GEOTHERMAL RESOURCES
in
RUSSIA & UKRAINE

November 22, 1996

Prepared by:
Bojan Stoyanov
Anthony Taylor

Bob Lawrence & Associates, Inc.
424 N. Washington Street
Alexandria, VA 22314

TABLE OF CONTENTS

INTRODUCTION

This report describes the geothermal resources of the Russian Federation and Ukraine. The name Russian Federation will be used interchangeably with Russia. The term *geothermal resources*, in this report, is limited to underground/subsurface water fields or hydro-geothermal resources. No reference to hot dry rock (HDR) is made in this report, because the team found no practical use or experimental development of HDR in Russia and Ukraine. Limited theoretical study of HDR is part of the activity of the Earth Science Institute of the Russian Academy of Science and other affiliated institutes.

The currently known geothermal resources of Russia are concentrated in the following two areas (please see map):

A- the Caucasus Mountains and surrounding territory, and

B- the far-eastern part of the Russian Federation.

Considerations of general geological character supported by extensive drilling for crude oil prospecting and extraction along with natural discharge of thermal waters, suggest that the region of Western and Middle Siberia and the Sayano-Baikal mountain range might be also rich in geothermal resources. In the body of this report we will refer to this large territory as Region C.

The currently known geothermal resources of Ukraine are believed to be concentrated in two separate areas (please see map): the territory of the Crimea Peninsula and in the Transcarpathian trough -- in the eastern provinces of the country, bordering Romania and the Republic of Slovakia.

Region A is composed of Krasnodarskii Krai[1], Stavropolskii Krai, the Republic of Adigea, the Karachaevo-Cherkeskaia Republic, the Republic of Kabardino-Balkariia, the Republic of Northern Osetiia-Alaniia, the Chechen-Ingushet Republic[2] and the Republic of Dagestan.

---

[1] According to the Constitution of Dec. 12, 1992, the Russian Federation is composed of the following entities: republics, Krai (regions), Oblast (provinces), Avtonomnaia Oblast (autonomous provinces), and Avtonomnii Okrug (autonomous districts) -- all of which have equal rights in the Federation.

[2] At the time of preparation of this report, the process of separation of the Chechen-Ingushet Republic into Chechen Republic and Ingushet Republic had not been concluded. The legal border between the two republics had not been established. Thus it is impossible to determine the location of certain geothermal prospecting sites between the two countries. Therefore, for practical purposes, in the body of this report, where necessary, we will be referring to the territory of the former Chechen-Ingushet Republic, which includes the territory of the Chechen Republic and the territory of the Ingushet Republic.

Base 801997 (R00183) 1-92

Region B includes Kamchatskaia Oblast, Sahalinskaia Oblast, Magadanskaia Oblast and the Chukotskii Avtonomnii Okrug.

Region C includes Tiumenskaia Oblast (including the Hanti-Mansiiskii Avtonomnii Okrug and the Iamalo-Nenetskii Avtonomnii Okrug), Tomskaia Oblast, Omskaia Oblast, Novosibirskaia Oblast, Altaiskii Krai, the Republic of Gornii Altai, Kemerovskaia Oblast, Republic Tuva, Republic Hakasiia, Krasnoiarskii Krai (including Taimirskii Avtonomnii Okrug and Evenkiiskii Avtonomnii Okrug), Irkutskaia Oblast (including Ust-Ordinskii Buriatskii Avtonomnii Okrug), Republic of Buriatia and the eastern territories of the Republic of Saha (Yakutia).

Regions A, B and C differ dramatically from each other in their climatic conditions and levels of socio-economic development.

STRUCTURE OF THE RUSSIAN GEOTHERMAL INDUSTRY, CONTACTS AND PARTNERS, NOMENCLATURE OF TABLES

Administrative Structure of the Industry

The Russian geothermal industry is administratively subordinated to two government bodies of ministerial or department level -- The Ministry of Oil and Gas of the Russian Federation and the Committee of Geology and Utilization of the Earth's Crust of the Russian Federation. This dual subordination has historic reasons dating back over 30 years, which are beyond the scope of this report. An exception occurs when a power plant is involved. Power plants are subordinated to the Energy Ministry.

The major efforts of drilling, prospecting and developing geothermal resources have been performed under the Ministry of Oil and Gas. Research, prospecting and accounting for geothermal resources have been performed under the Committee of Geology.

Contacts and Partners

Among the numerous companies and research centers under the two ministries (one ministry and one committee), the team found contacts with the following institutions most fruitful and beneficial (not ranked in order of preference):

1. All Russian Institute for Hydro-Geology and Engineering Geology,

2. BurGazGeoTerm State Limited Company,

3. Committee of Geology and Utilization of the Earth's Crust of the Russian Federation,

4. SevKavBurGeotermiia,

5. Institute of Geophysics, The Ukrainian Academy of Science.

The *All Russian Institute for Hydro-Geology and Engineering Geology* is a leading R & D center on the practical problems and aspects of the utilization of the geothermal energy.

BurGazGeoTerm State Limited Company is by far the largest drilling and prospecting company in Russia. The company was solely responsible for oil and gas drilling on the territory of the entire former Soviet Union. It is an integral part of Gazprom, the largest liquid petroleum gas developer, producer and distributor in the world, with revenues that rank it among the Fortune Top 10 (not 100), according to Fortune magazine itself. BurGazGeoTerm enjoys the cash windfalls from Gazprom and seems the least affected, among the geological and geothermal entities, by the stagnation in the Russian economy. In addition the company has international drilling activity and develops geothermal resources internationally as well (for example in Latin America).

BurGazGeoTerm maintains its own database of the wells, drill sites and geothermal fields it has under development and exploitation. The database includes very detailed information on the geology, the lythology and the energy potential of the sites. We are obliged to the company for sharing a part of that information with us. This information is organized in Tables 2, 4 and 5.

The Committee of Geology and Utilization of the Earth's Crust of the Russian Federation is broadly responsible for the exploration, development and utilization of all natural resources on the territory of Russia except oil and gas. These broadly defined responsibilities encompass policy making as well as purely commercial activities, including business plan preparation, joint venture establishment and operation, granting of concessions, etc.

SevKavBurGeotermiia, a spin-off of BurGAzGeoTerm and now an independent state owned company, has been involved in the prospecting, development and exploitation of geothermal resources on the territory of Caucasus for more than thirty years. The company, and its management are demonstrating an extremely high level of entrepreneurship and initiative. The management of the company is actively searching for partners and possibilities to increase the output of the current resources and the efficiency of their use. According to the company, approximately 35 % to 50% of the available geothermal resources on the territory of Region A are currently being utilized.

Institute of Geophysics, The Ukrainian Academy of Science, is one of the few entities left on the territory of Ukraine that deal with geothermal energy. It is one of the very few usable contacts on geothermal issues in Ukraine.

Nomenclature of Tables

The information contained in *Tables 1* and *3* has been provided by the Committee of Geology and Utilization of the Earth's Crust of the Russian Federation. *Table 1* contains the official opinion of the Committee with respect to the geothermal energy potential of the different parts of the Russian Federation, broken down by major geothermal water fields and by the kind of the resource, i.e. hot water or geothermal steam (steam-water mixture). The shaded part of the table contains sites in Region A, the un-shaded, Region B. *The information in Tables 1,2 and 4* may be combined to give the most comprehensive understanding of the capacity and geology of any geothermal site.

Table 3 provides important aggregate information along with important time perspective. *Table 3* is the latest word of the Committee of Geology and Utilization of the Earth's Crust of the Russian Federation on the geothermal energy potential of the country. It contains sites being certified by the GKZ -- the State Commission on Resources, the government body authorized to standardize, approve and classify information on natural resources in Russia. Translation of the working definitions applicable to geothermal resources adopted by GKZ are provided in the Appendix.

The information contained in *Tables 2, 4* and *5* has been provided by BurGazGeoTerm. *Table 2* provides detailed information on the sites in the Russian Caucasus -- defined as Region A in this report. The sites that are located in Region A but are not accounted for in *Table 2* are listed in the footnotes of the table.

The information in *Table 4* has also been provided by the Geological Department of BurGazGeoTerm. This table covers in detail the geothermal sites in Region B -- the Russian Far North-East. The information in this table is a an integral part of an aggregate body of information known as "The Balance of Natural Recourses of the Russian Federation". Therefore, this table provides a comprehensive and exhaustive list of all geothermal water fields in Region B, including those that are no longer under the developmental responsibility of BurGazGeoTerm. However, the information in Table 4 is a lot richer in detail and therefore more valuable in its own way than the aggregate numbers provided in, for example, *Table 1* and *3*.

Table 5 provides information on the two sites that were under exploitation by BurGazGeoTerm on the territory of Ukraine. Other geothermal sites do exist on the territory of Ukraine, but no systematic information, approved by the Ukrainian equivalent of the GKZ, on those sites is available. The information provided in *Table 6*, although reliable, does not carry a seal of state approval.

REGION A, THE CAUCASUS

Geomorphologically, the Caucasus region is divided into the Precaucasian Platform, the Greater Caucasus, Transcaucasia and Lesser Caucasus. Only the Precaucasian Platform and the eastern slopes of the Greater Caucasus remained in the territory of the Russian federation after the disintegration of the former Soviet Union (USSR).

The Precaucasian Platform and the eastern slopes of the Greater Caucasus are administratively divided among the following republics and krai -- regions:

1. Krasnodarskii Krai
2. Stavropolskii Krai
3. Republic Adigeia
4. Karachaevo-Cherkeskaia Republic
5. Republic of Kabardino-Balkaria
6. Republic of Northern Osetiia-Alaniia
7. Chechen-Ingushet Republic
8. Republic of Dagestan

all of which are members with equal rights in the Russian Federation. Currently there are no known geothermal resources or geological prospecting operations in the of the Republic of Northern Osetiia-Alaniia.

The Precaucasian Platform hosts two artesian water basins that cover a total area of 150,000 square kilometers: the Azov - Kubanskii basin to the north and the Tersko - Kumskii basin to the south. These two artesian basins are separated by the Stavropole dome. The two basins are piedmont type and have external water recharging pressure forming sources of piedmont type in the eastern slopes of the Greater Caucasus.

Extensive drilling in the region for crude oil prospecting and exploitation has provided ample data on the water-bearing horizons. Generally these are the sedimentary deposits of the Lower Cretaceous and the Neogene deposits. The Apsheron Neogene water-bearing formation is one of the largest in the eastern Precaucasia. It almost reaches the coastal line of Caspian sea, where it produces geothermal waters with temperatures of 46 to 100^0 C at the Kizliarskoe site and Chervlennie Buruni near the town of Uzno-Suhokumsk . The deposit strata at this site reach a depth of over 1000 meters and are up to 700 meters thick.

The Chokrakian water-bearing formation is a Neogene deposit with industrial significance as a source of geothermal water. It is situated in the eastern collar of the Caucasus range transcending into Precaucasia. Water-charging occurs on the eastern slopes of the Caucasus though Chokrakian monoclinals. Reaching significant depths through highly permeable sandstone interlayered with clay, the water acquires high pressure and temperatures of over 100^0 C .

Another major Neogene deposit with industrial significance is the Karaganian water-bearing formation. It extends as a band, 50 kilometers wide, along the slopes of Caucasus mountain. These slopes, especially to the north charge the water-bearing strata of the formation in the eastern and the southern parts of Precaucasia in the Azov - Kubanskii basin. The sedimentary sandstone is of very high water permeability, reaching a depth of four kilometers and a thickness of 400 meters. Water temperatures vary with depth, with maximum levels of over 100^0 C and mineralization in the range of 10 to 20 g/l.

Several of the most significant geothermal water fields in Region A are connected to Chokrakian and the Karaganian Neogene deposit levels: Hankalskoe and Goitinskoe, respectively south and south-east of the town of Grozni, Mahachkalinskoe and Mahachkala-Ternair, Kizliarskoe and Izberbashskoe, just to name a few (for details, please refer to Table 1 and Table 2).

The Pontian-Meotian Neogene deposit horizons of sand, poorly cemented sandstone and siltstone are of very high permeability. These deposit horizons stretch north of the Stavropol dome and into the Azov-Kubanskii sag as well as into the Tersko-Kumskii basin sag. The geothermal water in these strata is of low mineralization. The highest temperatures are 70^0 C .

The Cretaceous, especially the Lower Cretaceous (Albian, Aptian, Barremian and Cenomanian) formations in southern Precaucasia provide favorable conditions for the formation of geothermal water fields. Although the Lower Cretaceous strata form a belt 10 to 20 kilometers wide along the foothills of the Caucasus range, it is only at the southern end, where thermal water has been associated with them. At Tersko-Galiugaevsoe, in Stavropol Region, at depths of 2600 to 2700 well temperatures of 160^0 to 220^0 C have been measured.

Details of all of the geothermal water fields and sites in the territory of Caucasus region can be found in Table 1 and Table 2.

REGION B, THE COASTAL FAR EAST

1. Kamchatskaia Oblast

The Kamchatka Peninsula is a part of the Asian Alaska sector of the Circum-Pacific Cenozoic volcanic belt. The geothermal resources in Kamchatka are of volcanic origin. Tectonic activity on the peninsula is determined by the northeastern dislocations. These dislocations are the reason for the volcanic activity and the associated geothermal phenomena. Most of the significant geothermal systems on the territory of the peninsula are located along the Eastern Kamchatka volcanic zone. The formation of this zone is related to the formation of graben-synclinal structures -- large faults in the northeastern plate. These graben-synclinal structures are limited by the regional fractures of very large amplitudes (up to 1000 to 1500 meters) or by a series of scalariform faults of medium amplitude, filled with Quaternary volcanic and volcanic-sedimentary rocks (Erlich et al.).

The following paragraphs provide a brief geomorphological description of the most important geothermal complexes on the territory of the Kamchatka peninsula. The text should be reviewed along with Table 4 which provides detailed numerical information on all commercially viable geothermal sites in Kamchatka as per the Committee of Geology and Utilization of the Earth's Crust of the Russian Federation.

Paratunskoe is one of the most important geothermal water fields in Kamchatka. It includes the *Paratunskoe, Bolshe-Bannoe, Karimchinskoe, Nachikinskoe* and some other sites. The Paratunskoe region is part of the south-eastern outskirts of the inner volcanic arc of the Kamchatka Peninsula. The region includes the basins of the Plotnikov, Karimchini, Bannoi and Paratunka rivers. The most important geological-tectonic structures are the metamorphic zone of the Ganalskii ridge, Nachikinskaia block folding zone, the Verhnekarimchinskaia volcanic zone, the Nizhnekarimchinskaia volcanic zone, the Tolmachevski area of regional basalt vocalism, the northern collar of the Gorelogo volcano, the Paratunka trough and the Nachikinskaia trough.

Without doubt the P*auzhetka* geothermal complex is the best known geothermal water field in the territory of the Russian Federation and the former Soviet Union in general. A water/steam mixture of geothermal origin has been sufficient to power the first Russian Experimental Geothermal Power Plant with a capacity of 5MW continuously for thirty years now. It is important to point out however that the installed capacity of the plant is 11 MW. The Pauzhetka geothermal complex is located in the boundary between two structure-facies zones: the West Kamchatka and the Central Kamchatka, as defined by G. M. Vlasov and V. A. Iarmiuliuk. The Pauzhetka geothermal complex is also an integral part of the following volcanoes as a part of the southern end of the Eastern-Kamchatka volcanic range: the Zheltovskii, the Ilinskii, the Kambalnii, Koshelevskii and Mashkovtsov volcanoes.

Mutnovskoe geothermal complex is another commercial source of water/steam mixture with electricity generation potential at the current level of technology. Mutnovskoe geothermal complex is located 70 kilometers south of the town of Petropavlovsk-Kamchatskii, in a region of rather intensive and diverse volcanic activity. The complex is named after the complex massif of the Mutnovskii volcano, developed through several different geologic periods. This massif provides for the most powerful fumarole fields in the Kamchatka peninsula. Two separate characteristic formations of the Mutnovskoe complex are the Gorelii volcano with an active strata-volcano within the caldera at the top of the cone, and the disintegrated Zhirovskii volcano with thermal activity within the eroded crater. A specific, narrow depression, 3 to 10 kilometers wide, extends in the sub-meridianal direction, overlapping the peripheries of the above described volcanic structures from the Mutnovskii to the Viliuchinskii volcanoes. The depression is overlaid with a dense set of tectonic faults with multiple demonstrations of aerial volcanic activity such as scoria cones, dykes and extrusions of different age and composition. This graben-like structure is referred to as the Northern Mutnovskii volcanic zone (E. A. Vakin, et al.) Morphologically, this area is a plateau, tilted eastwards and down-cutted by the beds of the Zhirovaia, Falshivaia and Mutnovskaia rivers. The volcano formations rise high, more than one kilometer above the plateau with latitude of 700 to 800 meters.

2. Sakhalinskaia Oblast

Sakhalinskaia Oblast consists strictly of island territory -- that of the large Sahalin island and the group of the Kurile islands that stretches from the southern tip of Kamchatka peninsula to the northern end of the Hokkaido island of Japan.

2.1. Sakhalin Island

Several artesian basins have been discovered on the territory of Sahalin island during crude oil prospecting. The most significant include Severo-Shalinskoe, Tatarskii and Susuniskii artesian basins. The best studied is the Severo-Sahalinskii artesian basin covering some 22,000 square kilometers. The water bearing strata are Neogene sand, sandstone and siltstones. Water temperatures range from 60^0 to 97^0 C at Tungur at a depth of 3300 meters. Mineralization ranges from 3 g/l to 20 g/l.

The Tatarskii artesian basin covers some 8,000 square kilometers. Although Neocene and Paleocene deposits form the largest part of the basin, the highest water temperature, 128^0 C, has been measured at the Krasnogorskaia site in Upper Miocene deposits at a depth of 2.9 kilometers.

The Susunaiskii basin covers some 1,500 square kilometers. It is formed in Neogene sedimentary environment with a thickness of three kilometers. Water temperatures in the range of 70^0 C have been measured at a depth of 1800 meters, again during crude oil prospecting.

2.2. The Kurile Islands

The Kurile Islands include the following larger islands from north to south: Paramushir, Simushir, Urtup, Irtup and Kunashir. They are part of the same chain of eastern Pacific dislocations as Japan and Kamchatka. Consequently, the same tectonic and volcanic forces cause the geothermal phenomena on these islands. The islands are formed from Neogene volcanic sedimentary deposits broken by a number of major dislocations that focus the thermal activity.

Regardless of the favorable conditions for the existence of geothermal water and steam, due to the small size and the remote location of the islands, very few sites have been explored and rated of commercial significance.

One of them is *Goriachii Pliazh*. The site is located on the eastern shore of Kunashir island, the one closest to Japan. The geothermal field is located in a narrow coastal stretch, about one kilometer long and a quarter of a kilometer wide. It is in immediate proximity to the Mendeleev volcano. The geothermal water system is bedded in a fissured Neogene layer of tuffs, sandstone, conglomerates and redeposited volcanic rocks and has total thickness of 570 meters.

Another site with a very promising commercial potential, due to the high enthalpy of the water-steam mixture is Okeanskoe (Kipiashtii), located on the Ohotsk Sea coast of Irtup Island. It is also in close proximity (eight kilometers) to the Town of Kurilsk.

3. Chukotskii Avtonomnii Okrug and Magadanskaia Oblast

Chukotskii Avtonomnii Okrug and Magadanskaia Oblast are part of the vast Russian North-East permafrost area. The entire region covers more than 4,000,000 square kilometers and geologically is a Mesozoic fold belt. Both Chukotskii Avtonomnii Okrug and Magadanskaia Oblast are part of the Ohotsko-Chukotskii volcanic belt, which is one of the five major geologic structures of the Russian North-East: the Kolima fold zone, the Iano-Kolima fold zone, the Chukotka fold zone, the Ohotsk fold zone and the Ohotsko-Chukotskii volcanic belt. The two geothermal sites known in the area are both located in the Ohotsko-Chukotskii volcanic belt. These are the Tavatumskoe site in Magadanskaia Oblast and the Lorinskoe site (Kukinskie outflows) in the Chukotka peninsula. Due to the severe climatic conditions, the region is poorly studied.

REGION C

Region C covers the territory between the rivers Lena and Ob, and includes:

> Tiumenskaia Oblast (incl. the Hanti-Mansiiskii Avtonomnii Okrug and the Iamalo-Nenetskii Avtonomnii Okrug),
> Tomskaia Oblast,
> Omskaia Oblast,
> Novosibirskaia Oblast,
> Altaiskii Krai,
> the Republic of Gornii Altai,
> Kemerovskaia Oblast,
> Republic Tuva,
> Republic Hakasiia,
> Krasnoiarskii Krai (incl. Taimirskii Avtonomnii Okrug and Evenkiiskii Avtonomnii Okrug),
> Irkutskaia Oblast (incl. Ust-Ordinskii Buriatskii Avtonomnii Okrug),
> Republic of Buriatia, and
> the eastern territories of the Republic of Saha (Yakutia).

From a geophysical viewpoint, Region C includes the West Siberian Plain, the Middle Siberian Highland and the Sayano-Baykal fold range.

1. West Siberian Plain

The Western Siberian Plain hosts one of the world's largest artesian complexes. The complex was very well studied during extensive exploration and development of crude oil fields. Geothermal waters have been encountered in the Aptian, Albian, Cenomian and Neocomian formations.

The water bearing strata of the Aptian, the Albian and the Cenomian formations consist of sand, sandstone, siltstone and clay with aggregate thickness of about one kilometer. The waters reach 60^0 C and contain methane and nitrogen gases. Mineralization varies in content and composition from 1 to 75 g/l, sometimes including iodine and bromine. Some examples of drill sites to the south are Koplashevo, Kupino and Ipatovskaia and to the north are Vikulovo and Tara.

The water bearing strata of the Neocomian formations consist of interlayered sandstone, siltstone, clay and argillite, reaching depths of 200 to 1800 meters. The highest water temperatures of 70^0 to 95^0 C at bedding were recorded in the Middle Ob River Valley and Toblosk sites where Irtish river merges with the Ob river. At the Tobolsk site, near the town of Tobolsk, the water has sodium chloride mineralization of about 17 g/l and methane gas contamination.

2. Middle Siberian Highland

The Angara-Lena artesian basin is situated in the Irkutsk amphitheater, which itself is a result of the interaction of the wedge-shaped anticlinal nose of the Middle Siberian Highland platform with the Sayano-Baykal fold region. Heavily mineralized brine waters, with up to 500 g/l of dried compound and temperatures of up to 77^0 C were confined to Ordovician and Cambrian formations.

3. Sayano-Baykal fold range.

The Sayano-Baykal fold range is a result of volcanic activity during tertiary Neogene. The result is a system of consecutive grabens and mountain ranges, the grabens actually replicating large faults in the strata. Lake Baykal occupies the deepest of these grabens. Natural outflows of hot water indicate the existence of geothermal water systems. Two types of such systems are found in the Sayano-Baykal fold range: waters in sedimentary environment and waters in fissures in the fault zones.

No resources with commercial significance have been identified in Region C for the following three reasons:

- although extensive geological prospecting work has been performed in the region, it was primarily focused on the investigation and exploration for crude oil reserves, not geothermal water reserves;

- none of the known geothermal sites offers high temperature resources suitable for electricity production; and

- the region is very sparcely populated and most of the known geothermal water fields are away from urban areas, which limits the usefulness of these geothermal resources.

UKRAINE

The usable hydro-geothermal potential of Ukraine is estimated to be 10,000,000 metric tons crude oil equivalent per year.

The Transcarpathian and the Ciscarpathian depressions, along with the Skifskaia (Scythian) platform, the Dneprovsko-Donetskaia trough and the Donetskoe folding system are considered to be the most promising for geological prospecting operations for geothermal water (V.V. Baibakov, et al). This conclusion is based on the study of thermal flow and the depth of the 150^0 C isotermic strata by geophysical methods. The recommendation does not consider the geological prerequisites for existence of subsurface waters.

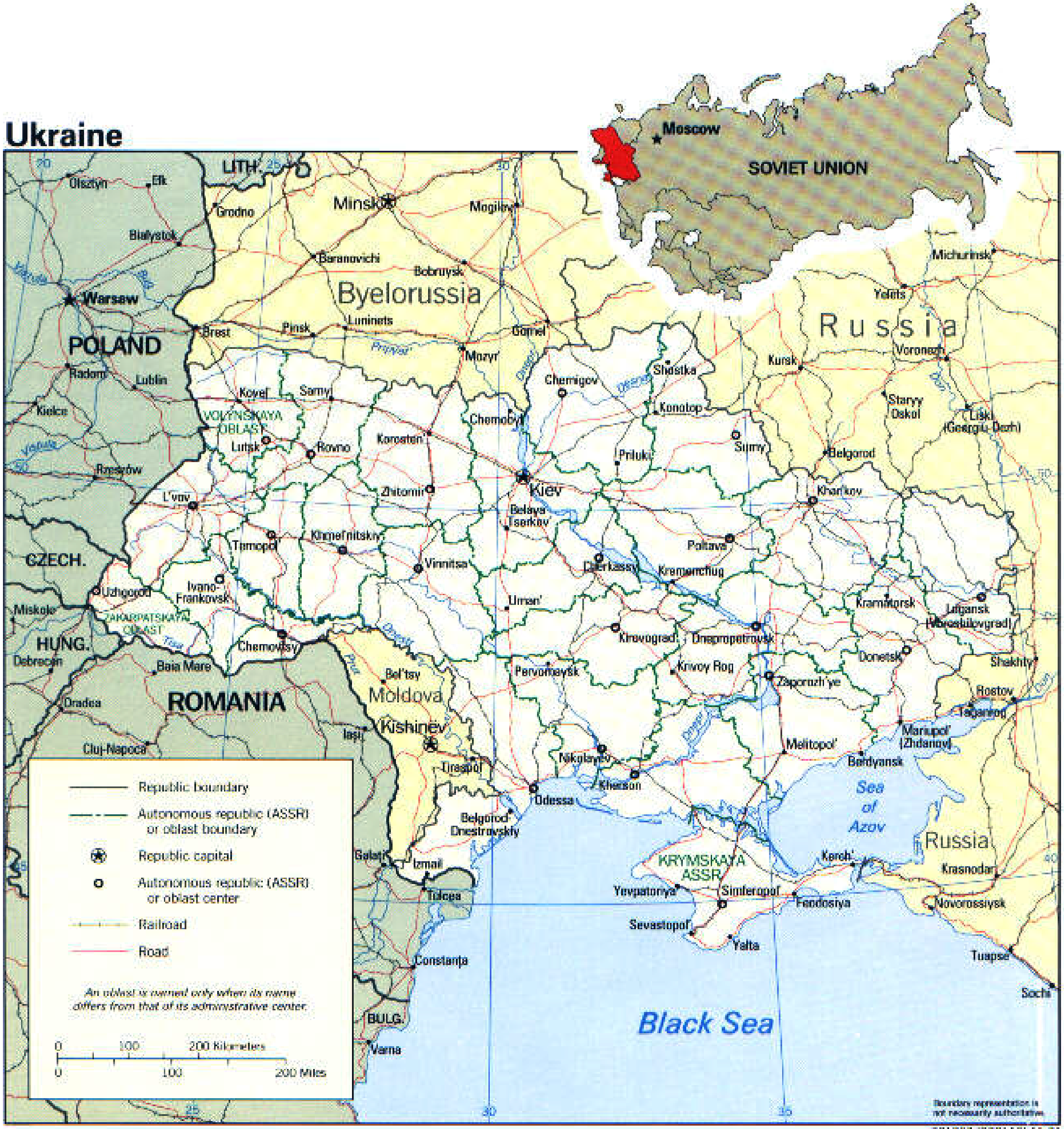
1. Crimea Peninsula

In the relatively small territory of the Crimea Peninsula, interaction of tectonic regions of completely different structure and time of development has been observed. Almost all major structures of the Earth’s crust are represented here: the southern slope of the ancient East European Platform, part of the Epipaleozoic Scythian plate, a part of the Alpo-Himalayan folding system, represented by the Crimean mega-anticline bordered by the Hindolo-Kubanskii edge sag and a region of the bathipelagic depression of the Black sea, characterized by the typical structure of a pelagic depression.

According to E.A Babinets, from hydro-geological point of view, the Crimea Peninsula, which is a part of the Prichernomoskii (the Black Sea) artesian basin, is subdivided into the following three basins, due to their differences in tectonic structure and hydro-geological characteristics:

- Prisivashskii artesian basin,
- Alminskii artesian basin, and
- Indolskii artesian basin.

Ukraine



801807 (R00110) 11-91

1.1. Prisivashskii (Sivashkii) Artesian Basin

The Prisivashskii (Sivashkii) artesian basin is located between the Ukrainian crystalline massif and the Evpatoria block rise. The northern and the eastern marts of the basin are located in the Ukrainian crystalline massif, while the southern part of the basin is in the area of the Prichernomoskii (the Black Sea) bathipelagic depression.

1.2. Alminskii Artesian Basin

The Alminskii artesian basin is a part of the Alminskii trough.

1.3. Indolskii Artesian Basin

The Indolskii artesian basin is a part of the Indolskii trough.

Characteristics of the water bearing horizons in the sedimentary mantel of the Crimea Peninsula follows. Please, refer to Table 5.

The speed of water penetration of the Paleozoic deposits represented by marbly limestone schists with intercalation of effusive rock ranges from 6 cubic meters per day at the Novoselovskoe site, consisting of three parts: Ilinka, Trudovoe and Sizovka, to 860 cubic meters per day at the Saki site. The chlorine-sodium mineralization ranges from 2 g/l to at the Goncharovka site to 70 g/l at the Krilovskaia site.

Water bearing horizons from the Jurassic period occur at depths of 400 to 3000 meters and are characterized by low holding and filtration capacity. The flow rates of the wells reaching into such horizons range from 0.11 cubic meters per day, at Oktiabrskoi site to 18.4 cubic meters per day at Krasnovskoi site. The chlorine-sodium mineralization ranges from 2.4 g/l to 63.5 g/l.

The water bearing strata from the Cretaceous period are basal sandstone, aeurolites, gritstones and conglomerates. The best water trapping capacity is demonstrated by the basal aleurolite-sandstone bench reaching open porosity of 3% to 29% and perviousness of 987 f/m^2 at the Novoselovskoe uplift and the Simferopolskii protrusion. The flow rate of the gushing wells is sometimes higher than 1200 cubic meters per day.

The Upper Cretaceous water-bearing horizons found in limestone-clay formations are characterized by low open porosity of 1-2% to 10-20%, fissure porosity of not more than 1% and fissure perviousness from zero to 183 f/m^2. The flow rates range from 0.2 to 532 cubic meters per day at the *Kuibishev* area to 2600 cubic meters per day at the intensively fissured series of the *Krilovskoi* area. The mineralization of the Upper Cretaceous water-bearing horizons is 20 to 30 g/l.

The Paleocene water-bearing strata are mostly sandstones, often poorly cemented, and characterized by high open porosity. Such formations are spread throughout the Tarhankut and the Kerchen Peninsulas and in the *Sivash* area. The flow-rate of the wells sometime reaches very high values -- 2240 cubic meters per day at a gushing well at *Medvedovskoi* site. The chlorine-sodium mineralization is in the range of 16.7 g/l to 60.8 g/l.

The water trapping properties of the Middle Eocene deposits at the *Prisivashe site* were thoroughly studied. The average open porosity ranges from 22% to 26% producing a flow-rate at the well of 870 cubic meters per day. The water has chlorine-sodium mineralization of 30 to 50 g/l.

The water bearing horizons in the Maikop series turn out to be the aleurolite and the fine-grained sandstone interlayers. They have low water-trapping capacity of 65 cubic meters per day. Chlorine-sodium mineralization with values of 10 to 65 g/l is typical.

The *Severo-Sivashkoe* prospecting site is located north-east of the town of Djankoi, near the coastal line of the Asov See.

Novoselskoe geothermal water bed is located opposite from the Severo-Sivashkoe, across the territory of the Crimea Peninsula, near the Black See coast, north of the town of Evpatoria. It consists of three prospecting sites: Ilinka, Trudovoe and Sizovka. The largest and most intensive temperature anomaly has been observed at this geothermal water bed. Its proximity to urban areas enhances its ranking as the most commercially viable geothermal resource of the Crimea Peninsula.

2. Ciscarpathia

2.1. The Ciscarpathian Depression

From a hydro-geological point of view, the Ciscarpathian Depression is a first class, pressurized water-bearing basin. It is sub-divided into two second class water-bearing basins: the *Chop-Mukachevskii* and *Solotvinskii* pressurized water-bearing basins. The hydro-geological environment in the Ciscarpathian water-bearing basin is not homogenous. It is not uniform even within the two sub-basins. The mineralization of the geothermal waters of the Chop-Mukachevskii basin vary in quantity and kind from 10 g/l to 300-350 g/l.

2.1.1.

Significant flow-rates (see Table 6) of waters from Paleozoic, Early Miocene and Sarmat deposits have been observed during prospective drillings in the area of the town of *Uzgorod*, situated in the north-western part of the Ciscarpathian Depression, close to the borders with Romania and the Republic of Slovakia.

The *Uzgorod* site is characterized, as is the territory of the entire depression, by a block structure of pre-Neogene folding base. Multi-directional tectonic movements of the blocks have resulted in significant variations in the depth of the base. The highest part is the Uzgorod transversal uplift. The roof of the base is located at a depth of less than 1000 meters. Uneven, but sometimes up to hundreds of meters thick, the sedimentary mantle of lower Miocene is a significant structural element of the hydro-geothermal environment of this site. The most productive area proved to be the sandstone water bearing horizon of the adjacent Russko-Komarovskii uplift. The name of the drill-site is Uzgorod - 2T (see Table 6). The mineralization of the water is 16 - 30 g/l. The formation pressure at 1700 m is 167.9 Atm. and at 1300 m, 134.64 Atm. A maximum water temperature of 108^0 C was measured at a depth of 1940 m. The discovered hydro-geothermal resources have been determined to have no commercial value and are currently in conservation. The geological and hydro-geological investigation carried out at the site is however considered insufficient to a large extent.

2.1.2.

Some of the drillings in the region of the town of *Irshava* also demonstrated significant free-flowing hot water. At that site, an anticlinal crypto-diapir fold is to be found under the Neogene mantel. Most promising are the waters in Cretaceous sedimentary environments. Such waters and environments have been discovered by the drillings at Irshava - 2, located in the area of the Danilovo-Nevitskovo abyssal fracture (see Table 6). The water-bearing rock is of fissured type, probably due to the fracture zone. Mineralization is about 189 g/l.

2.1.3.

The hydro-geothermal complex at the *Tereblia* site (see Table 6) is also of significant interest. The formation is located in the central part of the Solotvinskaia depression. The maximum thickness of the water bearing tuffs is 700 meters. The dip angle of the thrust fault planes of the Cretaceous blocks of the base is between 5-20 deg. The water bearing suites are enveloped between these practically water-impermeable blocks and talabor rock which is also water impermeable. This creates very favorable conditions for the accumulation of geothermal waters. Well Tereblia -6, drilled in the central part of the syncline, reached pressurized water-bearing horizon in the interval between 2009 and 2360 meters. The well is a gushing type, with flow-rates between 500 and 900 cubic meters per day. The pressure at the well head was measured at 1.2 Atm. The pressure at 1767 meters was 217 Atm. Water mineralization is in the range of 138 g/l. Water temperature measured at 2350 meters was 105^0 C, and at the well head was 95^0 C (Tereblia - 6).

The size of the *Tereblia* water-bearing complex is 15 by 5 km. Assuming the thickness of the water-bearing rock is 300 m. and the porosity of the rock is 10% the accumulated reserves are 3 km^3. With a temperature of over 100^0 C, the accumulated thermal energy is then $1.5x10^{18}$ J (A. A. Andrusenka et.al.).

Among the different sites of the Chop-Mukachevskii and Solotvinskii pressurized water-bearing basins, Uzgorod, Mukachevskii, Irshavskii, Vinogradskii and Beregovskii sites were deemed promising for geologic prospecting for thermal waters. As a result of extensive, but still incomplete, studies carried out in the ‘80s, the Uzgorod site was determined to be of highest priority for commercial utilization of the discovered hydro-geothermal resources. The proximity of the site to the towns of Uzgorod and Chop played a significant role in the estimation of the resources for commercial utilization. The *Tereblia* hydro-geothermal site received second highest priority with respect to the potential of its geothermal resources.

2.2. The Vigorlat-Gutinskoi Volcanic Range

The Vigorlat-Gutinskoi Volcanic Range is an independent geological and hydro-geological formation. The geothermal waters of the Vigorlat-Gutinskoi Volcanic Range are famous for their qualities as table spring waters. However, due to the small depth of their bedding they are of low temperature and have low energy and therefore commercial potential.

OUTLOOK FOR DEVELOPMENT

Currently the Russian Federation is undergoing uneasy changes on the road to a market economy and democracy. The process of economic readjustment is resulting in severe shrinkage in industrial output. The economy is cash strapped. The government is re-defining not only the state borders but also its own roles and functions within the new Russian society.

In this reality, it is not surprising that geothermal problems have lost some of their priority. However, these problems have not lost their importance.

As indicated to the team by the Director of the North Caucasus Drilling Company, Mr. Boris Nirko, the utilization of geothermal resources in the Caucasus region is only 35% to 50%. The North Caucasus Drilling Company, which is solely responsible for the prospecting and exploitation of all geothermal resources in the territory of the Caucasus region (Region A), expressed very strong interest in partnering with US and other international wildcatters in two areas: increasing the output of geothermal waters and increasing of the efficiency of their use.

Mr. Postnikov the Head of the Geological Department of BurGazGeoTerm -- the largest national drilling and developing organization -- indicated potential interest in joint efforts with international partners in the development of a new geothermal field -- on the island of Paramushar (one of the Kurile islands). The field is so new that it is not yet included in the national balance of geothermal resources.

Another geothermal site that is being packaged for attracting international partners is the Kusminka site in Stavropolskii Krai. The field offers waters with temperatures of 130 C . The Committee of Geology and Utilization of the Earth's Crust has prepared a complete business plan.

Another example is the Mutnovka site. In addition to the existing 50 to 60 MW, an additional 70MW of geothermal resources with potential for electricity generation has been identified. A 70 MW geothermal power plant project will be financed by the European Bank for Reconstruction and Development (EBRD). However, the project is still open for investors and for equipment suppliers.

To conclude, regardless of the general problems of the Russian economic environment, the Russian geothermal industry sub-sector offers selected possibilities for promising international cooperation.

APPENDIX

This appendix provides some of the working definitions used by GKZ -- the Russian State Commission on Resources -- that are necessary for the correct understanding and interpretation of the data provided in the body of Tables 1 and 3.

Geothermal reserves are divided into three subtypes:

1. *Static reserves* are the volume of subsurface water, contained in water-bearing strata in the natural state, i.e., the overall volume of subterranean water found in pores and fissures in water-bearing rock. Static reserves may be extracted from the stratum only when it is drained.

2. *Elastic reserves* may be extracted from the stratum by reducing hydrostatic pressure which causes of both the water (when the pressure is reduced water expands) and the water-bearing rock (rock becomes more dense and the water is squeezed off).

3. *Dynamic reserves (resources)* are the waters in natural circulation. Dynamic reserves are usually exploited simultaneously with elastic reserves when hydrostatic pressure in the reservoirs drops.

Exploitable reserves of subsurface waters (including geothermal) consist of subsurface water that can be extracted from wells and other installations in a technically and economically rational fashion, under the given conditions of exploitation that maintain optimal quality and quantity. Such exploitable reserves may not be limited to elastic and dynamic reserves in the exploited water-bearing horizons. During extensive withdrawal of subsurface water, changes occur in the water budget of the water-bearing unit. Due to the fact that a cone of depression forms during the exploitation of a geothermal water field, conditions are created for drawing additional water resources into the exploited area that were not taken into account when the natural conditions were evaluated.

Examples of the additional reserves of geothermal thermal water that can form in a geothermal water field include leakage from neighboring water-bearing strata, and concentrated supplementary feeding through high-permeability rock that allows improved recharge -- so called lythologic windows.

The exploitable reserves represented by the following equation;

$$Q_e = Q_{el} + Q_{dyn} + Q_{add}$$

where:

Q_e are exploitable reserves;
$Q_{el} + Q_{dyn}$, elastic and dynamic reserves; and
Q_{add} , the reserves that are added during exploitation.[3]

In the Russian Federation, geothermal water resources are subdivided into four categories – C_2 , C_1, B, and A – ranked by increasing degree of exploration, research on water quantity, quality, and exploitation conditions. When a regional estimate of the exploitable reserves of geothermal water is prepared, the so-called hypothetical exploitable resources are also determined. This term indicates a level of knowledge that is below the C_2 category.

In addition, exploitable reserves of thermal water are further subdivided into 2 groups, with respect to their current economic value:

a. Reserves that can now be exploited economically, and which satisfy both the intended use and the proposed system of exploitation;

b. Reserves that are presently uneconomical due to the small volume of water for the intended purpose, or because they require extremely complex methods of exploitation; viewed as potentially exploitable in the future.

Classification is overseen by GKZ -- the State Commission for Resources, which examines and approves for development all mineral, oil, gas, and subsurface water resources. The Commission is under the jurisdiction of the Council of Ministers of the Russian Federation.

---

[3] During exploitation static reserves are not extracted.

The following table gives the definitions of the categories used by the GZJ:

Classification of Exploitable Thermal Water Reserves on the Basis of Level of Study

Category of Reserves	Characterization of Level of Study	Type of Reserves
A	Reserves have been explored and studied to the degree that the data assure complete understanding of stratigraphy, structure, pressure heads, and permeability of water-bearing rock. The means by which water-bearing formations are replenished and their potential to add to exploitable reserves have been ascertained. The volume of subsurface water has been determined with a certainty that assures the useful life and the potential for a desired purpose. Exploitable reserves of subsurface water have been determined at the water supply site using pump (flowing) tests and/or other means.	Commercial
B	Reserves have been explored and studied in detail. The data obtained assure determination of basic stratigraphic features, structure, and recharge sources for replenishing exploitable resources of subsurface water. Water quality has been studied to the point where its use may be established. Exploitable reserves of subsurface water at a site of projected supply have been determined on the basis of pump (flowing) tests and extrapolated estimates.	Commercial
C_1	Reserves have been explored and studied to the point where the data assure general determination of the structure, stratigraphy, and extent of water-bearing formations. Exploitable reserves are determined by sampling data from single exploratory wells, and through analogy with well-known fields.	Potential
C_2	Reserves have been established on the basis of geologic and hydrothemal data, and have been confirmed by sampling of water-bearing formations at specific locations, or by analogy with other explored areas.	Potential

Table 1

Resources of Geothermal Hot Water and Steam as of January 1, 1991 /as per the Committee of Geology and Utilization of the Earth's Crust of the Russian Federation/[1]

Name and Location of Source	Temp. ^0C	Potential in m^3/day x 10^3				
		A	B	C_1	C_2	Total
1	2	3	4	5	6	7
Resources of Geothermal Hot Water						
Krasnodarskii Krai[2,3]						
1. Mostovskoe, town of Mostovskoe	68 - 70	--	11.1	--	--	11.1
2. Ulianovskoe, village of Ulianovskii	75 - 82	1.646	0.218	--	--	1.864
3. Maikopskii termovodozabor, town of Maikop	73 - 83	4.98	--	--	--	4.98
Stavropolskii Krai[4]						
4. Cherkesskoe, town of Cherkessk	50 - 73	3.10	1.70	--	--	4.80
Checheno-Ingushetskaia Republic						
5. Hankalskoe, 10 km. south of town of Groznii	88 -98	3.60	2.00	3.90	--	9.50
6. Goitinskoe, southwestern outskirts of town of Groznii	66 - 83	0.15	1.00	--	--	1.15
7. Novogrozneneskoe, 18 km. southeastern of town of Gudermes	75 - 77	2.72	--	0.69	--	3.41
8. Chanti-Argunskoe, 45 km south of town of Groznii	55	0.233	0.115	--	--	0.348

[1] The Baksanskoe geothermal water field in the territory of the Republic of Kabardino-Balkaria is not accounted for in this table.

[2] The shaded area represents Region A, the un-shaded area represents region B

[3] Including the resources of the Republic of Agideia

[4] Including the resources of the Karachaevo-Cherkesskaia Republic

1	2	3	4	5	6	7
Republic of Dagestan						
9. Mahachkala-Ternair, 6 km west of town of Mahachkalla	42 - 70	--	4.10	0.70	--	4.80
10. Mahachkalinskoe, town of Mahachkalla	30 - 70	--	6.10	--	--	6.10
11. Izberbashskoe, town of Izberbash	77	4.12	0.42	--	--	4.54
12. Terekli-Mekteb, town of Terekli-Mekteb	81 - 86	0.50	--	--	--	0.50
13. Chervlennie Burunti, village of Chervlennie Burunti	81 - 86	0.50	--	--	--	0.50
Kamchatskaia Oblast						
14. Paratunka, 3 km. from village of Paratunka	74 - 86	--	14.50	-	--	14.50
15. Essovskoe, village of Esso	75	--	3.888	--	--	3.888
16. Verhne-Paratunskoe, 50. km west of town of Petropavlovsk-Kamchatskii	76	--	21.60	1.70	--	23.30
17. Apavgaiskoe, village of Apavgai	63 -76	--	2.72	--	0.65	3.37
Magadanskaia Oblast						
18. Tavatumskoe, 76 km. from village of Eveisk	59	--	0.135	--	--	0.135
19. Lorinskoe, village of Lorino	???	--	2.20	--	--	2.20

Resources of Geothermal Steam

Kamchatskaia Oblast						
1. Pauzhetskoe, 30 km. from village of Ozernovskii	195 - 205	10.00	5.20	--	--	15.20
2. Mutnovskoe, 70 km. south-west of town of Petropavlovsk-Kamchatskii	147 - 300	--	--	9.288	7.992	17.28
Sakhalinskaia Oblast						
3. Goriachii Pliazh, 8 km. south of town of Uzno-Kurilsk, island of Kunashir	???	--	3.450	0.961	--	4.147

Table 2

List of the Geothermal Sites under Exploitation and Development by Burgazgeoterm State Limited Company as of January 1, 1996[1]

Name	Mineralization in g/l	Contamination in mg/l	Temp. at borehole in ^0C	Pressure at borehole in Mpa	Flowrate in m^3/day	Average depth of boreholes in m	Usage
1	2	3	4	5	6	7	8
Krasnodarskii Krai							
1. Mostovskoe	1.4 - 2.5	none	72	0.1 - 0.5	800	2000 - 2200	industrial heat, furniture factory, space heating
2. Ulianovskoe	1.8 - 2.3	phenols	75 - 82	0.8	900	2000 - 2200	space heating
3. Voznesenskoe	1.0 - 4.7	phenols	82 -111	0.2 - 1.2	1000	2500	space heating
4. Uzhno Voznesenskoe	1.4 - 1.8	none	83 -87	???	600	2000	space heating
5. Otradnenskoe	1.1 - 2.0	none	88 - 100	0.5 - 0.9	800	1800	space heating
6. Griaznorechenskoe	1.1	phenols	106	1.4	1000	2000	space heating
7. Voskresenskoe	1.5 - 3.5	phenols	112 - 116	1.28	1000	2200	under conservation
8. Severo-Ereminskoe	2.5 - 2.9	phenols	107 - 117	0.7	1000	2200	under conservation
9. Harkovskoe	1.6	none	98	???	500	2000	under conservation
10. Uzhno-sovetskoe	1.4	none	116	17.0	1000	2200	hot water supply, space heating
11. Priurupskoe	1.5 - 1.7	none	99 - 103	11.0	800	2200	hot water supply, space heating
12. Mezhchohrakskoe	2.9 - 8.6	phenols	86	0.4	500	2000	under conservation
13. Rodnikovskaia	???	???	74	???	500	1800	under conservation

[1] All sites on the territory of the former Chechen-Ingushet Republic are under conservation for obvious reasons and are not included in this account

1	2	3	4	5	6	7	8
Stavropolskii Krai							
14. Kazminskoe	1.26 - 3.92	arsenic, 0.05 - 0.1; phenols, 0.05	115 - 128	0.3- 1.2	2000	2100 - 2700	space heating, industrial heat
15. Georgievskoe	12.3	none	55	0.5	1000	900 - 1200	hot water supply
16. Tersko-Galiugaevskoe	12.3	none	55	0.5	1500	2600 - 2700	hot water supply
17. Nizhne-Zelenchukskoe	23.0	none	118	0.562	1500	2300 - 2400	hot water supply, space heating

Republic of Agideia							
18. Maikopskoe	3.1 - 8.5	phenols	74 - 86	0.5	500	1800	industrial heat, space heating
19. Dagestano-Kurdzhipskoe	0.95 - 1.1	none	79 - 91	1.5 - 1.7	500	2000	space heating
20. Hodzevskoe	2.3 - 2.8	phenols	70 - 86	0.4	1000	2100 - 2400	space heating
Karachaevo-Cherkeskaia Republic							
21. Cherkesskoe	0.7 - 2.9	none	50 - 75	0.03 - 0.87	1000	1000- 1500	space heating, hot water supply, swimming pool
Republic of Kabardino-Balkariia							
22. Vostochno-Baksanskoe	8.1	phenols, 0.032	56 - 58	???	1500	1900	space heating
23. Nizhne-Baksanskoe	8.1	phenols, 0.032	56 - 58	???	1500	1900	space heating
Republic of Dagestan							
24. Mahachkala-Ternair	2.2 - 12.8	phenols, 0.0084 - 4.0	42 -100	0.12 - 1.3	600 - 1000	900 - 2100	industrial heat, space heating
25. Terekli-Mekteb	0.25 - 6.94	phenols, 2.8	82	0.37 - 0.40	600	1900- 2000	space heating
26. Chervlennie Buruni	8.6 - 8.9	phenols, 0.88 - 1.18	82	0.15 - 0.20	500	1500	space heating
27. Izberbashskoe	1.29 - 6.22	none	40 -62	0.06 - 0.32	400 - 500	800 - 1600	hot water supply
28. Kizliarskoe	1.29 - 6.94	none	46 - 100	0.35- 1.4	1000	1000 - 2900	space heating, hot water supply

1	2	3	4	5	6	7	8
29. Kordonovskoe	2.2 - 22.3	phenols, 1.48 - 1.70	44- 103	0.82 - 1.4	1000	1000 - 2800	under conservation
30. Kaiakentiaskoe	1.29 - 1.66	none	45 - 62	0.08 - 0.15	500	700 - 900	space heating, hot water supply
31. Manasskoe	2.5 - 6.2	none	40	0.05	500	1400	space heating, hot water supply
32. Rechninskoe	2.7 - 26.84	phenols, 0.0048 - 2.86	42 - 104	0.04 - 1.12	1000	1100 - 3000	under conservation
33. Krainovskoe	2.1	none	40	0.2	1000	700 - 800	hot water supply
34. Tarumovskoe	4.0 - 26.0	phenols, 0.16 - 0.94	62 - 90	4.7	600	1500 - 2000	space heating
35. Kalinovskoe	5,78 - 20.07	phenols, 0.7 - 1.8	57 - 92	1.0 - 1.4	1000	1500 - 2500	under conservation

Balance of the Geothermal Resources of the Russian Federation as a whole, in Regions and Parts (Subjects) of the Feder

Geothermal waters in thousands of cubic meters/day; Geothermal steam in thousands of metric tons/day

Region or Subject of the Federation	Total as of January 1995							Including Locations and Resource			
Kind of Geothermal Resource	A	B	A+B	C1	A+B+C 1	C2	Total	A	B	A+B	
1	2	3	4	5	6	7	8	9	10	11	
Russian Federation											
Geothermal Waters	26.416	90.663	117.079	31.380	148.459	0.650	149.109	-	-	-	
Geothermal Steam	10.000	8.656	18.656	14.109	32.765	7.992	40.757	-	-	-	
Northern Caucasus											
Geothermal Waters	21.716	32.508	54.224	21.880	76.104	-	76.104	-	-	-	
Republic of Dagestan											
Geothermal Waters	5.520	16.490	22.010	17.290	39.300	-	39.300	-	-	-	
Krasnodarskii Region											
Geothermal Waters	1.646	11.318	12.964	-	12.964	-	12.964	-	-	-	
Republic of Adigeia											
Geothermal Waters	4.980	-	4.980	-	4.980	-	4.980	-	-	-	
Karachaevo-Cherkeskaia Republic											
Geothermal Waters	3.100	1.700	4.800	-	4.800	-	4.800	-	-	-	
Republic of Chechnia											
Geothermal Waters	6.470	3.000	9.470	4.590	14.040	-	14.060	-	-	-	

Table 3

nce of the Geothermal Resources of the Russian Federation as a whole, in Regions and Parts (Subjects) of the Federation

nds of cubic meters/day; Geothermal steam in thousands of metric tons/day

	Total as of January 1995							Including Locations and Resources that Underwent State Certification in 1994						
rce	A	B	A+B	C1	A+B+C 1	C2	Total	A	B	A+B	C1	A+B+C 1	C2	Total
	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	26.416	90.663	117.079	31.380	148.459	0.650	149.109	-	-	-	-	-	-	-
	10.000	8.656	18.656	14.109	32.765	7.992	40.757	-	-	-	4.130	4.130	-	4.130
	21.716	32.508	54.224	21.880	76.104	-	76.104	-	-	-	-	-	-	-
	5.520	16.490	22.010	17.290	39.300	-	39.300	-	-	-	-	-	-	-
	1.646	11.318	12.964	-	12.964	-	12.964	-	-	-	-	-	-	-
	4.980	-	4.980	-	4.980	-	4.980	-	-	-	-	-	-	-
epublic														
	3.100	1.700	4.800	-	4.800	-	4.800	-	-	-	-	-	-	-
	6.470	3.000	9.470	4.590	14.040	-	14.060	-	-	-	-	-	-	-

Balance of the Geothermal Resources of the Russian Federation as a whole, in Regions and Parts (Subjects) of the Fede

Geothermal waters in thousands of cubic meters/day; Geothermal steam in thousands of metric tons/day

1	2	3	4	5	6	7	8	9	10	11
Far East										
Geothermal Waters	4.700	58.155	62.855	9.500	70.020	0.650	73.005	-	-	-
Geothermal Steam	10.000	8.656	18.656	14.109	32.765	7.992	40.757	-	-	-
Kamchatka										
Geothermal Waters[1]	4.700	55.820	60.520	9.500	70.020	0.650	70.670	-	-	-
Geothermal Steam[2]	10.000	5.200	15.200	9.288	24.488	7.992	32.480	-	-	-
Sakhalin Region										
Geothermal Steam	-	3.456	3.456	4.821	8.277	-	8.277	-	-	-
Magadan Region										
Geothermal Waters	-	0.135	0.135	-	0.135	-	0.135	-	-	-
Chukotka Autonomous Region										
Geothermal Waters	-	2.200	2.200	-	2.200	-	2.200	-	-	-

[1] The free outflows of Nachikinskoe (1,175 thousand cubic meters/day as of protocol GKZ #6011, 1970) and of Ketkinskoe (3,509 thousand cubic meters as of protocol TKZ 31(document. They are a part of a separate balance of free outflowing mineral waters.

[2] Some 13.5 thousand metric tons/day of free outflow in Bolshe-Bannoe location are NOT included in this balance (protocol GKZ #5657, 1969). They are a part of a separate bal

Table 4

in the Far East of the Russian Federation

n	Application (Intended) Company or Institution responsible Development started in year	Demand vs. Capacity	Water	Steam	Mix	Temperature and Pressure at well head	Depth and Thickness of water bedding	Age and Lithology of water bearing strata	Mineralization	Contamination
		$10^3 m^3$/day 10^3tons/day	Enthalpy MJ/kg			^{0}C MPa	m m		g/l	mg/l
	2	3	4			5	6	7	8	9
rces under simultaneous development and exploitation										
Termalnii own of	Space heating, balneotherapy *RAO Gazprom,* 1968	33.2 --	W			40 - 97 0.00 - 0.11	70 2500	P_3-N_1, Q_1, tuffs, andesito-basalt, diorite-porphyrite	0.8 - 2.2	arsenic: 0.01 - 1.0 fluorine: 0.2 - 3.0 silicic acid: 50 - 80
on, in central oi river and	Space heating *RAO Gazprom,* 1970	17.2 12.2	W			54 - 83 0.03 - 0.41	220 850	N_{1-2}, tuffs	0.96 - 1.30	arsenic: <0.2 fluorine: <3.5 metaboric acid: <1.8 lithium: 0.1 - 2.5
age region, estern coast	Electricity generation *RAO Gazprom,* 1966	42.2 42.2			M 0.64 - 0.88	100 0.15 - 0.18	90 1200	N_2-Q_1, tuffs, P_3-N_1, sandstone	2.5 -3.8	arsenic: 1.2 - 4.4
nchatka, at Bistroi	Space heating *RAO Gazprom,* 1971	4.8 0.7	W			63 - 81 0.01 - 0.34	210 1220	N_{1-2}, tuffs, andesito-basalt	1.4 - 2.0	arsenic: 0.01 - 0.16 fluorine: 0.9 - 2.8 metaboric acid 3.7
Blizhnii) - amchatskii	Space heating *RAO Gazprom,* 1989	-- --	W			72.5 0.01	986 1444	P_3-N_1, sandstone, tuffs, basalt	<11.1	arsenic: 1.0 arsenious acid: 1.68 metabiric acid: 17.1

Geothermal sites/locations in the Far East of the Russian Federation

Name and location	Application (Intended) Company or Institution responsible Development started in year	Demand vs. Capacity	Water / Steam / Mix	Temperature and Pressure at well head	Depth and Thickness of water bedding	Age and Litholo[gy] of water bearing strata
		$10^3 m^3$/day 10^3tons/day	Enthalpy MJ/kg	^0C MPa	m m	
1	2	3	4	5	6	7
Kamchatskaia Oblast						
Resources under simultaneous development and exploitation						
1. Paratunskoe - Paratunka and Termalnii settlements region, 60 km SW of town of Petropavlovsk-Kamchatskii	Space heating, balneotherapy *RAO Gazprom,* 1968	33.2 --	W	40 - 97 0.00 - 0.11	70 2500	P_3-N_1, Q_1, tuffs, andesito-basalt, diorite-porphyrite
2. Essovskoe - Esso village region, in central Kamchatka, in the valleys of Bistroi river and its left tributary Uksichan	Space heating *RAO Gazprom,* 1970	17.2 12.2	W	54 - 83 0.03 - 0.41	220 850	N_{1-2}, tuffs
3. Pauzhetskoe - Pauzhetka village region, the mouth of river Ozernoi, the western coast of S-E Kamchatka	Electricity generation *RAO Gazprom,* 1966	42.2 42.2	M 0.64 - 0.88	100 0.15 - 0.18	90 1200	N_2-Q_1, tuffs, P_3-N_1, sandstone
4. Anavgaiskoe - in central Kamchatka, at the junction of rivers Anavgai and Bistroi	Space heating *RAO Gazprom,* 1971	4.8 0.7	W	63 - 81 0.01 - 0.34	210 1220	N_{1-2}, tuffs, andesi[te] basalt
5. Uzhnoberezhnoe (region Blizhnii) - the S outskirts of Petropavlovsk-Kamchatskii	Space heating *RAO Gazprom,* 1989	-- --	W	72.5 0.01	986 1444	P_3-N_1, sandstone, tuffs, basalt

	2	3	4	5	6	7	8	9
...orozhe and ...uthern	Space heating *RAO Gazprom,* 1983	--	W	87 0.03 - 0.08	548 940	N_{1-2}, tuffs, tuff-breccia	14 - 23.2	arsenic: <6.8
...m town of	Road de-icing, balneotherapy KamchatGeologKom 1990	12.2 --	W	60.5 --	341 1800	J3-K1, N1-QII-III, tuffs, tuffites, basalt	2.4 - 11.4	arsenic: 0.08
... Nachiki ...k-	Space heating, balneotherapy *Federation of Independent Trade Unions* 1950	1.5 1.5	W	n/a n/a	200 300	K_2, N_1, dacite, hornfels, grano-diorite, diorite	n/a	n/a
Resources under preparation for exploitation								
...km S-W of ...n S of ...nka river	(Space heating), *RAO Gazprom,*	21.6 --	W	76.5 0.46 - 1.19	32 1670	P_{2-3}, N_1, tuffs, lava, extensively fissured quartzose diorites	0.9 - 1.5	arsenic: 0.13 - 1.0 fluorine: 2.8 - 4.4
...of ... springs of	(Energy Generation) *AOZT "KamTek"*	10.4 10.4	M 2.77	147 -320 0.7	255 873	P_3- N_1, tuffs, lava, tuffites	0.6 - 2.5	arsenic: 0.01 - 2.5 fluorine: 0.4 - 3.2
Resources under conservation								
...W of ...oi river	(Space heating) *KamchatGeologKom - The National Reserve*[1]	-- --	M 0.67	150 -170 0.1 - 0.35	164 598	N_1-N_2, andesite, tuff, welded tuff	1.0 - 1.4	arsenic: 0.04 - 0.5 fluorine: 2 - 11
...ushtino ...ttlement,	(Space heating, balneotherapy) *KamchatGeologKom - The National Reserve*	1.3 --	W	60 - 63 0.15 - 0.28	127 780	J_3-K_1, N_1, andesite-dacite, schist,	4.6 -7.0	arsenic: 0.04 - 0.18

... been identified as commercial and placed currently under conservation by the Russian Federal Authorities.

1	2	3	4	5	6	7
6. Nizhne-Ozernovskoe - Zaporozhe and Ozernovskii settlements region, southern Kamchatka	Space heating *RAO Gazprom,* 1983	--	W	87 0.03 - 0.08	548 940	N_{1-2}, tuffs, tuff-breccia
7. Ketkinskoe - 5 km S-E from town of Elizovo	Road de-icing, balneotherapy KamchatGeologKom 1990	12.2 --	W	60.5 --	341 1800	J3-K1, N1-QII-III tuffs, tuffites, basa
8. Nachikinskoe - 1.5 km N of Nachiki village, 60 km W of Petropavlovsk-Kamchatskii	Space heating, balneotherapy *Federation of Independent Trade Unions* 1950	1.5 1.5	W	n/a n/a	200 300	K_2, N_1, dacite, hornfels, grano-diorite, diorite
Resources under preparation for exploitation						
9. Verhne-Paratunskoe - 30 km S-W of Petropavlovsk-Kamchatskii, 10 km S of Termalnii settlement, upper Paratunka river valley	(Space heating), *RAO Gazprom,*	21.6 --	W	76.5 0.46 - 1.19	32 1670	P_{2-3}, N_1, tuffs, lava extensively fissure quartzose diorites
10. Mutnovskoe - 70 km S-W of Petropavlovsk-Kamchatskii, at the springs of rivers Falshivaia and Zhirovaia	(Energy Generation) *AOZT "KamTek"*	10.4 10.4	M 2.77	147 -320 0.7	255 873	P_3- N_1, tuffs, lava, tuffites
Resources under conservation						
11. Bolshe-Bannoe - 60 km W of Petropavlovsk-Kamchatskii, Bannoi river valley	(Space heating) *KamchatGeologKom - The National Reserve*[1]	-- --	M 0.67	150 -170 0.1 - 0.35	164 598	N_1-N_2, andesite, tu welded tuff
12. Pushtinskoe - 18 km N of Pushtino village, 70 km N-W of Milkovo settlement, Kashkan river valley	(Space heating, balneotherapy) *KamchatGeologKom - The National Reserve*	1.3 --	W	60 - 63 0.15 - 0.28	127 780	J_3-K_1, N_1, andesite dacite, schist,

[1] Indicating that the resource has been identified as commercial and placed currently under conservation by the Russian Federal Authorities.

1	2	3	4	5	6	7
Magadanskaia Oblast						
Resources under simultaneous development and exploitation						
13. Tavatumskoe - the N coast of Gizhiginskoi cove of the Shelehov bay, Ohotsk sea, 7.5 km from the mouth of Tavatum river, 70 km W of Evensk settlement	Space heating, balneotherapy *SevVostGeolKom*	-- --	W	n/a n/a	150 250	K_2, diorite, andesi
Chukotskii Avtonomnii Okrug						
Resources under simultaneous development and exploitation						
14. Lorinskoe - (Kukunskie outflows) - 28 km S-W of Lavrentia village, 12 km N-E of Lorino village	Space heating, balneotherapy *ChukotGeolKom*	-- --	W	60 - 80 n/a	natural outflow	K_1, granite, granosyenite
Sakhalinskaia Oblast						
Resources under preparation for exploitation						
15. Goriachii Pliazh - 7 km S-W from Uzhno-Kurilsk settlement, Kunashir island	Space heating *SahalinGeolKom*	3.5 --	M 0.8	70 - 105 1.8	50 300	N_1, Q, tuffs, tuffit
16. Okeanskoe (Kipiashtii) - 17 km S of town of Kurilsk, Irtup island	Energy generation SahalinGeolKom	3.3 --	M	250 - 320 1.6 - 3.2	400 1200	N2, Q, tuffs, tuffit andesite

	2	3	4	5	6	7	8	9
rces under simultaneous development and exploitation								
of bay, Ohotsk vatum river,	Space heating, balneotherapy *SevVostGeolKom*	-- --	W	n/a n/a	150 250	K_2, diorite, andesite	n/a	n/a
krug								
rces under simultaneous development and exploitation								
outflows) - 2 km N-E of	Space heating, balneotherapy *ChukotGeolKom*	-- --	W	60 - 80 n/a	natural outflow	K_1, granite, granosyenite	3.0 - 4.0	none
rces under preparation for exploitation								
W from ir island	Space heating *SahalinGeolKom*	3.5 --	M 0.8	70 - 105 1.8	50 300	N_1, Q, tuffs, tuffites	3.5 - 10	none
17 km S nd	Energy generation SahalinGeolKom	3.3 --	M	250 - 320 1.6 - 3.2	400 1200	N2, Q, tuffs, tuffites, andesite	2.7 - 7.5	none

Table 5

Geothermal Resources of Crimea[4]

Name of Drilling Site	Location	Water-bearing horizon depth in m	Mineraliz-ation of water in g/l	Stratum pressure in MPa	Water temperature at bedding ^0C	Flow rate at borehole in m^3/day
Novoselovskoe - consists of three parts: - Ilinka - Trudovoe - Sizovka	Crimea	700 - 1500	2-3 to 35	0.3 - 1.22	47 - 75(80)	690 - 2300
Severo-Sivashkoe	Crimea	1350 - 1750	26 - 32	0.4 - 0.8	52 - 74	1400

All of the above described resources are in a state of conservation as of the end of 1994.

4 As described by Burgazgeoterm of the Russian hydrogeological department (Head of Dept. Postnikov)

Table 6

Some Examples of Geothermal Prospective Drillings in the Ciscarpathian Region[5]

Location	Hydro-geothermal complex	Depth of temperature measurement, m	Flow-rate in m^3/day	$ÄT_1$[2] in ^0C	$ÄT_2$[3] in ^0C
Uzgorod - 1T	Paleozoic	1900	300 - 500	50.5	88.6
Uzgorod - 2T	Early Miocene	1350	46.8	--	76.15
Uzgorod - 2T	Early Miocene	1700	12.4	--	90.8
Uzgorod - 2T	Early Miocene	1940	214	--	97.6
Uzgorod - 2T	Early Miocene	1820	79.3	--	92.7
Uzgorod - 2T	Early Miocene	--	138 - 273	--	--
Uzgorod - 4T	Early Sarmat	1300	43	--	72.2
Uzgorod - 5T	Paleozoic	1012	40 - 90	--	65
Tereblia - 6	Tuffs	2350	500 - 900	86.5	96.5
Irshava -2	Cretaceous	3200	115	--	136.3
Beregovo 2T	Early Sarmat	--	346 - 691	44.5	--

[5] As per A.A. Andrusenko et al.

Bibliography

1. Proceedings of the United Nations Symposium on the Development and Use of Geothermal Resources. Pisa: 1970, vol. 1-3

2. Proceedings of the Second United Nations Symposium on the Davelopment and Use of Geothermal Resources. San Francisco; Lawrence Berkeley Laboratory. 1975, vol. 1-3.

3. Trudy pervogo vsesoyuznogo soveshchaniya po geotermicheskim issledovanlyam. Moscow: AN USSR, 1961, vol. 2.

4. Geotermicheskiye issledovaniya i ispolzovaniye tepla Zemli. Trudy vtorogo soveshchaniya po geotermicheskim issledovaniam v SSSR. Moskow: Nauka, 1966.

5. Regionalnaya geotermiya i rasprastranyeniye termalnykh vod v SSSR. Trudy vtorogo soveshchaniya po geotermicheskim issledovaniyam v SSSR; Moskow. Nauka, 1967.

6. Izucheniye i izpolzovaniye glubinnogo tepla Zemli. Moscow. Nauka, 1973.

7. Berman, E. R. Geothermal Energy. Park Ridge, N.J. Noyes Data Corporation, 1975.

8. Nurshanov, V. A., and B. M. Drozd. Ispolzovaniye glubinnogo tepla Zemli v narodnom hazyaystve. In: (6).

9. Fomin, V. A., et al. Geothermal Resources of the USSR and Their Geologic-Economic Subdivision. In: (2), vol. 1.

10. Mavritskiy, B. F. and V. G. Khelkvist. Exploration for Thermal Water Fields in the USSR. In: [2], vol. 1.

11. Edwards, L. M., et al. Handbook on Geothennal Energy. Houston: Gulf Publishing Company, 1982.

12. Frolov, N. M. et al. Metodicheskive ukazaniya po izucheniu termalnih vod v skvazhinah. Moscow; Nedra. 1964

13. White, D. E. Geothermal Energy. U.S. Geolgical Survey Circular 519, 1965.

14. Bogorodistkiy, K. F, Vysoko-termalnyie vodi v SSSR. Moscow: Nauka, 1968.

15. McNitt, J. R. The Geologic Environment of Geothermal Fields as a Guide to Exploration. In: (1), Rapporteur.

16. Mavritskiy, B. F., et al. Resursi termalnih vod v SSSR. Moscow: Nedra, 1975.

17. Vadatskty, Yu. V. Burenie neftianih i gazovih skvazhin. Moscow: Nedra, 1978.

18. Polevoy, S. L. K voprosu rayonirovaniya plastovykh vodonapornykh sistem dlya otsenki perspektiv ispolzovaniya termalnih vod. In: Geologiya, burenie i razrabotka gazovih mestorozhdenii Predkavkazia. Moscow: Nedra, 1967.

19. Tishlyar, I. S., and 8. L, Polevoy. Metod ekonomicheskoy otsenki ekspluatatsii i ispolzovaniya geoternalnogo mestorozhdeniya. In (18).

20. Polevoy, 3. L., I. P. Kovshov, and I. L. Lumelakly. Obrabotka rezultatov opitnih vipuskov termalnih vod iz skvazhin. In: Razvedka i Ohrana Nedr 11, 1968.

21. Polevoy, S. L., and I. P. Kovshov. Otsenka prognoznih ekspluatatsonnih zapasov termalnih vod v uslovliah vodonapornih sistem (na primera Predkavkazia). Izvestia visshih uchebnih zavedenii. Seriya "Geologiya i Razvedka" 10, 1968.

22. Polevoy, S. L., V. I. Savchenko, and V. V. Lisovin. Opredelenlye gidrodinanlcheskikh parametrov po dannim oprobovaniia skvazhin. Razvedka i Ohrana Nedr 10, 1972.

23. Lumeiskiy, I, L., and S. L. Polevoy. Noviie danniie o zakonomernostiah razmeshchenia i gidrogeologii nekotorih mestorozhdenii termaltnih vod Tsentralnogo I Vostochnogo Predkavkazia. Trudi po geologii i poleznim iskopaemim Severnogo Kavkaza. 13, 1972.

24. Polevoy, S, L. Opredelenlie koeffitsienta teploprovodnosti gornih porod v yestestvennih usloviyah. Izvestiia Visshih uchebnih zavedenii. Serlya "Geologia i Razvedka" 10, 1972.

25. Polevoy, S. L., and I. P. Kovshov. Poiskovo-razvedochniie rabotiy na termalniie vody v usloviyah plastovih vodonapornih sistem (na primere Vostochnogo Predkavkaz'i). In: (6).

26. Polevoy, 8. fi. Izsledovania i otsenka mestorozhdenii ternalnih vod v usloviah plastovih sistem na primere Vostochnogo Predkavkazia (Avtoreferat kandidatskoi dissertatsii). Novocherkassk: 1969.

27. Polevoy, S. L., I. P. Kovshov, and V. G, Senkevlch. Obosnovanie ploshchadei dlia burenia geoternalnih skvazhin na teritorii Vostochnogo Predkavkaziia. SevKavNIIgaz Library, Stavropol: 1966.

28. Suharev, G. M. Gidrogeologia neftianih i gazovih mestorozhdenii. Moscow: Nedra, 1971.

29. Polyak, B. G. Geotermicheskie obennosti oblasti sovrenennogo vulkanizma (na primere Kamchtki). Moscow: Nauka. 1966.

30. Itenberg S. S. Izuchenie nefte-gazonosnih tolshch promslovo-geofizicheskimi i geologicheskimi metodaini. Moscow: Nedra, 1967.

31. Litvinov, A. A., and A. F. Blinov. Promislovvie issledovaniia skvazhin. Moscow: Nedra, 1964.

32. Altshul, A. D. Gidravlichskie poteri na trenie v truboprovodah. Moscow: Gosenergoizdat, 1963.

33. Bochever, F. M., and N. N. Verigin. Metodicheskoe posobie po raschetam ekspluatatsionnih zapasov podzennih vod dlia vodosnabzheniia. Moscow: Gosstroyizdat, 1961.

34. Bochever, F. M. Rascheti ekspluatatsionnih zapasov podzemnih vod. Moscow: Nedra, 1968.

35. Maksimov, V. A. O neustanovivshemsya pritoke uprugoy zhidkosti k skvazhinam v neodnorodnoy srede. Prikladnaia matematika i tehnicheskaia fizika 3, 1962.

36. Guseyn-Zade. M. A. Osobennosti dvizhenia zhidkosti v neodnorodnorm plaste. Moscow: Nedra, 1965.

37. Shchelkachev, V. N. Razrabotka neftevodonosnih plastov pri uprugom rezhime. Moscow: Gostoptekhizdat, 1959.

38. Bindeman, N. N., and F. M. Bochever. Regionalnaia otsenka ekspluatatsionnih zapasov podzemnih vod. In; Sovetskaia Geologiya 1, 1964.

39. Krashin, I. I., and D. I. Peresun'ko. Otsenka ekspluatatsionnih zapasov podzemnih vod metodom nodelirovaniya. Moscow: Nedra, 1976.

40. Healy, I. Pre-Investigation Geological Appraisal of Geothermal Fields. In: (1), vol. 2 (part 1).

41. Gildenson, M. I. K voprosu ob ohlazhdenii nefti v stvole skvazhine pri yeye dvizhenii ot zaboya k ustiiu. In: Trudy Kuybyshevskogo NII neftianoy promishlennosti 11, 1960.

42. Goleva, T.A. Ed. Gidrogeologiia SSSR. Kamchatka, Kurilskie i Komandorskie ostrova. Moscow: Nedra, 1972.

43. Galvina, G.B., and F. A. Makarenko. Geothermal Map of the USSR. In: (2), vol. 2.

44. Lyalko, V. I. Balans termalnih vod Zakarpatiia i prognozirovaniye ih zapasov In; (6).

45. Beder, S. A. Resursy termalnih vod Srednei Azii. Shema ih rasprostraneniia i puti ratsionalnogo ispolzovaniia. In: (6).

46. Grebenshchikova, T. B., G. V. Kulikov, and L. H. Safayeva. Gidrotermalniie resursi Uzbekistana. In: (6).

47. Mavritskiy, B. F., and G. K. Antonenko. Prognozniie ekspluatatsionniie zapasi termalnih vod Zapadno-Sibirskogo artezianskogo basseina i perespektivi ih osvoieniia. In; (6).

48. Mizinov, N. V. Tobolskiie mestorozhdeniia termalnih vod i ikh prakticheskoie ispolzovaniye. In: (4).

49. Lysak, S. V. Geotermicheskie uslovia i termalnie vodi yuzhnoi chasti Vostochnoi Sibiri. Moscow: Nauka, 1968.

50. Teplo Zemli I ego izvlecheniye. Kiev: Naukova Duma, 1974.

51. Naboko, S.I. Pauzhetskiie geyzeri. In; Biuletin vulkanologicheskii stantsii. 22, 1954.

52. Dunichev, V. M. Parogidrotermi Goryachego Pliazha I perespektivi ispolzovaniia termalnih vod Kurilskih ostrovov. In: (6).

53. Dvorov, I. M. Geotenrmalnaia energetika. Moscow: Nauka, 1976.

54. Vakin, Ye. A. Gidrogeologia sovrenennih vulkanicheskih struktur I gidroternalnie sistemi yugo-vostoka Kamchatki (Kandidatskaia dissertatsia). Moscow: AN USSR Institute of Geology, 1968.

55. Sanoylenko, P. I., V. N. Popov, and G. Z. Avdeyeva. Rezultati issledovaniia termalnih vrod Kamchatki i perspektivi ih ispolzovaniia. In: (6).

56. Gavronskly, A. A. Ekonomicheskaia effektivnost parovodianih skvazhin Pauzhetskogo mestorozhdeniia. In; (4).

57. Kutateladze, S. S. Nauchniie i prakticheskie meropriiatiia po razvitii geoternalnoy energetiki v Sovetskom Soiuze. In; (4).

58. Kozlov, B. K. Energeticheskoye ispolzovaniye terrnalnih vod. In: (6).

59. Makarenko, F. A., and V. I. Kononov. Gidroternalnie raioni SSSR i perspektivi ih osvoyeniya. In: (6).

60. Gadzhiev, A. Skovannaia energiia. Pravda, July 5, 1981.

61. Kozlovskiy, Ye. A, Noviie rubezhi geologov. In: Razvedka i Okhrana Nedr 1, 1981.

62. Dobrinin, P. A., and P. A. Kulik. Dalnieshee usilenlie rahot-- glavnaia zadacha gidrogeologov. In Razvedka i Okhrana Nedr 6, 1981.

63. Natanov, Kh. Kh., and P. A. Kulik. Stabilizatsonnaya obrabotka ternalnoi vodi v vihrevih reaktorah. In: Geotermicheskie izsledovaniia v Dagestane i voprosi prakticheskogo ispolzovania tepla zemli. Makhachkala: Dagestan AN SSSR, 1970.

64. Mavritskiy, B. F., B. A. Lokshin, and A. V. Volfenfeld. Prognoznie zapasi termalnih vod SSSR, vozmozhnie obiemi vnedrenia geoternalnogo teplosnahzheniia. In: (6).

65. Sivashinskiy, I. I. Ispolzovamiie termalmih vod dlia teplosnabzheniia zashchishchennogo grunta. In: (6).

66. Carison, R. H. Utilizing Nuclear Explosives in the Construction of Geothermal Power Plants. In: Proceedings of the Second Plowshare Symposium. UCRL-5677, 1959.

67. Kozlovskii. Ye. A. Vsemirnii Forum Geologov. In: Nauka i Zhizn 10, 1984.