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Present State of Development of Geothermal Resources in Czechoslovakia

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ABSTRACT

In Czechoslovakia thermal waters are found in the Czech Socialist Republic (CSR) and Slovak Socialist Republic (SSR). Geological research to exploit their energy in the CSR is in the planning stage; in the SSR it has been performed since 1971. Hydrogeothermic evaluation of the Slovak territory resulted in the discovery of about 20 prospective areas and structures (Franko, 1972). It is possible to determine the aquifer temperatures of new thermal water resources in the Slovak area to 100°C by drill holes down to a depth of 2000 to 4000 m, and rarely to 200°C by deep drill holes to a depth of 4000 to 6000 m. The gain may possibly be 1 to 2 m^3 of thermal waters. At present, two structures are being investigated. Two drill holes were made in Triassic carbonates. The yield of free outflows from both drill holes is about 50 l/sec and temperatures are 40 and 80°C. Four drill holes were in Pliocene sands. The yields of outflows in the individual drill holes are up to 11 to 22 l/sec, and temperatures of 52 to 94°C.

To coordinate the research and exploitation of geothermal resources a Coordination Commission of the Slovak Government was established, headed by the Vice-President. Prospective development of geothermal resources in Czechoslovakia was judged by UN expert G. R. Robson in 1963. Cooperation with the UN commenced in 1975 by a study trip of leading economic executives to Iceland and to the USA.

INTRODUCTION

It is generally known that among geothermal resources are dry vapor, wet vapor from overheated thermal water, and thermal water. The first two resources are mainly exploited for generating electrical energy, and the third, mostly for spatial heating and in agriculture, industry, balneology, and recreation.

In Czechoslovakia at present there are actual possibilities for finding new thermal water and overheated thermal water resources. The existing hydrogeothermic data, for example, on the East Slovakian Neogene basin point out possible exploitation of the heat of the geothermal field by forced circulation by drill holes. In this area thermal waters occur to a limited extent due to the lack of favorable collectors, but the value of the heat flow is about 2.5 heat flow units (HFU) and temperature at a depth of 3000 m is about 150°C.

THERMAL WATERS IN CZECHOSLOVAKIA

In Czechoslovakia thermal waters are found in both the Czech Socialist Republic (CSR) and the Slovak Socialist Republic (SSR). The territory of the Czech Socialist Republic consists of the Bohemian massif and part of the West Carpathians (eastern Moravia). During the formation of the West Carpathians (part of the Alpine system) by the end of the Mesozoic and during the Cenozoic, the Bohemian massif (part of the European Variscian system) was only germanotypically destroyed.

In the Bohemian massif thermal waters are restricted to only the northern part of the massif that was most destroyed by germanotypical Saxon tectonics (Hynie, 1963). The waters are restricted to crystalline rocks, Permian porphyries, and sandstones of the Bohemian Cretaceous platform. The province of alkaline waters is restricted to the Bohemian massif. There are about 10 localities of thermal waters with yields totalling 150 l/sec. Temperatures of natural springs are up to 70°C. The heat power of thermal waters in the Bohemian massif is up to 20×10^6 kcal/hr (Franko, 1964).

Thermal waters in the West Carpathians are mostly associated with their inner zone occupying a predominant part of the Slovak territory (Mahel', 1952; Hynie, 1963). Thermal waters are mostly restricted to Triassic limestones and dolomites of autochthon and nappes, and partially to sands of the Neogene basins, particularly to the Danube basin. Thus a province of earthy gypsum waters, with some alkaline and alkaline-brackish waters is associated with the West Carpathians. There are about 60 localities of thermal waters with yields totalling about 700 l/sec. Maximum temperature of the natural springs is 70°C. The heat power of thermal waters in the West Carpathians is up to about 60×10^6 kcal/hr (Franko, 1964). Both in the West Carpathians and in the Bohemian massif, thermal waters are utilized primarily in balneology, and some in heating. Prospection for new thermal water resources to exploit their geothermal

energy commenced in 1971 in Czechoslovakia. At present the research of geothermal resources in Czechoslovakia is performed by Dionýz Štúr Institute of Geology (GÚDŠ) in Bratislava and by the Central Geological Institute (ÚÚG) in Prague.

DEVELOPMENT OF RESOURCES IN CSR

Geological research of geothermal resources in the Czech Socialist Republic, with respect to exploitation of their geothermal energy, is still in the stage of expanding studies and projects. For the first time the new geothermal resources in the CSR are mentioned in a study concerning possible occurrences of hyperthermal waters in Czechoslovakia (Franko and Jetel', 1973, unpub. manuscript). This study was done on the instigation of the Czech Geological Office (ČGÚ) and the Slovak Geological Office (SGÚ) as information for the UN Division of Resources and Transport in New York. It served as a basis for the project concerning prospection for resources of geothermal energy in the CSR (Jetel', 1973). A brief account of the project is included in a paper about the prospects of exploitation of resources of geothermal energy in the CSR (Jetel', 1975). In the project four prospective areas of possible new geothermal resources are considered, with their aquifer temperatures of 26 to 64°C (Fig. 1), to be found by drill holes to a depth of 250 to 1400 m: (1) the Děčín thermal area; (2) the Mělnik geothermal anomaly; (3) the area of the Hronov-Poříč fault; and (4) the eastern margin of the Doupovské hory mountains. The most likely area for high temperature resources at a depth of about 4 km and more, is the Ohárec rift between the Doupovské hory and the Labe River. The results of the project are published in a paper dealing with the heat flow in the Bohemian massif and its relationship to deep structures (Čermák et al., 1968) and in a paper concerning heat flow in Czechoslovakia and its relation to some geologic features (Čermák, 1968). Later results are published in a paper treating the relationship between heat flow and deep structure in the Czechoslovakian territory (Čermák, 1971).

DEVELOPMENT OF RESOURCES IN SSR

Solving the Problem

In 1970 a sufficient amount of basic data on the deep structure of the West Carpathians (Ďuratný et al., 1965, 1968; Fusán et al., 1971), on geothermal conditions (Čermák, 1968), and on thermal waters (Franko, 1964, 1970a, 1970b) had been collected in Slovakia to facilitate judging the possibilities of finding new resources of geothermal energy. The possibilities of finding new thermal water resources of temperatures higher than those in natural springs were pointed out for the first time by O. Franko (1964) in a work on the research of thermal waters in Slovakia. The best possibilities in the inner depressions, and particularly in the deepest parts of reservoirs are emphasized. A prospective place is the Vienna basin where the surface temperature of water was 82°C in the oil drill hole Lakšśrska Nová Ves-2. The water comes from Triassic carbonates at a depth of 1900 m. Finally, there are Tertiary sediments, mainly in the Danube lowland, where in the oil drill hole Diakovce-1 at a depth of 2500 to 3000 m waters were found with an aquifer temperature of 138°C.

Later on, at Dionýz Štúr Institute of Geology studies on this theme were expanded for the State Commission on Technology (Franko, 1966 unpub. manuscript), for the UN (Franko et al., 1968 unpub. manuscript), for the Institute of Tourism and Travelling (Franko, 1969 unpub. manuscript), for the Slovak Geological Office, and for the Slovak Government Authorities (Franko, 1971 unpub. manuscript). Another study concerning all of Czechoslovakia was expanded for the UN. (Franko and Jetel', 1973, unpub. manuscript).

Data concerning new geothermal resources, obtained during 1964 to 1970, are published by O. Franko in works concerning the Bojnice thermae (1970a); the importance of information on hydrogeological structures and geothermal conditions with respect to finding new thermal water resources with low enthalpy in Slovakia (1970b); new data on geothermal conditions in the West Carpathians and their significance for the study of deep geologic structures and of thermal waters (1971a); and about possible exploitation of terrestrial heat in Slovakia by finding new resources of hyperthermal waters (1972).

Most important was the statement that geothermal conditions in the Slovak territory, when compared with world or European conditions, are quite favorable. This indicates that greater amounts of warmer waters may be gained here than in other areas with the same hydrogeological conditions. For this reason prospective areas and structures were chosen for new resources of geothermal energy.

The research on the resources has been performed since 1971 at Dionýz Štúr Institute of Geology in Bratislava within the state project "Basic Research of Spatial Distribution of terrestrial Heat and of Geothermal Resources in the West Carpathians (SSR)." Projects elaborated in 1970 (Franko, et al., unpub. manuscript) and in 1974 (Franko, et al., unpub. manuscript) served as a basis for solving the task quoted. The task is planned to be performed in the years 1971 to 1980 with further prospects for 2000. It involves solving two closely connected tasks:

1. The investigation of spatial distribution of terrestrial heat is carried out by the "Geofyzika," an organization in Brno, with a subsidiary in Bratislava.
2. The investigation of geothermal resources is performed at Dionýz Štúr Institute of Geology in Bratislava.

Data about heat activity of the territory and about its geothermal field, resulting from the research of terrestrial heat, are a part of the basic data required for the research and evaluation of geothermal resources.

Prospective Areas and Structures

At the beginning of the research, the entire Slovak territory was evaluated with respect to possible new finds of resources of geothermal energy. About 20 areas and structures were chosen as prospective sources (Fig. 1). Their number and potential is judged on the basis of existing general and regional information about thermal waters and by the degree of geological research performed so far in the respective areas and structures. (Franko, 1972):

1. The Central depression of the Danube basin is regarded as the most likely structure (Franko, 1972). It was geologically investigated by oil drill holes. The high potential of the depression is due to its large spatial extension, a dishlike

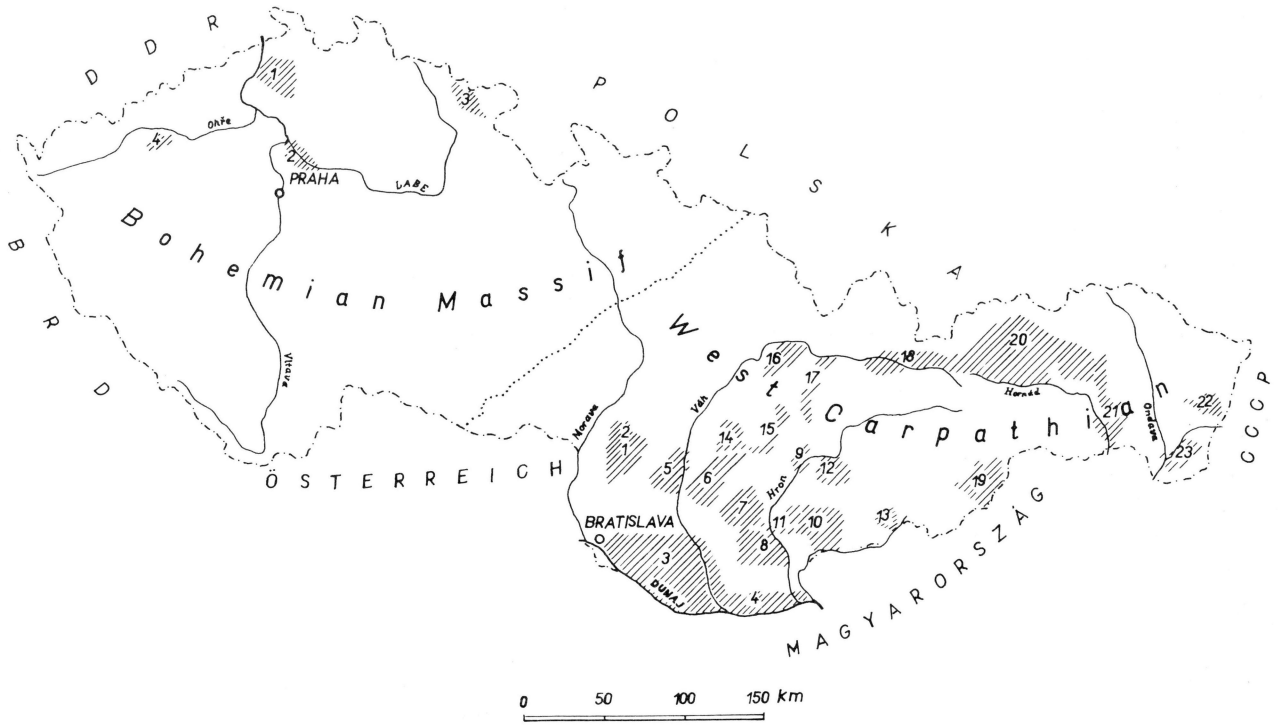

Figure 1. Prospective areas in Czechoslovakia for exploration of new geothermal resources. *Bohemian Massif:* (1) Děčín thermal structure; (2) Mělník geothermal anomaly; (3) area of the Hronov-Poříč fault; (4) eastern periphery of the Doupovské hory mountains. *West Carpathians:* (1) Lakšár elevation; (2) Šaštín elevation; (3) Central depression; (4) Komárno elevated block; (5) Trnava bay; (6) Topol'čany bay; (7) Komjatice depression; (8) Levice block; (9) Žiar depression; (10) Krupina depression; (11) Čajkov-Pukanec depression; (12) Bacúrov depression; (13) Horné Strháre-Trenč graben; (14) Bánovce depression; (16) Rajec depression; (17) Turiec depression; (18) Liptov depression; (19) Rimava depression; (20) Spiš depression; (21) Košice depression; (22) Humenné range; (23) Beša-Čičarovce structure.

form, and to the many Pliocene sandy collectors mutually interconnected vertically and horizontally with their thermally favorable depth, and their particularly porous permeability, granting positiveness of almost all drill holes.

2. As regards potential, the second place belongs to some areas consisting of Triassic carbonates. These structures were also investigated by oil and geological drill holes. The structures are the Lakšár and Šaštín elevations in the Vienna basin, the Komárno elevated block, the Trnava bay, and the Levice block in the Danube basin. This group also comprises some inner depressions like the Horná Nitra, Rajec, Turiec, and Liptov depressions, and Central-Slovakian neovolcanites like the Horné Strháre-Trenč graben and perhaps also the Žiar depression.

3. In the third group other areas and structures are included, namely the Topol'čany bay, the Komjatice depression in the Danube basin, the Krupina depression, the Čajkovo-Pukanec depression, and the Bacúrov depression in the Central-Slovakian neovolcanites. Among inner depressions belong the Bánovce, Spiš, and Rimava depressions and, from the East-Slovakian basin, the Košice depression, the structure Beša-Čičarovce, and the Humenné range.

In the areas and structures chosen, new thermal water resources with their aquifer temperatures mostly up to 100°C may be found by drill holes to depths of 2000 to 4000 m; those with occasional temperatures of 200°C may be found by drill holes to depths of 4000 to 6000 m. At present, drill holes to 4000 m are predominantly planned. Drill holes to 6000 m are only planned to be collectors at such depths. The yield of free outflow in one drill hole from Triassic carbonates is up to 50 l/sec and from Tertiary collectors, up to 20 l/sec. It is expected to gain the minimum of 600 l/sec of thermal waters with their mean temperature of 80°C (Franko, 1972). According to the latest data it may increase to 1 to 2 m^3/sec of new thermal water resources.

Progress of Research

Geological research of new resources of geothermal energy is performed gradually in the individual areas and structures. The research follows the evaluation of a prospective structure. An evaluating report comprises all geological, tectonical, geophysical, hydrogeological, hydrochemical, and geothermic data. They are interpreted with respect to realization of the basic hydrogeothermal research—prospection for new geothermal resources and their exploitation. On the basis of the results obtained, there are plans for geothermal drill holes and other operations necessary for investigation of a hydrogeologic structure and geothermal resources. So far the following structures have been evaluated in such a way: (1) the Žiar depression; (2) the Komárno elevated block in the Danube basin (Franko and Zbořil, 1972, unpub. manuscript); (3) the Central depression (Franko and Gaža, 1972, unpub. manuscript); (4) close surroundings of Bratislava (Franko and Zboři!, 1972, unpub. manuscript); and (5) a favorable structure in the Liptov depression (Franko, et al., 1974, unpub. manuscript).

Results

Since 1971 research has been performed on geothermal resources of the Komárno elevated block, on the close surroundings of Bratislava, and on the Central depression in the Danube basin. Research on resources in the close surroundings of Bratislava is expected to finish in 1976; in the Komárno elevated block, in 1977; and in the Central depression in 1980. Research in other areas and structures is planned for the years 1980 to 2000.

Komárno elevated block. The Komárno elevated block extends into southern Slovakia approximately between Komárno and Štúrovo. Evaluation of the structure proved that natural thermal springs are associated with partial elevations in which Triassic carbonates are shallow below Tertiary sediments to 300 m. In addition, there are other elevations in which no natural springs issue. Geothermal drill holes were made in the individual elevations, and one drill hole in the depression. The purpose of the drill holes is to ascertain the presence of thermal waters directly in the Triassic carbonates. The depth of the drill holes is between 200 and 2000 m. The drill holes are situated to catch water in the carbonates on faults or caverns and in a minute system of fissures in dolomites. Four drill holes were planned. One of them has been completed, two are being drilled, and one has been designed. Results of drill hole FGŠ-1 Štúrovo are in Table 1.

Central depression. The Central depression of the Danube basin is in southwestern Slovakia between Bratislava and Komárno. It is dish-shaped, with its center near Gabčíkovo in the area of the Danube, where the maximum thickness of Pliocene sediments is about 3500 m. Approximately one-half of the depression is in Slovakia and the other half is in Hungary. Evaluation of the structure showed no isolated sandy horizons; it is a continuous reservoir of thermal waters (Franko and Gaža, 1972, unpub. manuscript). More details about the structure are in the Proceedings of the Second UN Geothermal Symposium, under the title "Geothermal Resources in the Central Depression of the Danube Basin in Slovakia" (Franko and Mucha, 1976).

Current research consists of eight geothermal drill holes to a depth of 1500 to 3500 m. Six of them are situated in two mutually perpendicular profiles, approximately northwest-southeast and northeast-southwest-striking. The other two drill holes are out of the profiles—one in the southwestern part, another in the eastern part of the depression.

Coreless drilling of the rotary system with mud was done. Sediments are sampled at each 100 m to a length of 5 m, but the spacing is reduced if necessary. Collectors are tested at approximately 500 m intervals, mutually correlatable. In drill holes to a depth of about 1500 m, collectors are tested at an interval of 800 to 1500 m by a filter with a sieve of a 7 in. profile, prepared on the surface. This technique is chosen because sands are only slightly diagenetically compacted to the depth of 1500 m, and thus sanding of drill holes may be prevented. In deeper drill holes collectors are opened by jet perforation of cemented drill string of a 7 in. profile. In the lowest interval collectors are tested by a filter of a 4-1/2 in. profile, prepared on the surface and mounted loosely. When the entire drill hole is tested for permanent exploitation or observation, (depending on the technological state of the drill hole), an optimal interval is chosen according to the test results from the individual intervals—temperature and chemistry of water, and yield of inflow. The results were obtained from drill holes FGB-1 and FGB-1A in Chorvátsky Grob, FGS-1A in Senec, and FGT-1 in Topoľníky.

Besides research drill holes, there are two producing drill holes in the Central depression, in Dunajská Streda and in Čalovo (Gaža and Holéczyová, 1971, 1972, unpub. manuscripts) and one producing drill hole in the Levice block in Podhájska. During the investigation of mineral waters in the West Carpathians, thermal water was found by a borehole in Bešeňová in the Liptov depression. The results of all the drill holes mentioned are in Table 1. The table shows that about 30×10^6 kcal/hr of geothermal energy were obtained by geothermal drill holes realized in the years 1971 to 1974, which is by 30% more than the heat power of existing thermal waters in the Czech Socialist Republic.

Table 1. Geothermal results from drill holes.

Locality drill hole	Depth of drill hole (m)	Inflow from interval (m) from	to	Collector	Thickness of open Collectors	Yield of outflow (l/sec)	Surface temp. water (°C)	Exploitation temp. water (°C)	Heat power (kcal/hr) $\times 10^6$	M g/l	Chemical type of water = 20 mval % of ions
Štúrovo		77.5	87	dolomites							
FGŠ-1	210.5	126.5	128.5	limestones	11.5	50	40	20	3.6	0.7	HCO_3-SO_4-Ca-Mg
Bešeňová											
BEH-1	448.5	419.6	420.6	dolomites	1	22	34	14	1.1	3.2	SO_4-HCO_3-Ca-Mg
Chorvatský Grob											
FGB-1	1231	971.5	1209.7	clastics	171.2	2.2	46	26	0.2	1.8	Cl-HCO_3-Na
Chorvátsky Grob											
FGB-1A	500	275.4	454.7	sands	31.1	4.2	22			0.66	HCO_3-Na
Senec											
FGS-1A	1500	910.0	1370.0	sands	156	15.0	52	32	1.7	8.0	HCO_2-Cl-Na
Topoľníky		2037.0	2487.5	sands	116.5	11.0	90.0			3.9	HCO_3-Cl-Na
FGT-1		1394.0	1910.0	sands	76.0	15.3	67.0			1.4	HCO_3-Na
		1394.0	2487.5	sands	192.5	22	76	56	4.4	1.9	HCO_3-Na
Dunajská Streda											
DS-1	2500	2183.0	2474.0	sands	72	16.2	92	72	4.2	6.9	Cl-HCO_3-Na
Čalovo											
ČA-1	2502	2289.0	2460.0	sands	70	11.2	92	74	3.0	5.1	Cl-HCO_3-Na
Podhájska				limestones							
PO-1	1900	1157.0	1900.0	dolomites	743	53	80	70	1.20	19.6	Cl-Na
								Total:	30.2		

Geothermal Research

In the investigation of spatial distribution of terrestrial heat in the West Carpathians during 1971 to 1974, "Geophysics," a subsidiary in Bratislava, oriented their work toward interpretation of former geothermic measurements performed by ČND Hodonín and GP Spišská Nová Ves on drill holes completed by geological organizations. Records were kept on 120 drill holes and about 500 samples of aquifer temperatures of water and oil. In addition, new exact measurements were performed in 17 drill holes completed by GÚDŠ, GP Spišská Nová Ves, and Nafta Gbely. Interpretation of the measurements resulted in general geothermic characteristics of the West Carpathians (Marušiak and Lizoň, 1973, unpub. manuscript).

In connection with technological development some theoretical problems were solved concerning calculation of the heat flow in sedimentary basins (Marušiak and Lizoň, 1973, unpub. manuscript). Measurements were introduced of heat conductivity of rock samples by the method of divided bar. Also introduced at the same time was the problem of measuring thermal properties of rocks by the nonstationary method, particularly suitable for measuring disintegrating rock samples.

Beginning in 1972 the network of observation geothermic drill holes was developed on the basis of the respective drill holes completed by geological organizations. In 1977 geothermic observation drill holes of small diameter will be made in areas of exploitation of geothermal resources.

The most important result of the previous research is information about the widely variable heat activity and geothermal field of the West Carpathians (Marušiak and Lizoň, 1973, unpub. manuscript). Heat activity decreases toward the outer zone. While in the inner zone the heat flow varies between 1.3 and 2.7 HFU, in the outer zone it ranks from 1.3 to 1.5 HFU. The heat activity of the Czechoslovak territory decreases further toward the Bohemian massif. There it varies within 1.1 to 1.4 HFU (Čermák, 1968).

FINANCIAL, LEGAL, INSTITUTIONAL ASPECTS

At present, the prospection for and attestation of new geothermal resources in Slovakia are aimed at areas without natural or artificial issues of medicinal thermal waters. The purpose is to find new geothermal resources for economical, nonmedicinal exploitation. In some cases the new resources may also be utilized for medicinal purposes (for example, iodine-bromine thermae).

Expenses of the geothermal research in Slovakia are covered by financial means from state.

The main purpose of the research is to get information about the position and about the geothermal, hydrotechnical, and physical-chemical parameters of the resources in the areas mentioned to do a balance-estimate of supplies, and to suggest protection.

This stage of the work will be followed by exploitation of drill holes in the individual areas of the projected complex of geothermal resources, and by provision for their protection. Expenses for the operations will be covered by the organizations which will exploit the resources. At present, the exploitation drill holes are not finished. Exploitation of thermal waters brought to the surface by research drill holes and by formerly completed exploitation drill holes is not fully developed because of the beginning state of development and insufficient experiences.

In regard to the speed of work and expenses, two research drill holes will be completed each year to a depth of about 1500 m; one to two will be drilled to an approximate depth of 2500 m in basin areas; and two will be drilled, to a depth of 200 to 650 m in the basin areas or in others. In the basin areas the expenses for a research drill hole to a depth of 1500 m are about 5 million Cz. crowns; and for a research drill hole to a depth of about 2500 m, approximately 8 million Cz. crowns—including laboratory, geophysical, and geological operations. Realization of a drill hole in different geological conditions, in harder rocks, will perhaps cost twice as much. Expenses for an exploitation drill hole will be approximately half as much as for a research drill hole.

In Czechoslovakia we do not have enough experience with exploitation of thermal waters for purposes other than balneological. In Slovakia we started building glasshouses and plastic houses to be heated by thermal water. Cooled thermal water is utilized or prepared for utilization in swimming pools and recreation resorts. Solving technical problems is mostly based upon experience from neighboring socialist countries. At present the exploitation of medicinal thermal waters of temperatures up to 69°C is complex in the spa Piešťany. The waters are directly utilized in balneological treatment; by means of heat exchangers they are used for heating of buildings, for washhouses, and for the supply of warm water into hotels and swimming pools. Warmed water together with cooled thermal water entering heat exchangers is supplied to swimming pools. The amount of 4 Gcal/hr of the total 11 Gcal/hr of energy needed is gained from thermal medicinal waters at one-fifth of the expenses of other sources. Actually this is the first attempt at complex exploitation, and the existing data cannot be applied for other localities.

In connection with gradually increasing amounts of thermal waters brought to the surface by the research geothermal drill holes, the economical valuation of geothermal resources is necessary. Studies and projects are under way for the exploitation of geothermal resources (presented in Table 1) at Dunajská Streda, Čalovo, Podhájska, Topoľníky, Senec, Chorvátsky Grob, and Štúrovo. The purpose is to utilize the resources in agriculture, in recreation and, in one case, in medicine. Technical-economical evaluations (Papež et al., 1974) showed that all the prospective areas of Slovakia mentioned offer the possibility of gaining economically advantageous thermal energy from geothermal resources. Expenses for the thermal energy should be lower or the same as when using traditional fuels. The purity of the atmosphere however, was not considered in the economical evaluation.

G. R. Robson, (1974, unpub. manuscript) also mentioned the effectiveness of development of geothermal resources in the Central depression of the Danube lowland, especially in the vicinity of Bratislava. The experience from the exploitation of geothermal resources in Slovakia, so far for a single purpose, agricultural production (glasshouses, plastic houses), in Dunajská Streda, Čalovo, and Topoľníky, resulted in indicating the economic advantage of such exploitation. More detailed data cannot be presented as yet, because the economic indexes have been in use for only a short time.

A technically complicated problem influencing the effec-

tiveness and possibilities of exploitation of geothermal resources is mineralization of waters. In most cases it causes formation of incrustation and requires measures to limit or prevent this. Another problem is removing highly mineralized, cooled waters. As yet the only economically possible manner of liquidation of such waters is by discharging them into surficial streams at the maximum increase of temperature in a stream by 5°C (to the maximum of 26°C). At 355 day's discharge in a stream, the following indices must not be surpassed: mineralization, 1000 mg/l (in waterworks streams, 500 mg/l); total hardness, 46°N; chlorides, 400 mg/l; sulfates, 300 mg/l; calcium, 300 mg/l.

The qualitative and quantitative level of exploiting thermal water in balneology in Czechoslovakia is quite high. Utilization of thermal waters for other purposes is a new problem. For thermal waters the legal norms of the Ministry of Health are valid. In accordance with the norms, waters may be proclaimed natural medicinal resources if: (1) their temperature surpasses 25°C; (2) their mineralization is at least 1 g/l; (3) their gas contents are at least 1 g/l CO_2, at least 1 mg/l H_2S, and radium emanation is μ37 Ci/l; (4) the content of other components are at least 5 mg/l iodine, at least 0.7 mg/l arsenic, at least 10 mg/l iron; and (5) they contain other components with pharmacodynamical effects. It is compulsory for all organizations to inform the Inspectorate for spas and springs of the Ministry of Health of Slovakia about all finds of such waters. The Inspectorate will register the finds and decide about their exploitation and about the manner of prospection.

The exploitation of geothermal resources requires a broad cooperation. For this reason, it is directed by the Coordination Commission of the Slovak Government for the exploitation of thermal underground waters.

The prospection alone, the testing of geothermal resources, conveying them to the surface, service at drill holes, and preparation of basic data for protection of the resources are under the direction of the Slovak Geological Office and of its subordinate organizations.

Protection of geothermal resources, like that of natural medicinal resources, is planned and executed according to the legal norms of the Slovak Ministry of Health. The protection is provided by appointing protective zones and by protective measures determined by the Inspectorate for spas and springs of the Slovak Ministry of Health in accordance with a suggestion by the Slovak Geological Office.

Both institutions elaborated a new legal norm, "Principles of economical exploitation of thermal waters," which is to be approved. The norm is to provide purposeful and proper exploitation of geothermal resources for nonmedicinal aims, including the protection of resources. The resources are to be protected against activities with unfavorable effects upon their yields and their thermal and chemical stability. Along such activities are excess takeoffs, drilling further holes, deep and surficial mining of minerals, and unfavorable operations in an intake area. There is a protective zone of the first degree for the drill hole and its head. An area of possible injury of the resource regime (an area out of the drill hole) is protected by a zone of the second degree. Protective measures depend upon the economic importance of geothermal resources and of other operations performed or planned for the protective zones.

CONCLUSIONS

In Czechoslovakia the research of geothermal resources commenced with introductory and study work in the 1960s. The first project for the basic research of geothermal resources was expanded in 1970. Drilling of geothermal holes began in 1971.

At present all work is concentrated in Slovakia owing to more favorable geological conditions. By the end of 1974, eight positive geothermal drill holes were completed to depths of 200 to 2500 m. The drill holes offered about 30 $\times$ 10^6 kcal/hr of thermal energy. The research work advanced gradually in the individual prospective structures. The investigations of three structures in the Danube basin are to be finished in 1980. They will be followed by detailed exploration connected with exploitation drill holes. Other prospective structures will be explored after 1980.

The exploitation of geothermal resources for single or double purposes is not complete as yet. Complete development of these resources will require trained personnel, technological capacities, sufficient experience, and the thorough economic evaluation of the effectiveness of exploitation of resources, of solving technical problems concerning incrustation and liquidation of exploited waters, and of introducing new legal measures necessary.

Dr. Franko wrote this paper at the request of the Technical Secretary of the Second UN Geothermal Symposium, Mr. G. R. Robson.

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