-43	43-50	76	92	106	To 4000	>150	3,4-4,0	850-1120
		33	38	51	74-81	87	-	To 5000	>150	3,0-4,3	600-1100
Bukhara-Khiziny "step" zone		34-42	50-62	66-82	82-102	100-106	114-122	To 5000	>150	3,0-4,3	600-1100
		39	56	72	90	104	118	7,000-7500	100-200	2,3-3,3	-
Bakharod peripheral platform monocline		27-33	38-47	48-62	55-76	82-91	70-116	2,000-3,000	120-130	3,2-4,0	1000-2300
		31	43	55	67	77	95	About 4000	70-140	3,3	1000-1200
Chu syncline		26-29	42-50	59-70	70-90	-	-	2,000-3,000	92-118	3,2-4,0	1000-1200
		28	47	63	84	-	-	2700-3000	120-130	3,2-4,5	1000-2300
Syrdar'ya and T-zhent depressions		29-36	45-58	62-81	85-114	107,5	-	2700-3000	120-130	3,2-4,5	1000-2300
		32	51	70	102	-	-	About 4000	70-140	3,3	1000-1200
Nurgab depression (S. side)		30-33	46-50	63-67	81-84	97-101	113-118	2400-2500	100-120	3,2-4,5	1000-2300
		32	48	65	82	99	115	2400-2500	100-120	3,3	1000-1200

SKIF PLATE

Asov-Kuban and Tersko-Kum depressions

	19-59	31-84	41-111	62-124	70-140	70-107	5500	150	1,4-5,2	500-1680
	36	52	70	86	108	115				3,2
Stavropol' uplift	25-56	41-83	53-114	66-124	-	-	1000-2000	50-120	2,0-6,6	520-1350
	40	63	82	99	-	-	1000-1200	50-120	4,0	1320-2540

<sup>1</sup>The data characterize the northwestern and northern marginal portions of the downwarp.

Table 23. Temperature Distribution in the Upper Structural Stage of Folded Structures (in the numerator - minimum and maximum values, in the denominator - average values). (pp. 94-96).

Stage of folding	Structures	Temp. (°C) at depths (m)						Max. depths of basement, m	Temp. at these depths, °C	Average temp. gradient, °C/100m	Depth of occurrence (m)		
		100	1,00	2000	2500	3000	3500				500	1000	
Mesozoic	S. Mimosinsk depression	$\frac{17-22}{18}$	$\frac{22-35}{27}$	$\frac{34-58}{42}$	$\frac{40-84}{54}$	$\frac{50-82}{70}$	$\frac{56-97}{83}$	5000-7000	(50-160)	1,4-3,1	1000-2200	2000-5000	
	Kuznets' downswarp	$\frac{15-23}{18}$	$\frac{21-38}{29}$	$\frac{29-52}{40}$	$\frac{35-67}{52}$	$\frac{54-91}{68}$	$\frac{62-95}{80}$	(600)-9000	>200	1,3-2,8	1100-3100	2200-4200	
	Zeya-Burein depression	15	30	40	61	77	92	To 3000	92	3,1	1000-1700	-	
	Ural foreland marginal downswarp	$\frac{0-20}{15}$	$\frac{13-24}{21}$	$\frac{22-30}{27}$	$\frac{31-34}{31}$	$\frac{39-50}{44}$	$\frac{45-58}{51}$	Not specified to 15000	To 70 > 200	$\frac{1,0-1,8}{1,5}$	2200-2300	-	
	Greater Dnieper	$\frac{14-20}{22}$	$\frac{23-47}{35}$	$\frac{31-53}{40}$	$\frac{40-78}{60}$	$\frac{53-86}{78}$	$\frac{55-114}{84}$	>9000	>200	$\frac{1,5-3,2}{2,4}$	1100-2700	2500-6000	
	Khasan-Sa downswarp	E. edge (Nondvilk region)	$\frac{0,0-0,2}{0,1}$	$\frac{10-12}{11}$	$\frac{19-23}{22}$	$\frac{20-37}{32}$	$\frac{23-50}{43}$	$\frac{48-62}{56}$	5000-6000	85-100	$\frac{2-2,7}{2,6}$	$\frac{2,00-3100}{2600}$	2500-6000
		W. edge (Ust.-Port region)	$\frac{5-10}{8}$	$\frac{19-25}{22}$	$\frac{33-50}{47}$	$\frac{42-75}{51}$	70	-	2000-3000	79-82	-	$\frac{1000-3000}{1900}$	-
	Mesozoic	Borgoyak depression	18	28	41	-	-	-	To 2000	To 53	2,5	-	-
		Verkhoyansk foreland marginal downswarp	$\frac{0-9}{2}$	$\frac{10-21}{14}$	$\frac{19-34}{26}$	$\frac{29-47}{38}$	$\frac{38-64}{51}$	$\frac{45-80}{64}$	9000	>300	1,5-4,0	2200-2900	About 4000

<sup>1</sup> Thickness of permafrost to 400-600 m.

Table 23 (con't)

Stage of folding	Structures	Temp. (°C) at depths (m)								Max. depths of basement, m	Temp. at these depths, °C	Average temp. gradient, °C/100m	Depth of occurrence (m) of isotherms	
		500		1000		2000		3000					50°	100°
		min	max	min	max	min	max	min	max					
Albian	Rion depression	24-36 27	34-46 39	43-61 51	52-77 62	64-91 74	74-107 84			160-200	1,8-3,1 2,2	1800-1900	About 2700	
	Kurinsk depression	22-37 27	32-50 44	42-83 63	51-103 78	61-125 97	71-148 110			>300	2,0-4,5 3,3	-	-	
	Indolo-Kuban marginal downwarp	23-43 27	32-50 41	46-66 57	54-92 73	80-107 86	74-129 100			200-300	2,0-4,5	1000-1750	2130-4300	
	Tersko-Caspian downwarp	26-68 42	39-75 54	56-89 67	67-98 81	93-113 98	89-130 106			>250	1,8-3,7	425-1235	2110-3500	
	W. Turkmen depression	22-34 30	37-43 43	52-62 56	64-76 68	70-90 79	86-104 93			280-310	2,1-2,9	500-1800	2800-3600	
	Kopetdag foreland marginal downwarp	27-30 28,5	36-42 39	45-49 47	54-60 57	65-74 69	74-84 79			>200	1,8-2,2	1550-1800	-	
	West Kamchatka downwarp	24	33-38 33	42-52 47	50-63 58	-	-			>3000	2,8	1470	3400	
	East Kamchatka downwarp	22-26 24	29-42 35	49-56 52	63-71 67	-	-			-	2,8	1300-1530 1415	2970-3350 3100	
	West Sakhalin synclorium	20-25 23	32-40 36	55,0	70,0	-	-			>200	2,5-3,0	-	-	
	East Sakhalin synclorium	10-19 14	21-36 30	36-53 46	57-64 60	-	-			>200	2,4-3,4	-	-	

Cenozoic

Tikhookeanskij (Pacific Ocean)

Table 23 (cont)

Structure	Temp. (°C) at depths (m)								Max. depth of basement, m	Temp. at these depths, °C	Average temp. gradient, °C/100m	Depth of occurrence (m)			
	50		100		200		250					300		50'	100'
	min	max	min	max	min	max	min	max				min	max	min	max
Famir-Alai foothills (Sudzhander'ya, Kud'yab depressions)	28-31 30	30-40 35	50-60 55	73	87	100					2.2-3.0	1200	3000		
Kushkin group of uplifts	38-44 42	56-69 62	73-92 82	91-115 103	108-118 112	125-138 130					3.5-4.0	600-850	1700-1800		
Fergana depression	25-37 31	38-52 44	52-68 58	62-84 70	79-100 88	90-110 103					2.0-3.2	1100-1600 1350	2500-3000 2750		
III depression	16-24 19	26-37 32	39-49 46	50-64 59	62-76 69	74-91 82					2.3-3.0	1550-2000 1700	3000		
Imyl'-Kul' depression	20	36	52	68						68-70	3.2	1500	-		
Zaysan depression	21	34	46							46	2.5	-	-		
Tunkin depression	15	23	40	53						76	2.0	950-1900	-		
Selengin depression	13-23	22-34	30-45	48-64		53-71				100-125	2.0-2.9	1564	-		
Barguzin depression	9	24	44							38	2.7	-	-		

Cenozoic Neotectonic

Much of the information directly pertinent to the development of geothermal areas is concentrated in Chapter V and specifically, in the section entitled "Geothermal Resources of the USSR". In the brief introductory remarks to this section, the authors cite the following major sources containing data on USSR thermal water resources: the transactions of the First All-Union Conference on Geothermal Research, published as "Problemy geotermii i prakticheskogo ispol'zovaniye tepla Zemli" (Problems in geothermy and the practical utilization of the Earth's heat, vol. 1, 1959 and vol. 2, 1961); other All-Union geothermy conferences with the resultant publications "Geotermicheskiye issledovaniya i ispol'zovaniye tepla Zemli" (Geothermal research and the utilization of the Earth's heat, 1966) and "Regional'naya geotermya i rasprostraneniye termal'nykh vod v SSSR" (Regional geothermy and the distribution of thermal waters in the USSR, 1967); and specialized monographs such as "Otsenka resursov i perspektivy ispol'zovaniya termal'nykh vod SSSR kak istochnika tepla" (An evaluation of resources and prospects for the utilization of USSR thermal waters as a heat source, 1st edition in 1957 and 2nd edition in 1959) and "Termal'nyye vody SSSR i voprosy ikh teploenergeticheskogo ispol'zovaniya" (Thermal waters of the USSR and problems in their utilization for heat and power, 1963).

#### Distribution of Thermal Waters

The USSR is subdivided into nine regions in terms of hydrogeological and geothermal conditions, each subdivision offering different potentials for the utilization of thermal waters.

1. a) Volcanic regions of Cenozoic eugeosynclines and areas of Cenozoic activity (Kamchatka and the Kurile Islands - Pauzhetka, the Geyzer valley [Dolina Geyzerov], and Goryachiy Plyazh, directly associated with active volcanos;

b) Areas associated with active volcanos (Lesser Caucasus, Tranbaikalia, and northeastern USSR, and such as found in the Nalychevskiye hot springs in Kamchatka, the Dzhermuk spring in Armenia, etc);

2. Mountain structures of the Cenozoic miogeosynclines and areas of epiplatform orogeny (represented by the Carpathians, Greater Caucasus, Pamirs, Tien-Shan, Pribaykal'ye, etc., and at such sites as: the Khadzhi-Obi-Garm springs in the Tien-Shan; the Garm-Chashma, Dzhilandy, and Issyyk-Bulak areas of the Pamirs; the Mogoyskiye, Seyyuyskiye, Allinskiye, Pitatelevskiye springs in the Baykal folded system; and the Yelisu, Khaltanskiye springs in the Greater Caucasus);
3. Cenozoic marginal and interior troughs and neotectonic depressions (Caucasus foreland, and the Fergana, Rion and Kurin depressions);
4. Mesozoic folded mountain structures (Verkhoyansk folded zone, Sytygan-Sylba hot springs in the upper reaches of the Indigirka river);
5. Mesozoic troughs and depressions (the Verkhoyansk foreland downwarp, the Zeysko-Udskaya depression);
6. Paleozoic fold-mountain structures (Urals, the Altay);
7. Regolith of the Paleozoic plate (Skif, Turansk, West Siberia);
8. Precambrian shields (Baltic, Ukrainian, etc.);
9. Regolith of the Precambrian platforms (Russian and Siberian), i. e., Irkutsk basin of the Siberian platform, the Caspian, Dnepr-Donets and Vilyuy depressions.

#### Uses of Thermal Waters

Here, the authors examine possible uses of thermal waters in specific regions, taking into account engineering and economic considerations based on the particular use (see Table 36).

1. Geothermal energy. The authors mention that the basic design for a geothermal power station was described in the 1960 book "Geotermicheskiye resursy i ikh energeticheskaye ispol'zovaniye" (Geothermal resources and their energy utilization) by B. M. Vymorkov and N. L. Putnik. This

design, however, caused degradation of the steam parameters before the turbine with a resultant reduction of power output per unit of steam. Based on the above source and other data, basic engineering criteria were developed and are summarized in Table 36.

Type of utilization	Temp., °C, not lower than	Discharge, m <sup>3</sup> /day, no less than	Depth of occurrence of reservoir, m, no deeper than	Mineralization, g/l, not more than
Generation of electric power by GEOTES** using direct steam-water cycle.....	100	10 000	3000	4
Generation of electric power by GEOTES** using intermediate low-boiling-point substances.....	70	2500	2500	50
Heat supply of population centers.....	70	1000	2500	2 (50) *
Cooling supply.....	70	500	1500	50
Hot-water supply.....	40	1000	1500	1 (50)
Greenhousing-hothousing.....	40	500	1500	10 (50)
Hot-water irrigation.....	25	250	1000	2
Warming soil.....	25	500	1500	50
Melting permafrost.....	25	250	3000	50
Swimming pools and bath facilities.....	25	250	1000	50

\*In parentheses, allowable mineralization of water for geothermal equipment utilizing heat exchangers.  
 \*\*Geothermal electric power station

Table 36. Engineering Criteria Used in Identifying the Practical Utilizations of Thermal Waters with a Projected Exploitation Period of 25 Years or More (p. 203).

Studies have been carried out in recent years to find sites for new power stations (other than the Pauzhetka station) by such scientists as V. V. Aver'yev, Ye. A. Vakin, K. F. Bogoroditskiy, B. A. Beder, A. S. Dzhamalova, V. V. Ivanov, B. F. Mavritskiy, F. A. Makarenko, V. M. Sugrobov, and G. M. Sukharev, and others, in regions of active volcanism.

In the Kamchatka area, there are four geothermal regions whose energies are suitable for the construction of geothermal electric power stations (see Table 37).

Geothermal regions and sites	Heat transfer agent	Max. temp., °C	Natural heat capacity, 10 <sup>6</sup> cal/sec	Capacity increase factor	Predicted capacity	
					Thermal, 10 <sup>6</sup> cal/sec	Electrical, Mw
<u>Pauzhetskiy</u>						
Pauzhetskoye	s/w*	150-200	15	5		155
Koshelevskoye	steam	155	75	3	75	20 (30)
<u>Uzone-Semyachinskiy **</u>						
Nizhne-Semyachinskoye	s/w	100	25	3	75	270
Verkhne-Semyachinskoye	steam	136	50	3	150	30
Uzonskoye	s/w	250	60	3	180	90
<u>Mutnovsko-Zhirovskiy</u>						
Nizhne-Zhirovskoye	s/w	130	4	3	12	36
Verkhne-Zhirovskoye	steam	130	3,5	3	10,5	6
Severo-Mutnovskoye	s/w	130	15	3	45	27
Bol'she-Bannoye	s/w	150-170	5,6	6	30	—

\*Steam-water mix

\*\*Without consideration of the Valley of Geysers hot springs

Table 37. Energy Parameters of Geothermal Sites in Kamchatka (after Ye. A. Vakin, 1968). (p. 205).

Other areas which are recommended for investigation to determine their potential use for geothermal electric power stations are listed as being in the East Caucasus foreland (Tersko-Caspian trough and Tersko-Kum depression, near the cities of Makhachkala, Khasavyurt, Kizlar, etc.).

Areas in which the hydrothermal systems have temperatures in excess of 100°C (at attainable depths) but are not suitable for use as geothermal electric power stations occur in the Tersko-Kum basin (too highly mineralized) and in the Khodzha-Obi-Garm area [ sic ] area (too low discharge, i. e., 1500 m<sup>3</sup>/day).

Lower-temperature sources are capable of supplying electric power to industry using ground water at temperatures of less than 100°C. An experimental power station (750 kilowatts) operating on freon-12 is now in operation in Kamchatka at the Sredne-Paratunka wells. Regions

having similar potentials are mentioned as existing at Maykop, the villages of Kurdzhipskaaya, Kuzhorskaya, Tul'skaya in the Azov-Kuban artesian basin, at Georivevsk, Nevinnomyssk, Prikamsk in the Tersko-Kum basin, at Tashkent, Sary-Agach in the Syrdar'ya basin, at Krasnovodsk, Nebit-Dag, the Cheleken peninsula in the Western Turkmen basin, and at Alma-Ata and Panfilov in the artesian basin of the Ili depression. In addition, prospects are good for the construction of geothermal electric power stations of this type in the fracture waters of the northeastern USSR - the Mogoyskiye and Uakitskiye hot springs in the Buryat ASSR, and at the Mechigmenskiye, Sinyavinskiye and Chaplinskiye springs in the Chukotskiy National'nyy Okrug.

2. Heat supply for population centers. Plans are being developed at the present time for hot-water pipes to run from the Paratunka springs to Petropavlovsk-Kamchatka, a distance of 45-65 km.

The population centers in the USSR where hot water can be used for heating purposes include Armavir, Groznyy, Gudermes, Nal'chik, Cherkessk, Omsk, Tyumen', Tobol'sk, Arshan, Poti, Tsaishi, Fergana, Chartak, and others.

3. Utilization of thermal waters for cooling purposes. Uses in the chemical industry for refrigeration are possible in regions 1 - 3 and 7 as listed under "Distribution of Thermal Waters" above. The use of thermal waters for air-conditioning may be suitable in such cities as Tashkent, Dushanbe, Alma-Ata, and Frunze.

4. Hot-water supply. Here, the chemical composition of usable water becomes the limiting factor (regulated by State Standard GOST 2874-54), with hot-water supply possible in regions 1 - 3 and 7 as described above.

5. Hothousing - greenhousing. Experiments have been carried out in Kamchatka, Kazakhstan and the Caucasus foreland area. Besides these areas, it is stated that at the present time, the largest hothousing-greenhousing complex in the world is being completed at the Sredne-Paratunka springs; its withdrawal area is 60,000 square meters. Another complex is projected for the Puzhetka springs (serving 150,000 m<sup>3</sup>) with others planned in Dagestan at Makhachkala and Khasavyurt, in the Checheno Ingushskoy ASSR, in the Groznyy area,

in the vicinity of Stavropol' (Georgiyevsk), at Tobol'sk, and in other regions. Other potential areas are indicated in regions 1 - 3 and 7, and possibly in certain areas of regions 4 and 5.

6. Melting of permafrost. The hot springs suitable for use in mining operations in the north (melting of permafrost) are listed as occurring in Chutkotka, the deep Cenozoic and Mesozoic troughs and basins in the Yano-Kolyma, Chukotka and Koryak folded regions and in the Yano-Sugay, Olyutor and Parapol'sko-Penzhinsk synclinal zones.

7. Servicing of swimming pools and baths.

8. Balneology.

9. Extraction of chemical salts and elements.

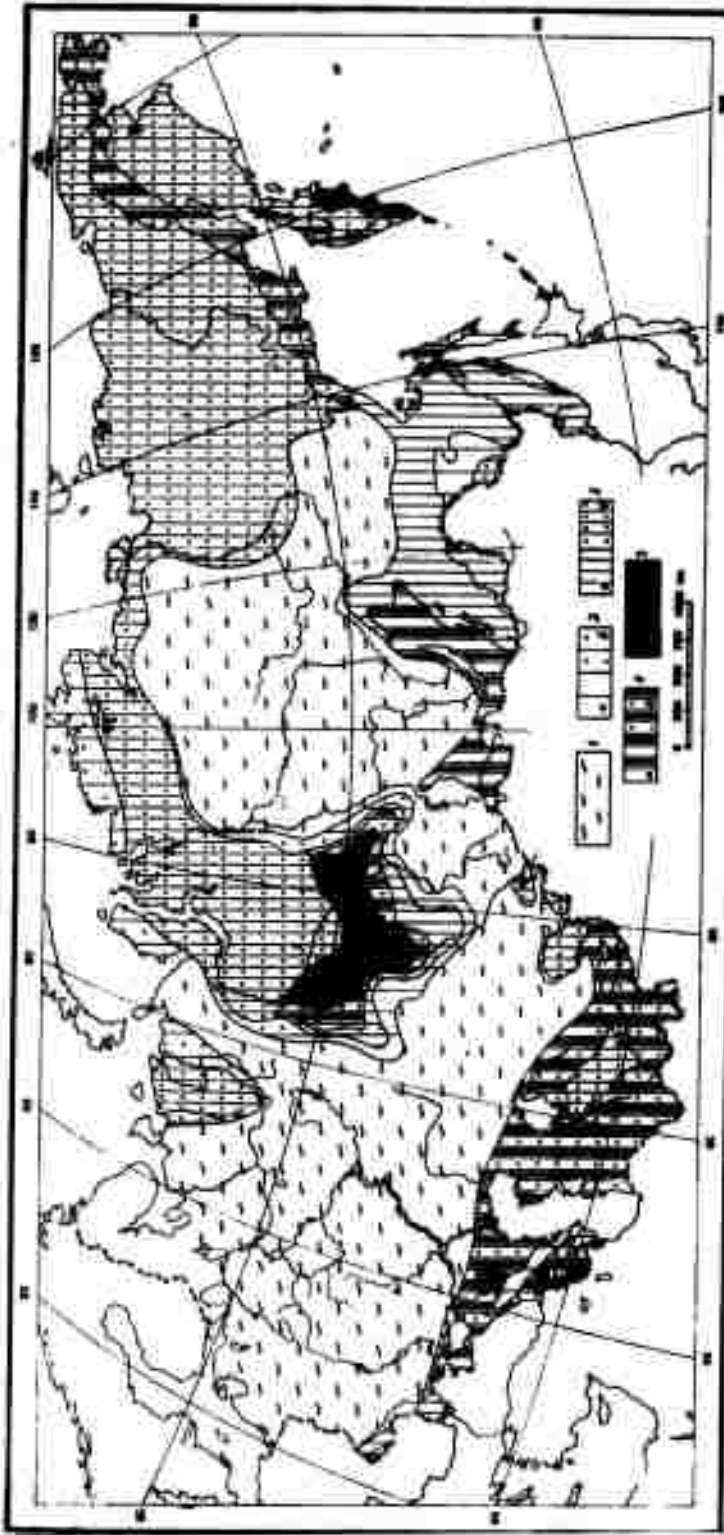


Fig. 54. Sketch Map Showing Potential Uses of Thermal Waters for Various Branches of the Economy (as per requirements cited in Table 36) (p. 210).

1 - regions where the use of thermal waters for modern technology is not economically favorable (in individual sections, the thermal waters can be extracted incidentally when deep drilling for petroleum); 2a - regions of possible utilization of thermal waters for thermal irrigation, warming the ground, melting permafrost, and for heating swimming pools and bath facilities; 2b - the same, excluding the first type of utilization; 3a - regions where all of the above enumerated uses of thermal waters are possible, in addition to their use as hot-water supply and in greenhouse-hothousing; 3b - the last two types of uses, possible only by using heat-exchangers; 4a - regions where, in addition to the above enumerated uses, space heating of population centers, cooling, and generation of electric power at geothermal electric power stations using intermediate low-boiling point substances, are possible; 4b - the same, using heat exchangers; 5a - regions in which all kinds of uses of thermal waters are possible, including a geothermal electric power station with a direct steam-water cycle; 5b - the same, using heat exchangers.

**Section B.**

- Fig. 16.** Schematic Geothermal Sectional Map of the European USSR at the 500-m Depth (p. 84).  
(Shows isotherms at 5<sup>o</sup>C intervals over the 10 to 40<sup>o</sup>C range, and the crystalline basement).
- Fig. 17.** Geothermal Section Across the Irkutsk Amphitheater. (p. 85).
- Table 21.** Distribution of the Geothermal Gradient (in <sup>o</sup>C/100 m) in the Paleozoic Structures of the USSR. (p. 89).
- Fig. 19.** Geothermal Section Across the West Siberian Plate. (p. 91).
- Fig. 20.** Schematic Geothermal Section of the Kopet-Dag -- Takhtakairskiy Arch. (p. 91).
- Table 24.** Differentiation of the Geothermal Field. (p. 103).
- Fig. 24.** Geothermal Conditions in the Area of the Avachinsk Volcano. (p. 107).
- Fig. 25.** Geological-Geothermal Section Across the Northwestern Part of the Russian Platform. (p. 108).
- Fig. 26.** Geothermal Section Across the Yangantau Mountain Anomaly. (p. 110).
- Fig. 29.** Distribution of Points at Which Heat Flow Has Been Determined in the Central and Southeastern Parts of the Russian Platform. (p. 117).
- Table 25.** Heat Conductivity of Rocks of Different Lithological and Stratigraphic Complexes in the Eastern Part of the Russian Platform. (p. 121).

**Table 26. Results of Determinations of Heat Flow in the Russian Platform Area. (pp. 130-133).**

(Gives names, numbers, coordinates, depths investigated, time lapse (in months) between drilling and temperature measurements, altitude of borehole heads, heat flow measurements (in  $\mu\text{cal}/\text{cm}^2 \text{ sec}$ ), accuracy, depth of basement, depth of Moho, and amplitudes of recent tectonic movements for 72 boreholes in the northern part of the Volga-Ural anteklise and Moscow syneklise, the Tatar arch, Rumanian uplift, the Sokso-Sheshim, Zhigulev, and Don-Medveditskiye dislocations, the Caspian foreland syneklise, the foreland Ural boundary downways, the Voronezh anteklise, and the Greater Donbass downwarp.)

**Table 27. Heat Conductivity of Rocks of Various Lithological and Stratigraphic Complexes in the Caucasus Foreland Area. (p. 141).**

**Table 28. Results of Heat Flow Determinations in the Caucasus Foreland Area. (pp. 143-146).**

**Table 29. Statistics of the Heat Flow in Various Tectonic Structures of the Caucasus and Caucasus Foreland. (p. 149).**

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**Table 34. Average Magnitudes of the Heat Flow in Various Tectonic Structures in the USSR and Adjacent Countries. (pp. 168-169).**

**Fig. 47. Sketch Map of the Geoisotherms of the Pauzhetka Pool. (p. 186).**

**Fig. 51. Hydrogeological Section Across the Pauzhetka Pool. (p. 193).**

## PROBLEMS OF DEEP-SEATED HEAT FLOW

Akademiya nauk SSSR. Institut fiziki Zemli. Problemy glubinnogo teplovogo potoka (Problems of deep-seated heat flow). Moscow, Izd-vo Nauka, 1966, 145 p.

This collection of articles represents one of the major pre-1968 references on the geothermy of the USSR. In the table of contents below, all but two of the articles are accompanied by annotations reflecting the general content or specific items of interest appearing in the article.

### Table of Contents

1. Lyubimova, Ye. A. Sources of deep-seated heat of the earth and the thermal characteristics of planets of the earth type. 3-30  

(In general, a theoretical discussion of the principles and procedures involved in investigations of the roles of radioactivity, gravity, tidal friction and energy dissipation, and rheological equations of state. Bibliography cites 30 Soviet and 42 non-Soviet references).
2. Lyubimova, Ye. A., R. von Herzen, and G. B. Udintsev. Heat exchange through the ocean bottom. 31-46  

(Bibliography cites 5 Soviet and 16 non-Soviet references).
3. Lyubimova, Ye. A. Estimate of the distribution of deep-seated heat flow for southern European USSR. 47-73  

(Data included in this paper include a small-scale sketch map showing the sites at which heat-flow measurements were made; tables giving the type of tectonic zone, geographic area, borehole number, geographic coordinates of boreholes, depths of probes, observation period, elevation of hole above sea level, heat flow measurements; temperatures are recorded relative to depth of measurement; chemical composition of water not given).

4. Kutasov, I. M., Ye. A. Lyubimova, and F. V. Firsov. Recovery rate of temperature field in boreholes on the Kola Peninsula. 74-87
- (Discusses methods used and gives results. Bibliography cites 4 Soviet and 5 non-Soviet references).
5. Lyubimova, Ye. A., and F. V. Firsov. Determination of heat flow in some regions of Central Asia. 88-106
- (Contains a small-scale sketch map showing sites of investigations in the Kazakhstan area between Alma-Ata on the south, to Frunze on the west, Taldy-Kurgan on the east and north to Lake Balkhash and Karaganda on the north. The data presented include the types of rocks in which the measurements were made, water temperatures and the geothermal gradients, heat conductivity, and heat flow measurements. The bibliography cites 4 Soviet and 2 non-Soviet references).
6. Lyubimova, Ye. A., V. A. Shelyagin, and A. P. Shushpanov. Apparatus used to determine deep-seated heat flow. 1-7-132
- (The bibliography cites 9 Soviet and 4 non-Soviet references).
7. Shushpanov, A. P. On the heat regime of the Carpathian area of the USSR. 133-143
- (Presents borehole data obtained in both the Hungarian and Ukrainian areas of the Carpathians: borehole depths and temperatures, the stratigraphy and lithology of the formation involved, the temperature gradients, and the heat conductivity. The bibliography cites 6 Soviet and 7 non-Soviet references). 133-143

## GEOHERMAL INVESTIGATIONS

Akademiya nauk SSSR. Institut fiziki Zemli. Geotermicheskiye issledovaniya (Geothermal investigations). Moscow, Izd-vo Nauka, 1964, 176 p.

In this book, another major pre-1968 reference, edited by Ye. A. Lyubimova, three major topics are discussed as outlined below.

1. Principles of Determination of Heat Flow from the Earth's Interior and Measurement Results (pp. 5-102), written by Ye. A. Lyubimova, L. N. Lyusova and F. V. Firsov, deals with the importance of heat flow data in understanding the physics of the earth, factors causing the deviation of borehole temperatures from actual rock temperatures, and problems involving field methods and equipment (the last discussion includes relatively detailed drawings of the T-8 and T-9 resistance thermometers). Other parts of this section of the book describe the results of measurements of deep-seated temperatures (borehole temperatures and geological sections) in the Ukraine, the Belgorod area, and the Stavropol' and Krasnodarskiy krays, as well as heat flow investigations. This section of the book contains a list of 37 Soviet and 34 non-Soviet references.

2. Analysis of Errors in Electrical Circuits Used in Measuring Temperatures in Deep Boreholes, written by A. P. Shushpanov (pp. 105-114). The bibliography contains 10 Soviet and 3 non-Soviet references.

3. Thermophysical Investigations of Rocks, written by Ye. A. Lyubimova, G. N. Starikova, and A. P. Shushpanov (pp. 115-174). The bibliography contains 30 Soviet and 10 non-Soviet references.

PART II. INFORMATION ON THE GEOTHERMY OF SPECIFIC  
AREAS OF THE USSR

HYDROCHEMICAL ANOMALY OF THE UZON HEAT FIELD ON KAMCHATKA

Pilipenko, G. F. IN: Vulkanizm i glubiny Zemli (Volcanism and the depths of the earth). Papers presented at the Third All-Union Volcanological Conference, 28-31 May 1969. Izd-vo Nauka, Moscow, 1971, 229-238.

Contains tables giving the comparative characteristic chemical compositions of the Uzon area hot springs by hydrochemical zones and the chemical characteristics of some of the hot springs in the Uzon caldera, as well as the following two sketch maps:

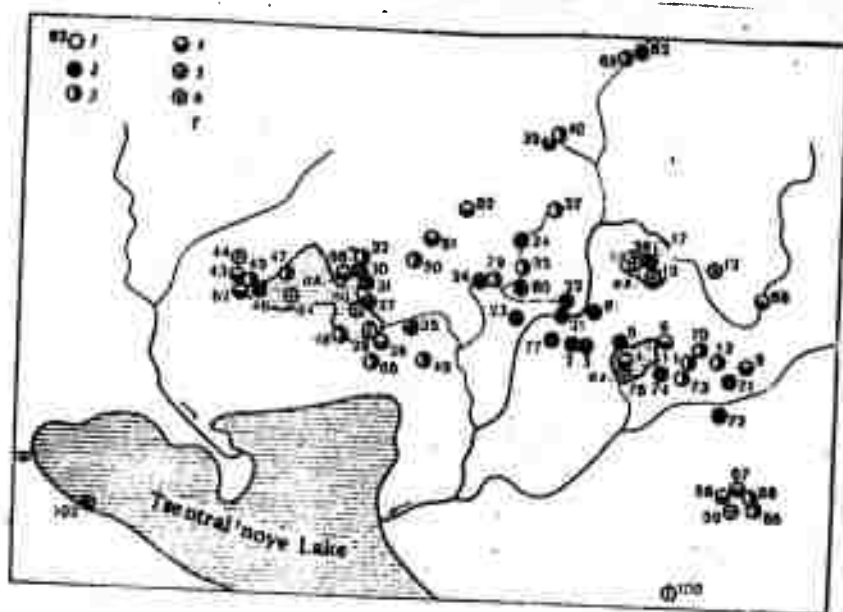


Fig. 1. Sketch Showing the Locations of the Uzon Hot Springs.

1 - hot spring numbers; 2-6 - hot springs with temperatures: 2 - higher than 70°C, 3 - 50-70°C, 4 - 30-50°C, 5 - 15-30°C, 6 - lower than 15°C.

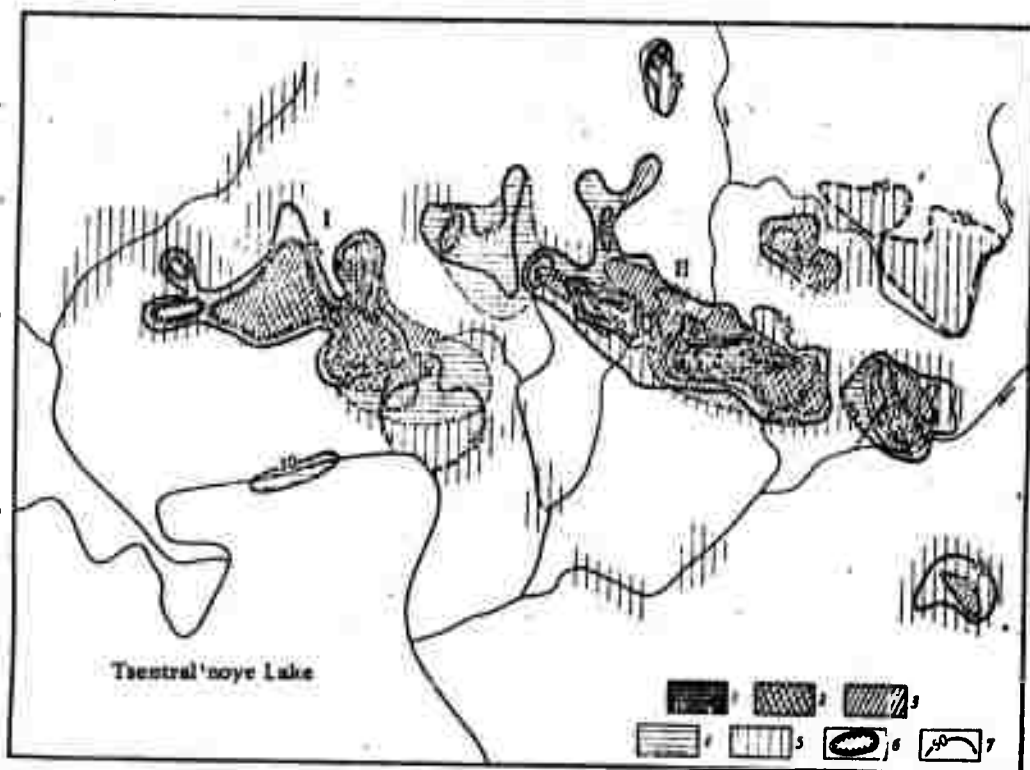


Fig. 2. Sketch Showing the Hydrochemical Zonality of Discharge Sites of the Uzon Steam-Boiling Springs (status in July - September 1966/1967).

The discharge zones are: 1 - sodium chloride waters; 2 - sodium sulfate - sodium chloride waters; 3 - sodium chloride - sodium sulfate waters; 4 - sodium hydrocarbonate - chloride and sodium chloride - hydrocarbonate waters; 5 - sulfate, hydrocarbonate - sulfate, and sulfate - hydrocarbonate waters of complex cation composition; 6 - acidic hot water lake (pH 2-3); 7 - isolines of temperature ( $T^{\circ}$ ) measured at depth of 0.5 m; I - thermal sector of Fumarol'noye Lake; II - Eastern heat field.

**HOT SPRINGS OF THE KIREUNA VALLEY IN THE CENTRAL RANGE  
OF KAMCHATKA**

Kirsanova, T. P. IN: Vulkanizm i glubiny Zemli (Volcanism and the depths of the earth). Papers presented at the Third All-Union Volcanological Conference, 28-31 May 1969. Izd-vo Nauka, Moscow, 1971, 239-246.

Describes the geography, structural geology and lithology of three hot spring areas in the Kireuna river valley: the upper group, the middle group and the lower group. The following large-scale sketch maps are given in the text:

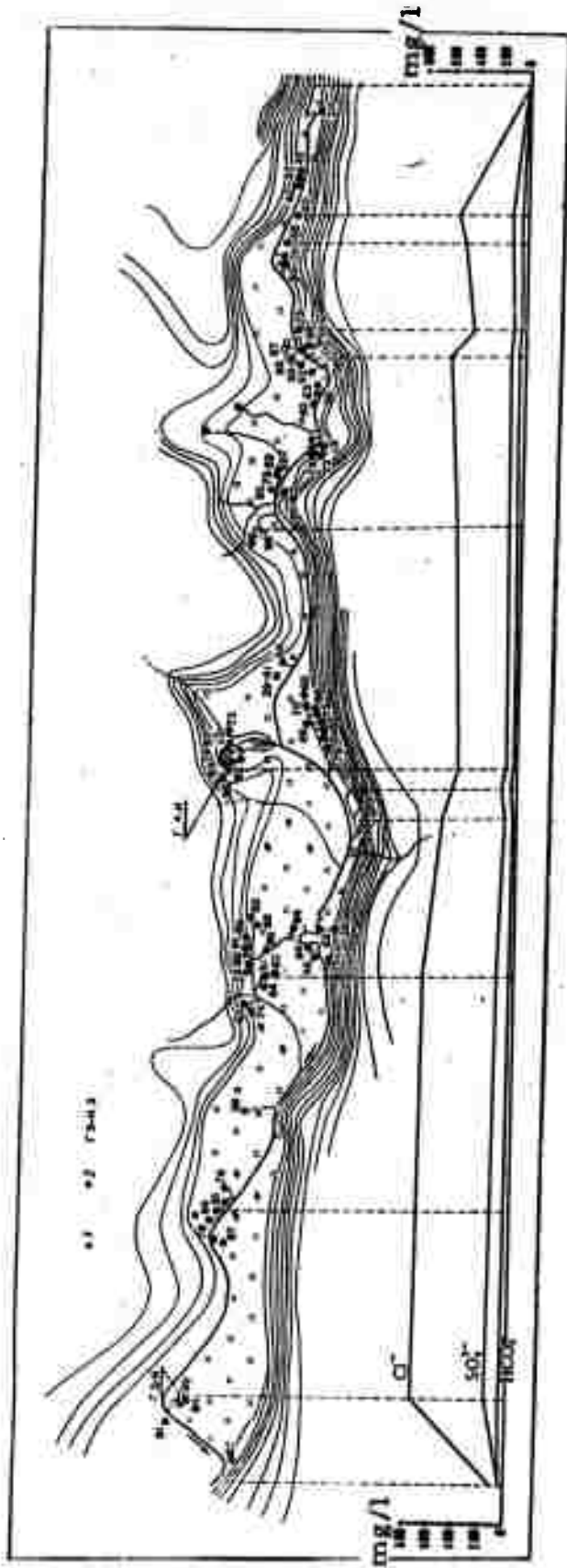
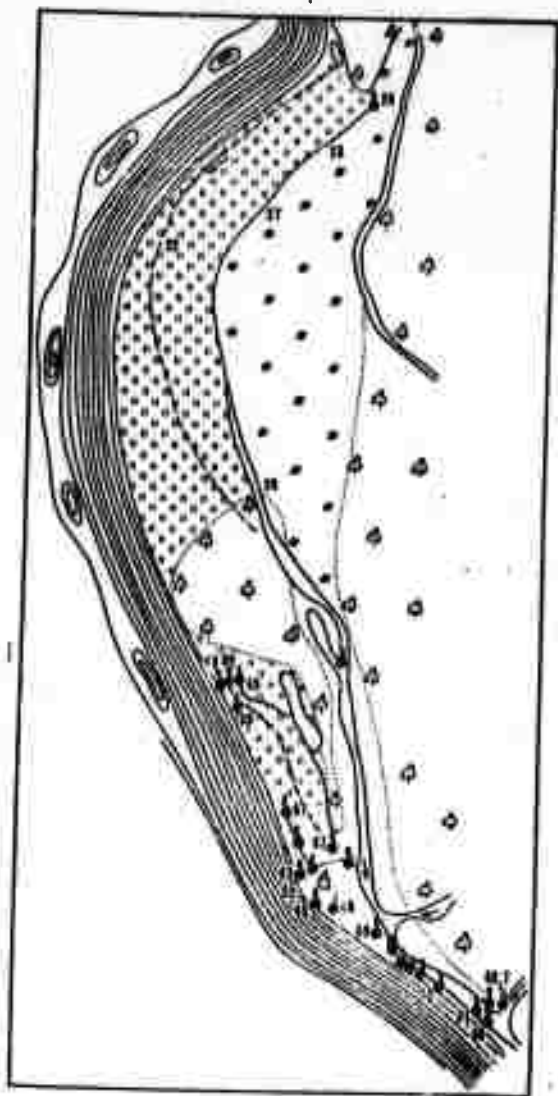


Fig. 1. Schematic Map Showing Vent Sites of Hot Springs in the Upper Group (about 100 springs, maximum temperature of 98.5 to 99°C, estimated heat capacity of 5000 kcal/sec).

1 - boiling springs; 2 - springs having water temperatures below 98°C; and 3 - sites at which gas samples were taken. A graph at the bottom of the map shows the  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$  and  $\text{HCO}_3^-$  contents in the samples in mg/l.





**Fig. 3. Sketch Map Showing Sites of the Malyy Klyuch Hot Springs of the Lower Group ( $t = 67^{\circ}\text{C}$ ).**

- 1 - Springs and their temperatures; 2 - warm-water swamp;**
- 3 - rocky hot spring area;**
- 4 - forested areas within the hot spring groupings;**
- 5 - (approximate) contours.**

Data on the kinds and percentages of metals determined in rock and water samples and the compositions of the hot-springs are given in two tables.

# THE BOL'SHE-BANNAYA HYDROTHERMAL SYSTEM ON KAMCHATKA

Krayevoy, Yu. A., V. A. Kovalenko, and A. D. Yevtukhov. IN: Vulkanizm i glubiny Zemli (Volcanism and the depths of the earth). Papers presented at the Third All-Union Volcanological Conference, 28-31 May 1969. Moscow, Izd-vo Nauka, 1971, 246-253.

The results of investigations carried out in the 1961-1969 period on the Bol'she-Bannaya hydrothermal system in Kamchatka by the Kamchatka Territorial Geological Administration are reported. Brief statements are given on the geological and lithological characteristics of the 65 km<sup>2</sup> area in which the boiling springs and steam vents occur. The thermal, hydrological, and chemical characteristics of the system are summarized in the following table.

Thermal phenomena	Amt, natural discharge, l/sec	Max. temp. of natural effluents, °C	Heat capacity (natural discharge), kcal/sec	Formulas of chemical composition of water
Bol'she-Bannaye steam-hot springs	60 *	98	8 400 **	$H_2SiO_3$ 0,215 $M_{1,3}$ $\frac{SO^4 68 Cl' 23}{(Na + K) 91}$ pH 8,4
Malye Bannaye hot springs	1,5	78	117	$H_2SiO_3$ 0,116 $M_{0,8}$ $\frac{SO^4 62 HCO^3 20 C 118}{(Na + K) 83 Ca 15}$ pH 8,0
Karymchinskiye hot springs	100 *	94	11 000***	$H_2SiO_3$ 0,208 $M_{0,9}$ $\frac{SO^4 54 HCO^3 25 Cl 21}{(Na + K) 90}$ pH 8,1

\*Taking into account latent discharge at drain-off level

\*\*Taking into account heat content of the steam-water mix of boiling springs

\*\*\*Heat loss due to heat conductivity of rocks taken into account. Data of V. G. Okhapkin

Table 1. Characteristics of Natural Thermal Phenomena in the Bol'she-Bannaya Hydrothermal System.

The geological and geothermal data are summarized in a schematic map and in two hydrogeological sections constructed from borehole data (see Figs. 1 and 2).

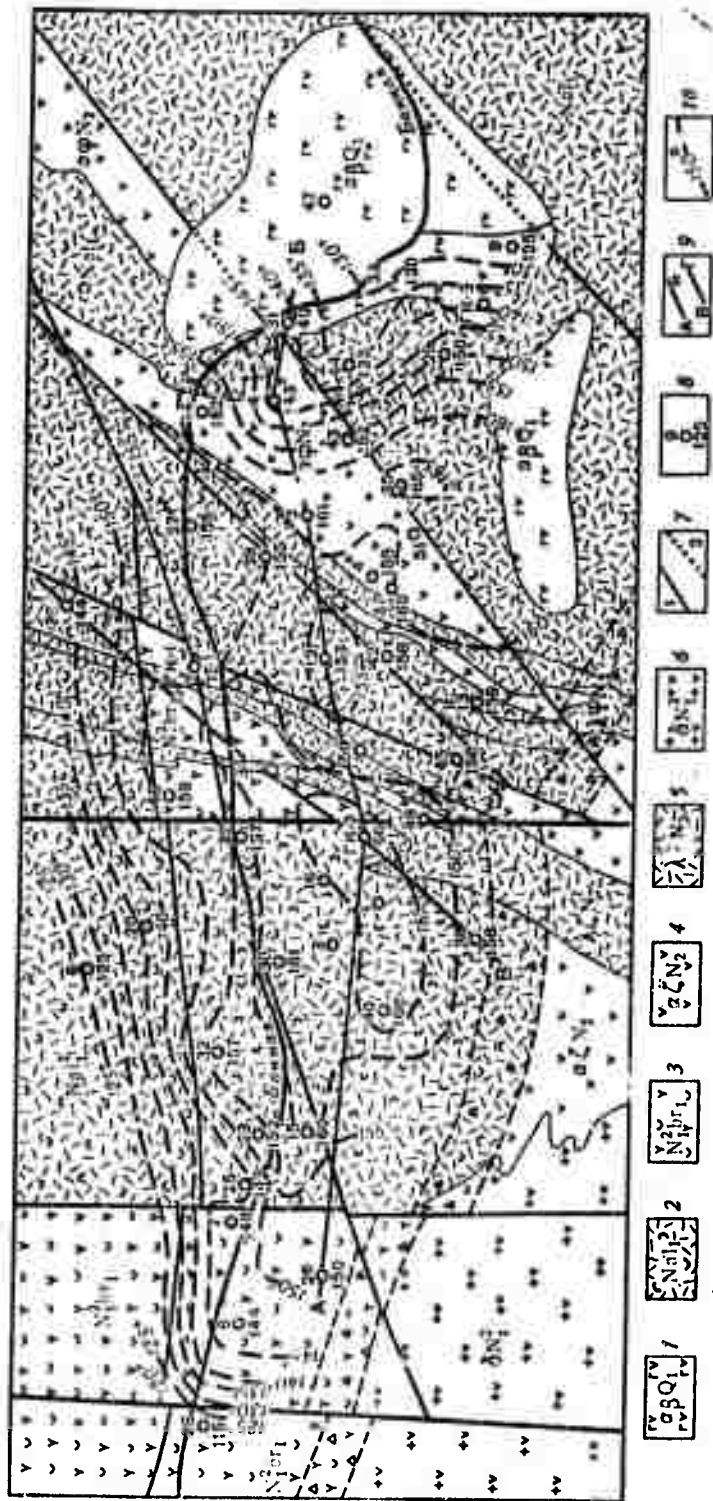


Fig. 1. Schematic geological-geothermal map of the Bol'she-Bannaya superheated hot-spring pools.

1 - andesite-basalts; 2 - andesites, andesite-dacites and their tuffs, welded rhyolite tuffs, tuffaceous conglomerate; 3 - andesite tuffs, ignimbrites; 4 - sub-volcanic andesite-dacite bodies; 5 - rhyolite-dacites; 6 - diorites and granodiorites; 7 - tectonic dislocations, determined (1) and passing under Quaternary deposits (2); 8 - borehole, upper (number) and lower (temperature) at the absolute level of 200 m; 9 - hydrothermal cross section profile line; 10 - geotherms.

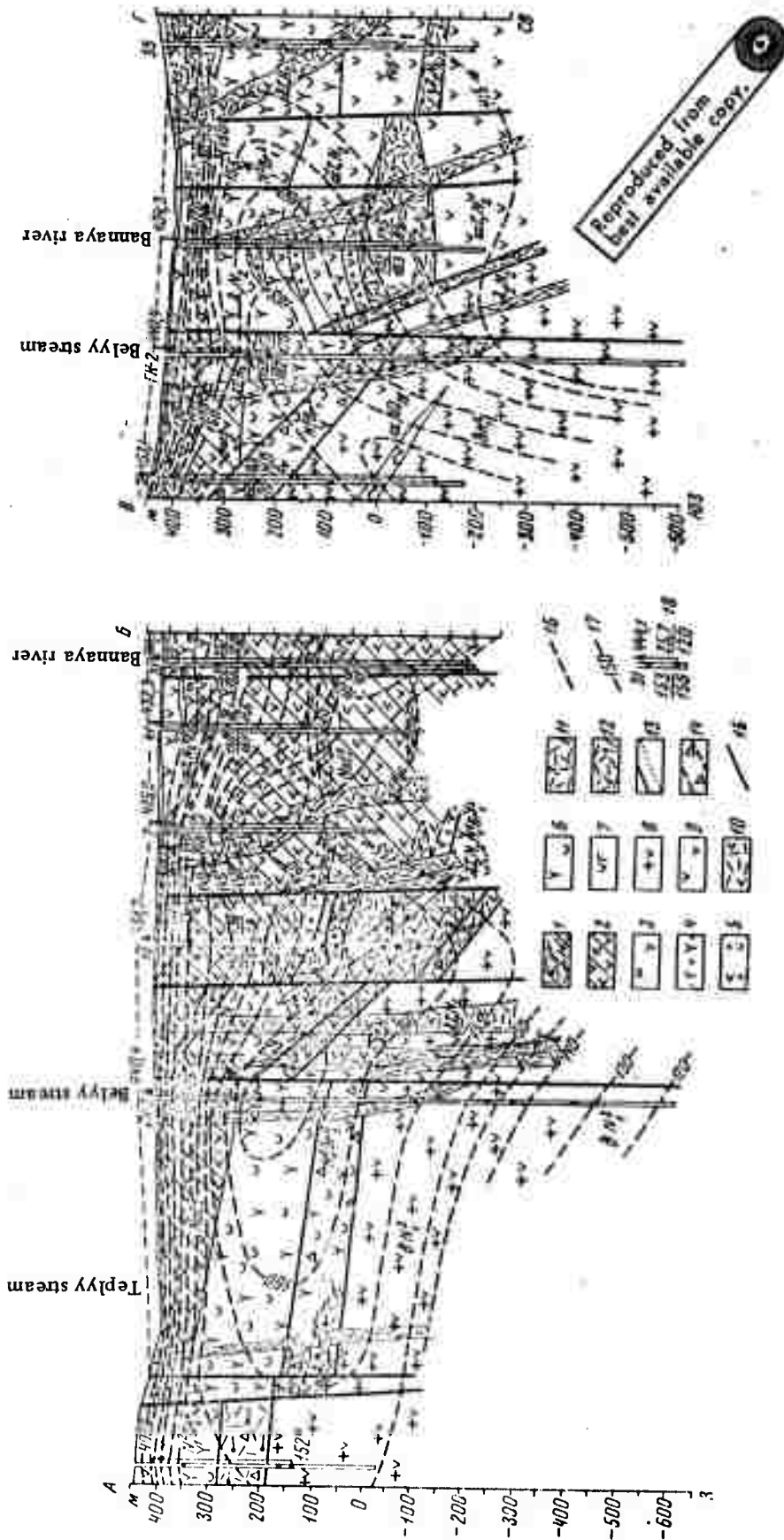


Fig. 2. Hydrogeological sections determined from borehole measurements.

1 - welded tuff rhyolite flows; 2 - andesite-dacite and andesite lavas; 3 - tuffaceous conglomerates of mixed composition; 4 - tuffs of mixed composition; 5 - andesite-dacite and andesite tuffs; 6 - andesite-dacite and dacite ignimbrites; 7 - andesite-basalts; 8 - quartz diorites, granodiorites, granosyenites; 9 - andesites and andesite-dacites; 10 - rhyolite-dacites; 11 - rhyolites; 12 - welded rhyolite tuffs; 13 - tectonic dislocations; 14 - brecciated zones; 15 - geological contacts, determined; 16 - geological contacts, inferred; 17 - geoisotherms; 18 - boreholes: top numbers represent borehole number and absolute level of the piezometer, lower left number represents heat content: numerator, for one sampling, denominator - under reaction conditions; numbers on right are corresponding borehole discharges.

On the basis of preliminary field investigations and calculations, the thermal capacity of these steam - and hot springs is estimated as 75,000 kcal/sec and that of the specific heat flow density for the 50 km<sup>2</sup> area as about 1500 kcal/sec km<sup>2</sup>, i. e., they are comparable with the specific heat loss at Pauzhetka and other such systems on Kamchatka and outside the Soviet Union.

#### THE PARATUNKA HOT-SPRING SYSTEM IN KAMCHATKA.

Manukhin, Yu. F., V. I. Vorob'yev, L. A. Vorozheykina, K. I. Mal'tseva, S. I. Fedorenko. IN: Vulkanizm i glubiny Zemli (Volcanism and the depths of the earth). Papers presented at the Third All-Union Volcanological Conference, 28-31 May 1969. Izd-vo Nauka, Moscow, 1971, 253-261.

The Paratunka (Kamchatka) hydrothermal system extends for more than 30 km along the Paratunka River valley and consists of seven groups of hot springs (temperatures up to 100°C). The chemical and hydrological characteristics of these hot-spring systems are summarized in the tables that follow:

Groups of springs	Observed discharge, l/sec	Discharge, taking into account latent discharge in water, l/sec	Max. temp. of water, °C	Heat capacity, kcal/sec	Chemical composition formula
Severnyye (Northern)	0,3	—	3,0	—	$M_{0,9} \frac{SO_4 81Cl 115}{(Na+K) 51Ca 46}$
Nizhniye (Lower)	26,3	—	61,6	1619	$M_{1,3} \frac{SO_4 71Cl 124}{(Na+K) 64Ca 38}$
Sredniye (Middle)	—	3,5	81,5	300	$M_{1,1} \frac{SO_4 84Cl 113}{(Na+K) 66Ca 32}$
Verkhniye (Upper)	15,0	70,0	70,2	4914	$M_{1,0} \frac{SO_4 49Cl 143}{(Na+K) 51Ca 49}$
Karymshinskiye	—	130,0	76,5	9945	$M_{0,55} \frac{SO_4 87}{(Na+K) 86Ca 11}$
Sivkiy	—	47,0	18,5	870	$M_{0,5} \frac{SO_4 66Cl 121}{(Na+K) 90Ca 10}$
Ovrazh'yi	—	8,0	16,0	128	$M_{0,35} \frac{HCO_3 18SO_4 34Cl 118}{Ca 50(Na+K) 45}$
Total		258,5		17 776	

Table 1. Characteristics of the Surface Hot Springs of the Paratunka System.

Sector, borehole	Hardness, overall, mg-equiv/l	Dry residue, mg/l	Mineralization, mg/l	pH		Anions			
				Eh, mv		SO <sub>4</sub> <sup>2-</sup>	Cl <sup>-</sup>	HCO <sub>3</sub> <sup>-</sup>	CO <sub>3</sub> <sup>2-</sup>
Middle Paratun, sector, GK-2	5,93	1260	1243,49	9,0 +60		710,25	72,42	10,37	13,80
Lower Paratun., 45	9,52	1971	1922,06	6,50 +90		813,12	368,13	37,21	not detected
Northern, GK-9	15,16	206,90	2009,6	8,3		1147,26	161,88	18,30	3,00
Karymshinskiy, GK-5	2,52	972,00	996,01	8,2		446,07	131,35	43,92	1,50
Springs (72°)	2,35	—	509,67	7,5		144,00	119,21	43,52	not detected
Upper Paratun., spring (70°)	2,60	—	997,00	8,5		500,0	111,00	26,00	not detected

Sector, borehole	Cations			CO <sub>2</sub>	Al	NH <sub>4</sub>	SiO <sub>2</sub>
	Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>2+</sup>				
Middle Paratun, sector, GK-2	245,19	7,98	118,60	not detected	0,30	0,25	65,0
Lower Paratun., 45	405,32	9,98	190,4	5,81	0,12	0,10	92,0
Northern, GK-9	305,45	8,38	303,20	not detected	0,08	0,20	59,0
Karymshinskiy, GK-5	254,06	5,11	50,40	not detected	0,40	0,2	42,0
Springs (72°)	108,75		46,99	7,92	—	0,2	47,0
Upper Paratun., spring (70°)	261,0		53,00	—	1	not detected	45,0

Table 2. Chemical Composition of the Hot Springs of the Paratunka Pools, mg/l.

The hydrogeological data are summarized on a large-scale map (Fig. 1) and in three sections (Fig. 2).

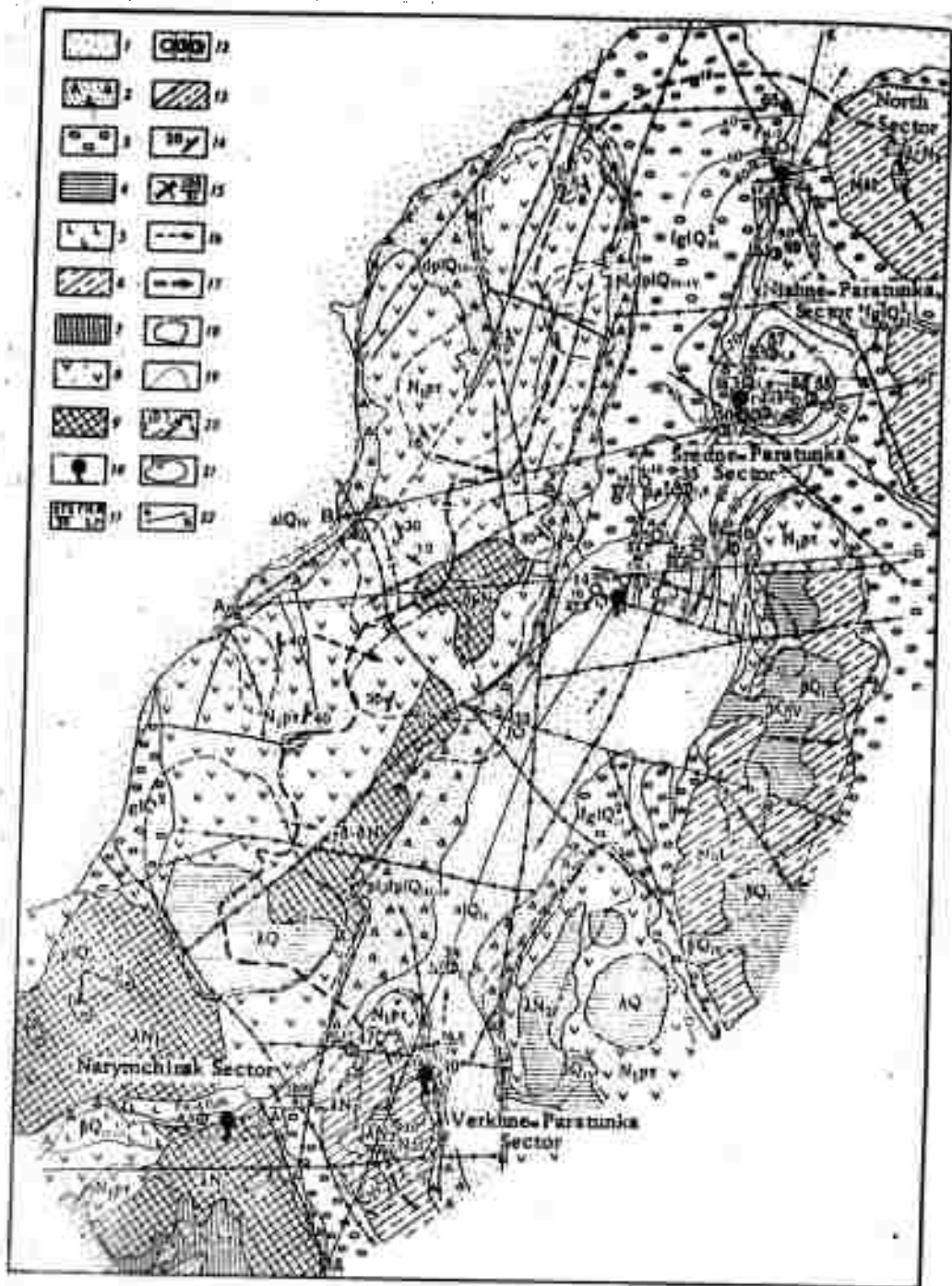


Fig. 1. Schematic Hydrogeological Map of the Paratunka Hot Spring Pools (see legend\* on next page).

\*) Due to a great number of inconsistencies in the original legend to this map, the translated legend has been revised to correspond to the map symbols.

1 - water-bearing bed of Recent alluvial deposits  $alQ_{IX}$  (sandy-gravelly -pebbly deposits containing boulders, occasionally-sandy loam); 2 - water-bearing complex of Recent and Upper Quaternary alluvial and talusalluvial fan deposits  $pl$ ,  $dplQ_{III-IV}$  (gravelly-pebbly and psephitic -detrital deposits containing sand and sandy loam matrixes); 3 - water -bearing complex of Recent and Upper Quaternary glacial and fluvioglacial deposits  $dl$ ,  $fglQ_{III}^2$ ,  $glQ_{IV}$  (gravels, sands, boulder-pebble deposits containing sand and sandy loam matrixes); 4 - water-bearing bed of Quaternary and Neogene extrusives and volcanic structures -  $\beta Q_{IV}$ ,  $\beta Q_I$ ,  $\lambda Q_I$ ,  $\lambda N_2$ ,  $d\beta N_2$ ,  $\lambda N$  (rhyolites, basalts, andesite -basalts and their scoria, andesite-dacites); 5 - water-bearing bed of the Middle - Upper Quaternary lava flows and acidic tuffs -  $\beta Q_{II-III}$ ,  $\lambda Q_{II-III}$  (basalts, rhyolite tuffs); 6 - water-bearing complex of Upper Miocene-Pliocene volcanic formations of the Alneyian series -  $N_{I}$  (basalts, andesite and rhyolite tuffs, ingimbrites); 7 - water-bearing complex of the Middle Miocene effusive-pyroclastic and welded tuff - sedimentary formation of the Berezovian series -  $N_{I}b\tau$  (tuffs and rhyolite tuffites, rhyolites); 8 - water-bearing complex of Miocene effusive-tuffaceous-sedimentary formations of the Paratunian series  $N_{I}p\tau$  (andesite tuffs, andesite-dacites, basalts, andesite-basalts, andesite, andesite-dacite and andesite-basalt flows); 9 - water-bearing complex of Miocene intrusives and the rocks of subvolcanic bodies (granodiorites, diorites, quartz diorites, diorite porphyries, rhyolites); 10 - hot springs; 11 - boreholes drilled to the hot water: top right number represents the borehole number; left (numerator) is discharge in l/sec; left (denominator) is static level at absolute level; lower right is the mineralization in g/l; 12 - waters:  $\bigcirc$  - containing predominantly the sulfate ion;  $\textcircled{S}$  - chloride - sulfate;  $\textcircled{H}$  - chloride - hydrocarbonate;  $\textcircled{M}$  - mixed type; 13 - faults: a - water-bearing ( $\text{---}\times\text{---}\times\text{---}$ ), b - determined ( $\text{---}$ ) and postulated ( $\text{- - - -}$ ) whose hydrogeological values were not indicated; 14 - elements of rock deposition; 15 - site at which the total discharge of the hot spring was measured, where the Arabic number is the yield in l/sec and the Roman numeral is the date (month) of the measurement; 16 - general direction of movement of hot-spring water in the upper parts of the pre-Quaternary section; 17 - assumed direction of movement of deep-seated sub-surface flow; 18 - boundaries between water-bearing beds and complexes; 19 - contacts between rocks of different age and the boundaries of one water-bearing bed or complex; 20 - isolines of minimum subsurface flow: a (light lines) - within the boundaries of local sectors, and b (dark lines) - within the limits of aquifer areas (the numeral indicates the modulus in l/sec  $\cdot$  km<sup>2</sup>); 21 - geoisotherms at the 600-m depth, in  $^{\circ}C$ ; 22 - hydrogeological section line.

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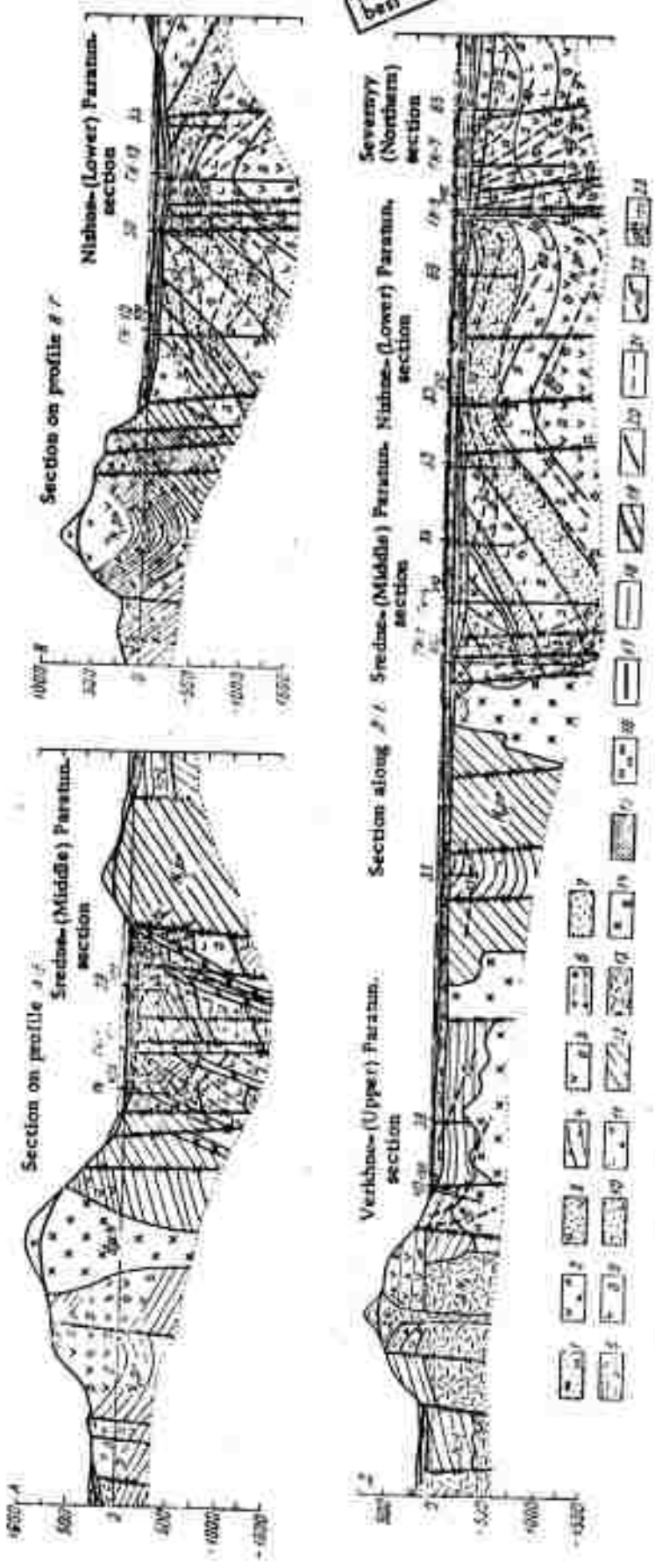


Fig. 2. Schematic Hydrogeological Sections (Profiles for Sections in Fig. 1).

- 1 - sandy-gravelly-pebbly deposits; 2 - psephitic rhyolite tuffs; 3 - rhyolite tuffs, psammitic (arenaceous); 4 - ignimbrites and ignimbrite-like tuffs; 5 - andesite and dacite tuffs, psephitic, containing andesite and dacite flows; 6 - interbedded tuffs of average composition, psammitic and psephitic, containing andesite and dacite flows; 7 - average-composition psammitic tuffs; 8 - average-composition silty-pelitic and psammitic tuffs containing andesite flows; 9 - psephitic basalt tuffs, containing basalt flows; 10 - interbedded, silty-pelitic, psammitic and small-ejecta psephitic basalt tuffs, containing basalt flows; 11 - psephitic andesite and basalt tuffs; 12 - interbedded volcanic and sedimentary rocks, primarily tuffs of varying composition; 13 - rhyolites; 14 - intrusives (diorites, quartz diorites, granodiorites, diorite-porphyrines); 15 - argillites and siltstones (assumed to be relatively impermeable); 16 - conglomerates; 17 - contacts between rocks of various ages; 18 - contacts between lithologically different rocks of a single age; 19 - faults; a - water-bearing (dark line) and b - hydrogeological importance not determined (light line); 20 - water table at free surface; 21 - piezometric level; 22 - geoisotherms; 23 - boreholes: top (larger) number is the borehole number on the map; the arrow is ground-water head; and the number (smaller) near the arrow is absolute elevation of the piezometric water level.

# HOT WATERS OF THE ALBIAN AQUIFEROUS COMPLEX OF THE YUZHNO-MANGYSHLAK DEPRESSION

Vasil'yeva, I. L. and N. S. Otman. *Sovetskaya geologiya*, no. 2, 1969, 153-156.

The hot water aquiferous beds of Albian age, located in the Yuzhno-Mangyshlak depression near the southwestern coast of the Caspian Sea in Kazakhstan, are identified as being the most promising in the area for

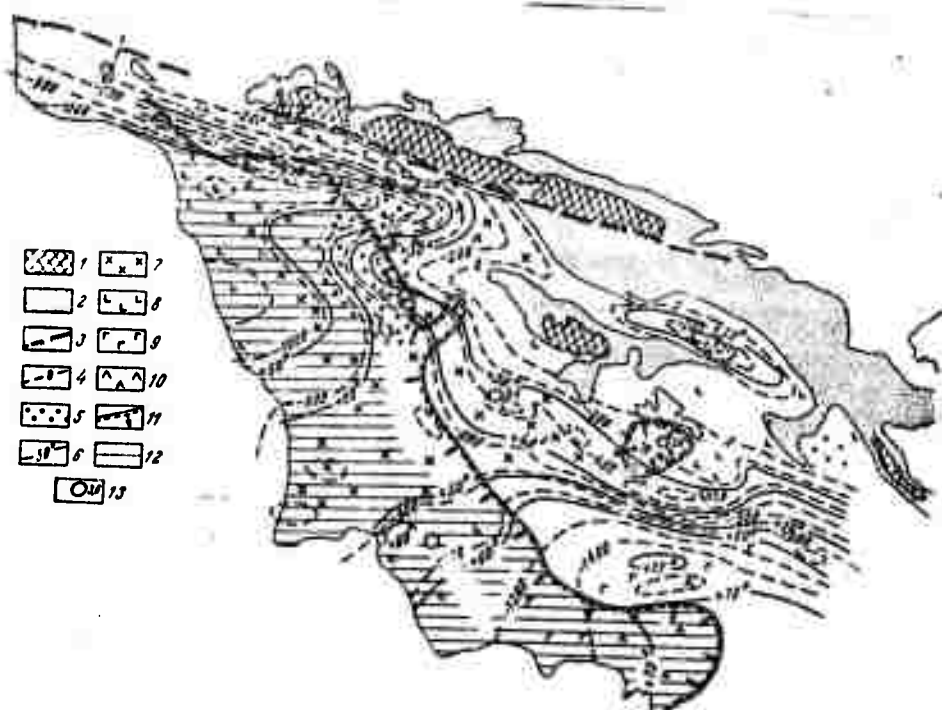


Fig. 1. Hydrogeothermal Map of the Albian Aquiferous Complex of the Yuzhno-Mangyshlak Depression.

- 1 - areas in which Lower Cretaceous deposits are missing;
- 2 - areas in which Lower Cretaceous deposits outcrop on the surface;
- 3 - faults; 4 - structural contours of the top of the Lower Cretaceous;
- 5 - sectors in which ground water with overall mineralizations of up to 3 g/l occurs; 6 - isotherms along the top of the Lower Cretaceous;
- 7 - sectors in which ground water with overall mineralizations of from 3 to 10 g/l occurs; 8 - the same, with mineralization ranging from 10 to 35 g/l; 9 - the same, with mineralization ranging from 35 to 50 g/l; 10 - the same, with mineralization exceeding 50 g/l;
- 11 - boundary of zones of self-discharge ground water from the Albian aquiferous complex; 12 - areas in which hot water having temperatures of more than +40°C occurs; 13 - magnitude of geothermal gradient.

such purposes as power and water supply for industrial uses on the peninsula. The author has compiled a hydrothermal map (see above) which shows water temperatures registered along the top of the Albian aquiferous complex, variations in the overall mineralization of the water throughout the depression, and the geothermal gradients. He has also identified areas where the water is discharged and where water temperatures are higher than +40°C.

Area	Depth of occurrence, m		Water temp., °C		Average geothermal gradient, °C/100m	Comments
	at top	at base	at top	at base		
Zhetybay	530—570	1080—1175	34—38	54—57	3,3	Gradient determined for the upper part of the bed
Uzen'	211—440	800—1045	22—30	42—50	3,6	
Karamandybas	346	932	30 (at 500m depth)	46	3,7	
Tenga	516—589	1155—1242	35—40	60—64	3,5	
Karagiye	912	1441	59	78	3,6	
Senek	—	—	—	—	3,4	
Tyuesu	—	—	—	—	3,6	

Shown in the table above are the values representing the geothermal gradient of the Albian aquiferous complex.

#### VOLCANISM AND THE HOT SPRINGS OF THE UZON-SEMYACHIKSKAYA GEOTHERMAL REGION OF KAMCHATKA

Aver'yev, V. V., G. Ye. Bogoyavlenskaya, O. A. Braytseva, Ye. A. Vakin, G. F. Pilipenko. IN: Vulkanizm i glubiny Zemli (Volcanism and the depths of the earth). Papers presented at the Third All-Union Volcanological Conference, 28-31 May 1969. Izd-vo Nauka Moscow, 1971, 207-211.

Contains two tables summarizing the thermal and chemical characteristics of the Uzon-Geyzernaya and Semyachikskaya hydrothermal systems located in the eastern volcanic zone of Kamchatka.

System	Max. temp. natural vents, °C	Predicted heat capacity, kcal/kg	Natural heat capacity, 10 <sup>5</sup> kcal/sec	Area of heat supply*, km <sup>2</sup>	Intensity of heat supply, kcal/sec/cm <sup>2</sup>	Investigators, years studied
<b>Uzon-Geyzernaya</b> Uzon caldera	Boiling	250	134 64	120	110	Aver'yev, Kovalev, Slezin, Filipenko (1966-1967) Aver'yev (1962) Aver'yev, Vakin, Kovalev. (1965)
Valley of Geysers	Ditto	> 250	70			
<b>Semyachikskaya</b> Verkhno-Semyachikskiy sector	137	~640 (steam)	75 50	100	75	
Nizhne-Semyachikskiy sector	50	100	25			

\*Ring-structure area

Table 1. Heat Parameters of the Uzon-Geyzernaya and Semyachikskaya Hydrothermal Systems.

Sytem		Ascension springs	Peripheral springs	Fumarole-hot springs (Undrained pools)	Condensates of steam vents	
Uzon-Geyzernaya	Uzon caldera	Typical sample	Geyzerite hot springs	Posledniy springs	Western field	Eastern field
		Mineralization, g/l	2.1	1.2	3.0	0.05
		Chem. composition formula	Cl <sub>194</sub> Na <sub>90</sub> K <sub>5</sub>	SO <sub>4</sub> 75HCO <sub>3</sub> 20 Mg53 (Na+K) 38	(HSO <sub>4</sub> +SO <sub>4</sub> ) 100 Al <sub>39</sub> H <sub>37</sub> Fe <sub>22</sub>	HCO <sub>3</sub> 100 NH <sub>4</sub> 100
	Valley of Geysers	Typical sample	Velikan geyser	Nizh. (Lower) Geyser sector	Verkh. (Upper) Geyser sector	—
		Mineralization, g/l	1.8	0.6	1.2	—
		Chem. composition formula	Cl <sub>185</sub> SO <sub>4</sub> 10 Na <sub>95</sub>	SO <sub>4</sub> 86HCO <sub>3</sub> 14 Na <sub>48</sub> Ca <sub>43</sub>	SO <sub>4</sub> 97 (Na+K) 9Mg <sub>12</sub> H <sub>8</sub>	—
	1, °C	Boiling	68	98	—	
	pH	7.6	7.2	3.5	—	
Semyachikskaya	Typical sample	Nizhne-(Lower) Semyachikskaya spring	Inter-montane basin	Sulphate field of Burlyashly volcano	Central Semyachik volcano	
	Mineralization, g/l	1.7	2.1	0.9	0.3	
	Chem. composition formula	Cl <sub>159</sub> HCO <sub>3</sub> 28SO <sub>4</sub> 13 Ca <sub>59</sub> Mg <sub>28</sub> Na <sub>21</sub>	SO <sub>4</sub> 67HCO <sub>3</sub> 28 Ca <sub>61</sub> Mg <sub>31</sub>	SO <sub>4</sub> 94 Na <sub>36</sub> NH <sub>4</sub> 3Al <sub>2</sub> O	11.15, 100 NH <sub>4</sub> 98	
	1, °C	49	55	95	98	
	pH	6.5	7.5	2.3	8	

Table 2. Comparative characteristics of the Chemical Composition of the Steam-Hot Springs.

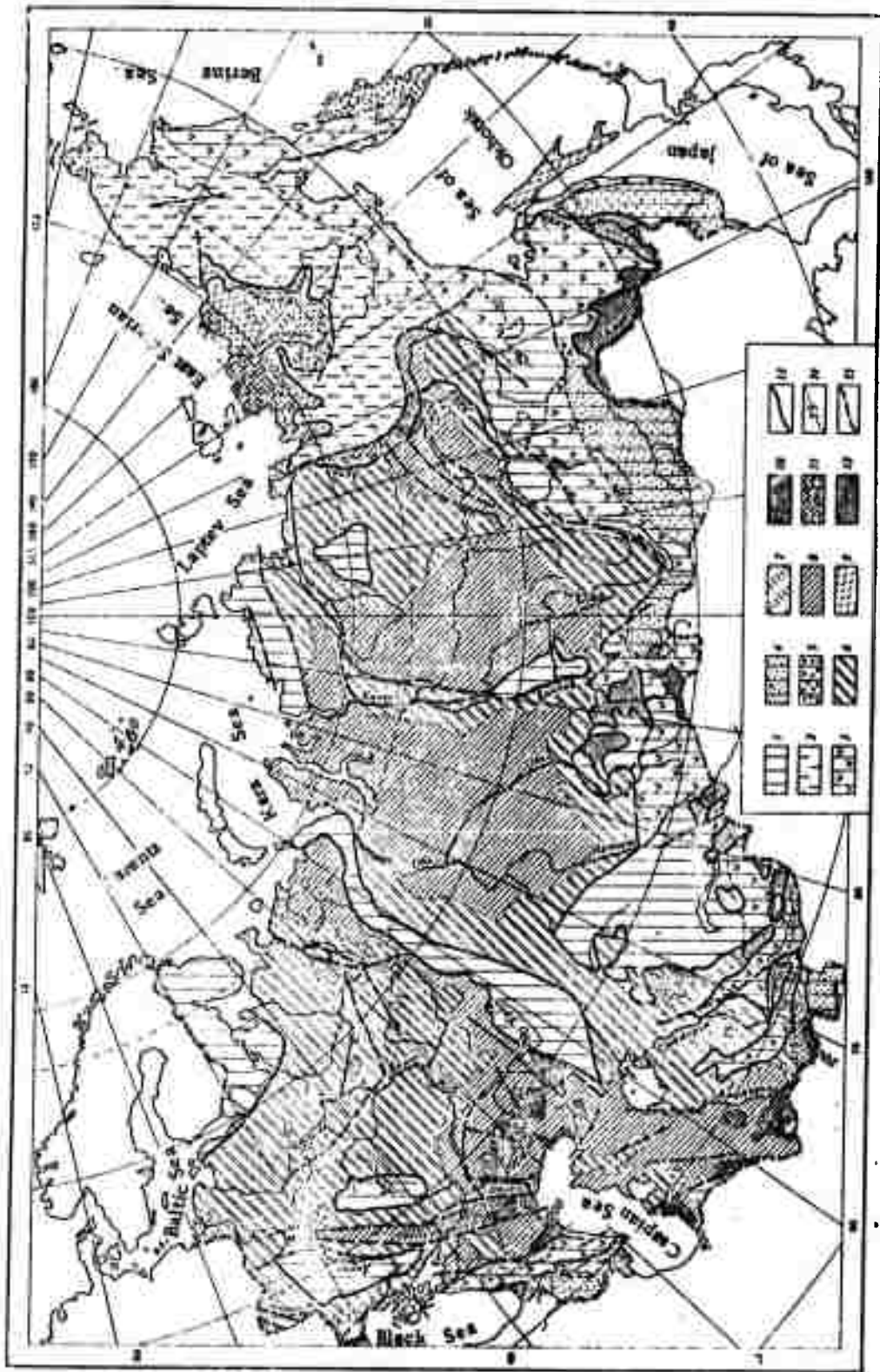


## GASES OF THE SUBSURFACE HYDROSPHERE OF THE USSR

Shcherbakov, A. V., F. A. Makarenko, G. N. Smirnova. IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Podzemnyye vody Sibiri i Dal'nego Vostoka (The ground water of Siberia and the Soviet Far East). Izd-vo Nauka, Moscow, 1971, 22-28.

Using all information available in 1968, the authors began a study of the regional patterns and interrelationships of the ground water and gases contained in the earth's crust in USSR territory, first investigating the gas compositions and saturations of the ground water and then determining and mapping the overall occurrence of gases and the distribution of individual gases in terms of their genetic associations. The paper briefly summarizes the procedures used and the general results obtained in the study and presents the small-scale map reproduced below.

(continued with map on next page)



Sketch Map Showing the Distribution of Gases and Ground Water in the USSR Territory

I - areas of occurrence of deep-seated oxidation conditions with local occurrences of ascending gaseous-hydrothermal manifestations: 1 - cold-water zones ( $t < 20^{\circ}\text{C}$ ) of varying ion content containing gases of atmospheric origin ( $\text{O}_2$ ,  $\text{N}_2$ ,  $\text{CO}_2$ , etc.); 2 - the same, postulated; 3 - zone of ascending nitrogen hot springs; 4 - zone of ascending carbonic acid water (cold and hot); 5 - zone of volcanic steam vents and hot springs. II - areas of replenishment in the lower part of the sedimentary regolith; 6 - zones of chloride water having temperatures up to  $75^{\circ}\text{C}$ , frequently enriched with biochemical gases ( $\text{N}_2$ ,  $\text{CO}_2$ ,  $\text{H}_2\text{S}$ ,  $\text{CH}_4$ , etc); 7 - the same, postulated; 8 - zone of chloride water with temperatures from  $75^{\circ}$  to  $200^{\circ}$  containing chemical and thermocatalytic gases of hydrocarbon composition ( $\text{CO}_2$ ,  $\text{H}_2\text{S}$ , etc.); 9 - the same, postulated; 10 - zone of chloride water with temperatures above  $200^{\circ}$  containing thermometamorphic hydrocarbons of the methane series (methanization zone),  $\text{CO}_2$ ,  $\text{CO}$ ,  $\text{H}_2\text{S}$ ,  $\text{H}_2$ , etc; 11 - the same, postulated; 12 - deep intermontane depressions and basins containing water of varying ion and gas composition; 13 - boundaries of shields, highlands and fold-mountain areas; 14 - isotherms on the surface of the crystalline and folded basements (in  $^{\circ}\text{C}$ ); 15 - lines of major tectonic faults.

## STATUS AND POTENTIALS OF LONG-RANGE HYDROGEOLOGICAL INVESTIGATIONS IN SIBERIA AND THE SOVIET FAR EAST

Pokryshevskiy, O. I. and V. A. Korobeynikov. IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Podzemnyye vody Sibiri i Dal'nego Vostoka (The ground water of Siberia and the Soviet Far East). Izd-vo Nauka, Moscow, 1971, 3-7.

In addition to mentioning the use of the Pauzhetka (Kamchatka) thermoelectric station in providing power, discusses studies carried out in the Pitatelevskiy area (Buryat ASSR) used as source of central heating, two additional sites on Kamchatka (central heating for Petro-pavlovsk-Kamchatkiy) and a thermoelectric station, as well as exploratory work on Kunashir Island (Kuriles).

## THERMAL REGIME OF THE UPPER PART OF THE EARTH'S CRUST IN SIBERIA AND THE SOVIET FAR EAST, IN CONNECTION WITH ESTIMATES OF HYDROTHERMAL RESOURCES

Makarenko, F. A., G. B. Gavlina, B. G. Polyak, and Ya. B. Smirnov. IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Podzemnyye vody Sibiri i Dal'nego Vostoka (The ground water of Siberia and the Soviet Far East). Izd-vo Nauka, Moscow, 1971, p. 44-48.

Includes two small-scale maps: 1) Map of the geothermal gradient in the upper part of the earth's crust of the USSR (schematic version), compiled in 1965, revised in 1967; 2) Map of temperature distribution on the surface of the crystalline and folded basement of the USSR (schematic version), compiled in 1963, revised in 1967. For translated legends of these maps see detailed discussion of the book Teplovoy rezhim nedr SSSR (Heat regime of the earth's interior in the USSR area) appearing in Part I of this report.

## ON THE QUESTION OF THE ENERGY OF ACTIVE VULCANISM

Kovalev, G. N. IN: Vulkanizm i glubiny Zemli (Volcanism and the depths of the earth). Papers presented at the Third All-Union Volcanological Conference, 28-31 May 1969. Izd-vo Nauka, Moscow, 1971, 41-46.

Gives data on the total heat capacity ( $10^3$  kcal/sec) and specific capacity of the hydrothermal systems (kcal/km<sup>2</sup>-sec) at the following sites of USSR thermoanomalies: Semyachik volcano (Kamchatka) - 75 and 870 - 750, respectively, over an area of 80-100 km<sup>2</sup>; Uzon, Geyzernaya (Kamchatka) - 6475 and 870, respectively, over an area 160 km<sup>2</sup>; Mendelejev volcano (Kurile Islands) - 5.4-4.8 and 900-800, respectively, over an area of 6 km<sup>2</sup>; and Golovnina volcano (Kurile Islands) - 12.8-9.5 and 1070-790, respectively, over an area of 12 km<sup>2</sup>.

## NATURE OF THE HEAT ANOMALIES IN THE VOLGA-URAL OIL AND GAS BASIN

Yerofeyev, V. F. Sovetskaya geologiya, no. 5, 1969, 81-90.

Five temperature-anomaly zones are identified in the Volga-Ural oil and gas basin. Positive temperature anomalies are associated with deep faults and do not reach the high-intensity level, the maximum temperatures recorded being 66°C at the 2000 m level at Sidorovskaya.

## FUMAROLE ACTIVITY OF THE BEZYMANNYY VOLCANO (NORTH KAMCHATKA) IN THE 1966-1967 PERIOD

Serafimova, Ye. K. Akademiya nauk SSSR. Sibirskoye otdeleniye. Institut vulkanologii. Byulleten' vulkanologicheskikh stantsiy, no. 47, 1971, 23-28.

Tabulates in detail the chemical composition and temperatures of the volcanic gases collected from the fumaroles of the older cones and a new cone developing on the sides of the volcano. The temperatures of the fumaroles located near the base of the new cone dropped from 170° in 1965 to 80° in 1967.

**RADON IN THE SPONTANEOUS GASES OF THE BANNYYE,  
KOSHELEVSKIYE AND KIREUNSKIYE (KAMCHATKA) HOT SPRINGS**

Chirkov, A. M. Akademiya nauk SSSR. Sibirskoye otdeleniye.  
Institut vulkanologii. Byulleten' vulkanologicheskikh stantsiy, no. 47,  
1971, 69-71.

Results of chemical analyses made of the spontaneous gases contained in samples taken from the hot springs of three areas are tabulated, along with their temperatures ( $^{\circ}\text{C}$ ), as follows: 1) the Malo- and Bol'she-Bannyye Springs -  $40^{\circ}$  to  $100^{\circ}$ ; 2) the Koshelevskiy field -  $35^{\circ}$  to  $99^{\circ}$ ; 3) the Kireunskiy springs -  $48^{\circ}$  to  $98^{\circ}$ .

**ON THE REGIME OF THE PAUZHETKA BOILING SPRINGS AND  
GEYSERS**

Sugrobova, N. G. Akademiya nauk SSSR. Sibirskoye otdeleniye.  
Institut vulkanologii. Byulleten' vulkanologicheskikh stantsiy,  
no. 47, 1971, 72-75.

Previous studies carried out on the behavior of the boiling springs and geysers in the Puzhetka field, had indicated that, for the most part, their activity was relatively constant with the exception of Geyser II. Fluctuations in the activity of these geysers are investigated as a function of atmospheric pressure and position relative to the low-water level of the nearby Puzhetka River acting as a possible source of cool ground water supply.

## PART III. BIBLIOGRAPHIES

### Introduction

This section of the report contains bibliographic information relating to geothermal power sources and is structured to reflect: 1) late 1971 - early 1972 information which will be exploited in forthcoming geothermy reports; and 2) citations (some retrospective to about 1964) to references which contain background, supplemental or marginal-interest information on geothermal problems. These sources could be exploited in detail in future reports in response to reader interest. In general, Section 2 is intended to supplement and update existing bibliographies. Unless specific interest is expressed, no further exploitation of information in this Section is anticipated at present. Other current and some retrospective materials, particularly relating to the power generation systems, are being investigated and will be described in subsequent reports.

### Section 1. Current Selections in Geothermy

Denisik, V. A., and I. M. Zaytsev. Some results of geophysical studies at the Paratunka geothermal fields. IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Geologiya i geofizika, no. 7, 1971, 92-100.

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