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PRELIMINARY ESTIMATES OF GEOTHERMAL POTENTIAL OF BELARUS

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SUMMARY

The territory of Belarus belongs to the Precambrian East-European Platform (Peive, et al., 1981, 1982). Such areas are usually rather cold ones and there are no high-enthalpy geothermal steam reservoirs useful for electricity production. Geothermal water and brines in Belarus have temperatures from 10°C at depths around 200-500 meters within the Belarussian Anteclise and the Orsha Depression to 80-110°C at depths of 4-5.5 km in the south-eastern part of Belarus. Their increased and high values are typical for the Brest Depression and the Pripyat Trough. Heat flow density for the territory ranges from below 20-30 mW/m² for Precambrian units (the Belarussian Anteclise, Orsha Depression, the Latvian, Polessian and Zhlobin saddles) to 70-80 mW/m² within the northern part of the Pripyat Trough. Preliminary estimates show that geothermal energy resources are equivalent 0.5 to 5-6 tons of an conventional fuel per square meter in Belarus. The highest geothermal potential is related to the Pripyat Trough. The present energy shortage dictates the necessity to use this geothermal energy as one of renewable resources, for instance, for: space heating, operation of greenhouses during cold seasons of the year, other agricultural production, warm water supply, creation of swimming pools, etc.

The most promising areas for geothermal energy utilization are the Pripyat Trough and the Brest Depression, where many deep boreholes were drilled. Both circulation scheme and the heat pumps technology could be used here. Rock salt domes and swells, representing ?accumulators? of the terrestrial heat, are widely developed within the Pripyat Trough, the Hot Dry Rock technology could be considered for the heat utilization from such structures.

INTRODUCTION

At present the geothermal energy is used in many countries, but its portion in the energy, produced in the World, is only around 2 percent. There was no practical use of the underground heat in Belarus until now due to low prices for oil and gas, existed during last decades. The energy shortage arises now in the country both due to growing prices for natural hydrocarbons and the increased cost of their import. The liberation of prices for coal and their permanent growing for imported oil and gas complicates the problem. Belarus produces now around 2 million tons of crude oil per year, which covers around 10 per cent of the annual request, the rest 90 per cents are purchased, mainly from Russia. Growing expenses for imported oil creates the necessity to use both energy saving technologies and the utilization of alternative energy sources, such as wind, solar and geothermal energy. Resources of low-enthalpy geothermal energy are available in Belarus among other mentioned renewable resources. The idea to use geothermal energy in Belarus was mentioned earlier (Bogomolov, 1959), later it was discussed several times, for instance (Tsalko, et al., 1997), but no practical steps towards its use was undertaken.

Regular geothermal investigations in Belarus were started since the end of sixties, but they were oriented mainly for heat flow determinations and related studies. More than 200 heat flow density determinations are available for the territory of Belarus at present. Geothermal investigations were conducted in both shallow and deep boreholes, located within all main tectonic units (Fig.1.). Mostly shallow ones were available within the Belarussian Anteclise and adjoining saddles. Fresh groundwater zone reaches the crystalline basement surface within the Central-Belarussian Massif, where the cooling effect of downward filtrating fresh water is distinctly visible. An opposite situation exists in discharge areas.

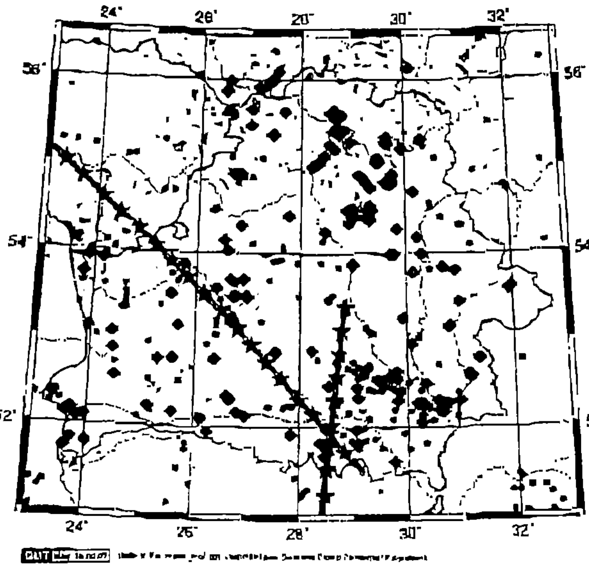

Figure 1. **Position of boreholes, studied in geothermal respect in Belarus.**

TERRESTRIAL TEMPERATURE FIELD

Temperature versus depth diagrams are available for hundreds of boreholes. They were recorded both in the process of standard boreholes logging by drilling companies frequently after 1-2 weeks after holes were finished and using the point-by-point method for boreholes, reached thermal equilibrium after their drilling was stopped. Boreholes deeper than 1 km were drilled as a rule within the deep Brest Depression and the Pripyat Trough.

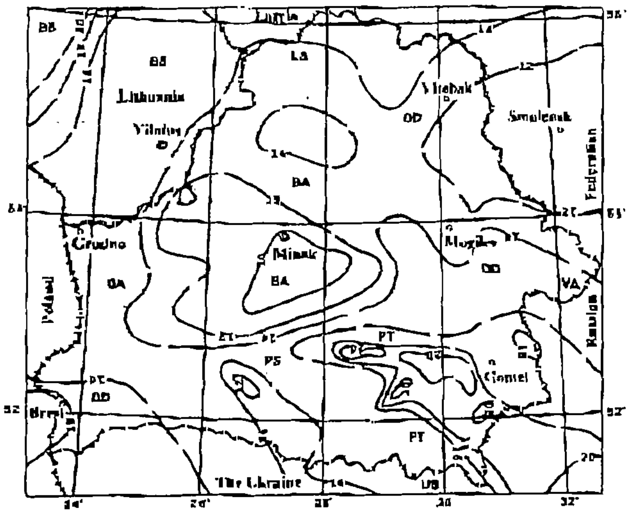

Figure 2. **Temperature distribution at the depth of 500 meters for Belarus. Isolines in °C.**

Background temperatures for the depth of 500 meters have a wide range. 14-16°C which is typical for junction zones of Precambrian and Paleozoic crustal units (**Fig.2.**). Within the Pripyat Trough, Brest Depression and the Baltic Syneclise, the main part of which is outside the considered area, the temperature exceeds 20°C. Both the Brest Depression, where temperature reaches 18-20°C, and the Pripyat Trough have a contrast pattern of geothermal field. The platform cover thickness within the Pripyat Trough reaches 5-5.5 km with highly developed salt tectonics. The crystalline basement is subdivided into many blocks by deep faults. The northern, central and southern parts, different in their geological development and thermal regime, are distinguished.

At the depth of 1000 meters temperature within the Pripyat Depression varies from 20 to 40°C from its western to the eastern part (Bogomolov, et al., 1972). The anomaly of increased temperature up to 30°C and heat flow in its northern part is stretched along the North-Pripyat marginal fault. It is limited in the south-eastern part by the Bragin-Loev Saddle. The zone of moderate temperatures 25-30°C is traced from Rechitsa and Svetlogorsk towns to Lyuban town and continues into the Dnieper-Donets Depression, within the Ukrainian territory.

At the depth of 2000 meters all investigated boreholes are in the Pripyat Trough. The terrestrial temperature field contrast continues to increase here. The background values range from 30 to 45°C. The temperature within the northern part of the Trough exceeds twice its values recorded within southern and western parts. It is above 50°C (Rechitsa and Svetlogorsk towns) and locally 60°C within the anomaly area as compared to around 30°C in its rest part. Another local anomaly in the eastern part of the Elsk Graven and the Vystupovichi Step with temperatures over 40°C was traced using data from only 3 boreholes.

At the depth of 3000 meters temperature increases to 70 and locally to 80°C within the anomaly area. A few temperature records at boreholes, reached **the depth of 4 km** indicated values over 80 and sometimes up to 90-100°C. Data for deeper horizons are sparse.

HEAT FLOW

Heat flow was studied more than in 200 boreholes within Belarus (Zui, et al., 1993). Its density ranges within the area from as low as 15-20 to as high as 100-110 mW/m^2 within some of salt domes of the Pripyat Trough (Fig.3.). Low heat flow values (20 -30 mW/m^2) are typical for Precambrian crustal blocks such as the Volyn-Orsha-Krestsy paleodepression and the Mikashevichi-Osnitsa Igneous Belt, the main part of the Belarussian Anteclise and the Orsha Depression. Heat flow within the Belarussian Anteclise ranges mostly from 20 to 30 mW/m^2 at the same time the background values for the Pripyat Trough are 40-50 mW/m^2. Low heat flow was observed within the Orsha Depression.

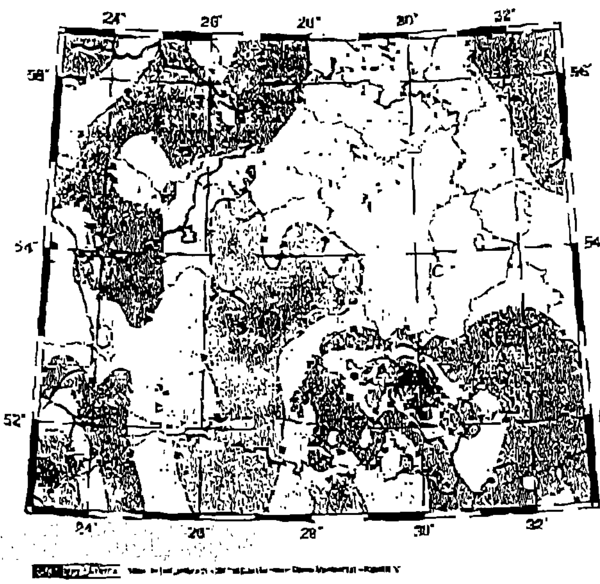

Figure 3. **Heat Flow density distribution within Belarus. Isolines in mW/m^2.**

The Pripyat Trough is the best studied area in heat flow. Heat conductivity contrast of the rock salt and terrigenous sediments, as well as complicated salt tectonics results in very contrast heat flow pattern here (Zui, et al., 1993). Though in the southern part of the Trough single heat flow values reach 51-59 mW/m^2, for instance, Kustovnitskaya-1 (51 mW/m^2), Karpovichi-1r (52 mW/m^2), Strelichevskaya-2r (54 mW/m^2), Kamenskaya-3r (53 mW/m^2), Elsk-28r (58 mW/m^2), Novo-Rudnenskaya-1r and 34r (58 and 59 mW/m^2), respectively. But for other boreholes of this region heat flow density reaches only 32-41 mW/m^2, for instance West-Sofievskaya-1r (32 mW/m^2), West-Valavskaya-1r (37 mW/m^2), Liplyanskaya-1r (39 mW/m^2), East-Elskaya-3r and 16r (41 and 37 mW/m^2). Local zones of increased heat flow here are traced sub-parallel to the South Pripyat marginal fault. The main part of the Trough exibits the heat flow above 50 mW/m^2.

Within the Brest Depression heat flow ranges from 31 to 60 mW/m^2 for individual boreholes. The main part of this anomaly is in Poland. Typical heat flow values for the Orsha Depression are 30-35 mW/m^2. Only within the Vitebsk mulde it is below 30 mW/m^2. It increases gradually in the direction of the Pripyat Trough.

AN APPROACH USED TO ESTIMATE THE GEOTHERMAL POTENTIAL

There are several approaches to estimate the density of geothermal resources distribution within given areas. The detailed estimates of geothermal potential were not fulfilled earlier for the territory of Belarus. As it was mentioned, there was no geothermal energy utilization in the country before. Therefore, it was quite reasonable to use as the first step a simplified approach, which does not require to know the hydrodynamic parameters of geothermal aquifers to outline areas perspective for geothermal heat utilization and for more detailed studies.

We used the approach, developed in the Mining Institute, Sankt Peterburg, Russia (Dyadkin, et al., 1991). They subdivide the resources into 3 categories: $\mathbf{P_1}$, $\mathbf{P_2}$, and $\mathbf{C_3}$. The category $\mathbf{P_1}$ determines the proved possibilities of the underground heat utilization, at the same time the category $\mathbf{P_2}$ reflects only the potential possibility of existence of geothermal resources and their localization, they are estimated for vast areas using available geologic-geophysical information and geothermal data within the depth range from the depth of seasonal temperature fluctuation to the depth, which is possible to reach by drilling using existed technology (usually 10 km). The resources of the $\mathbf{P_1}$ category are calculated up to the depth of 6 km, where many boreholes could be drilled with the modern drilling equipment. These 2 categories require to know parameters of the terrestrial temperature field distribution at 10 and 6 km for boreholes with available heat flow density determinations. Calculations show that maximal temperatures at such depths within Belarus reach 240 and 160°C, respectively. Finally, the category C_3 takes into account the economic feasibility to extract the geothermal energy and is closely related to parameters of a specific geothermal reservoir and other factors. As we don't consider here such reservoirs, this category was not estimated.

GEOTHERMAL RESOURCES OF THE P_1 CATEGORY

The category $\mathbf{P_1}$ shows the resource basis for geothermal heat supply and is determined using regional geological, geothermal and geophysical results of studies up to the depth of 6 km and requirements of users for heat supply. We kept in mind the temperature of warm water for heating of houses, agricultural and industrial enterprises consumed by heating equipment of users and the temperature of the returned water from the user, as well as warm water supply systems. For the warm water supply the upper limit of temperature used must be 70°C and the returned water 20°C, respectively, the temperature losses for heat exchangers and related equipment usually does not exceed 10°C. For heating purposes temperatures 90 and 40°C are accepted, respectively.

We used the next formula (Dyadkin, et al., 1991) to calculate the resources of the P_1 category (t.c.f/m^2):

$$\mathbf{q_{p1} = K\, R_{rec} C_v (H_L - H_U)(T_{av} - t_o)},$$

where

- K - the quantity of fuel used to produce the heat K = 0.043 10^{-9} t.c.f./J
- R_{rec} - 0,125+$\Delta t_g/(T-t_o)$ is the recovery coefficient
- Δt_g - the amount of heating up the fluid,
- T - the original temperature
- t_o - temperature of returned fluid
- C_v - the volumetric heat capacity, J/m^3· EC)
- H_L - the depth of the resource interval ~ 6 km
- H_U - the upper limit of the resource interval, determined from
- Hu - $(T_L-t_{nl})/G+h_{nl}$, where
- G - average geothermal gradient
- h_{nl} - the depth of so-called ?neutral layer?, or the depth below which annual temperature variations are absent
- T_{av} - average temperature within the interval

So, calculations were fulfilled for the $\mathbf{P_1}$ category of resources for 70/20 and 90/40 regimes. For the warm water supply (70/20°C) resources were subdivided into intervals, equivalent to 0-2, 2-4, 4-6 and more than 6 tons of conventional fuel (t.c.f.) per meter square. Results showed that the higher resources are related to the northern zone of the Pripyat Trough and the Brest Depression.

FAVORABLE AREAS FOR GEOTHERMAL ENERGY UTILIZATION

The comparison of available resources of $\mathbf{P_1}$ category of geothermal energy in Belarus and in Russia shows that values within the range 2-6 t.c.f./m^2 are useful for the 70/20 regime. In this respect, the most significant areas in Belarus are within the Brest Region to the west of the line crossing Vysokoe, Zhabinka and Malorita towns. The resources density doesn?t exceed 4 t.c.f./m^2 and the resources are around 60 million of t.c.f. It is possible to use thermal water here mainly for warm water supply systems. In the case of using of heat pumps to warm up the natural geothermal water, it is possible to construct here geothermal heating systems as well, because natural resources of the 90/40 regime are absent here.

The resources density of 4-6 t.c.f./m^2 are typical for the northern part of the Pripyat Trough. It is the main area located to the south of the Northern Marginal Fault. The resource boundary for 70/20 regime is located within the interval 1.2 - 2 km. As it was indicated, the developed salt tectonics exists here. Salt domes and cryptodiapirs could be considered as geothermal heat accumulators. If to consider the densities above 2 t.c.f./m^2, the resources will be around 4 billion of t.c.f./m^2.

Figure 4. **Density of the geothermal recoverable resources of the P1 category. Isolines in tons of conventional fuel per square meter.**

PERSPECTIVES FOR OTHER REGIONS OF BELARUS

The territory of Belarus was considered earlier when preparing small-scale maps as having low geothermal potential, but detailed investigation were absent (Shpak, et al., 1994; Hurtig, et al., 1991/1992]. Our calculations gave more details. It was shown that the density of resources exceeds 2 t.c.f./m^2 for some other areas of Belarus. Heat flow density calculations for granite bodies (Mosty, Vygodsk, Martsinkonis granite massifs) give values up to 48 mW/m^2. The recent investigations show that it reaches 50 mW/m^2 for areas around Grandichi, and Privalka settlements near Grodno town and the temperature at the crystalline surface at the depth around 500 m reaches 20°C, which increases perspectives of thermal water utilization here. Groundwater with such temperatures are used in some countries of the Western Europe using heat pumps. Areas of Belarussian Anteclise around Grodno and in the eastern part of the Naroch lake could be useful for geothermal energy utilization, but detailed geothermal investigations are to be conducted here.

Until now we considered mainly sediments saturated with groundwater and brines. But it is possible to extract underground heat from massifs of hot dry rocks too (petrothermal energy). It is possible to create the circulation system by drilling 2 boreholes and by pumping cold surface water into one of them and receiving the warm water from another one. Similar project was undertaken in Lithuania (Suveizdis, 1993; Suveizdis, et al., 1997), where the resources density is estimated to be 5 t.c.f./m^2. As preliminary, it is possible to consider areas around Gomel, Mikashevichi, Zhitkovichi, Brest Skidel, Grodno and Mosty towns.

CONCLUSIONS

Such territories as the Pripyat Trough and especially its northern and partially the central zones, as well as the Brest Depression are considered as the most perspective areas in Belarus for the geothermal energy utilization. For instance, the temperature of 50°C was registered at the depths of 1800 m in the borehole Vetkhinskaya-4, at the depth of 1360 m in the Borshchevskaya-7 hole. 90°C exists at the depth of 3800 m in the Semenovskaya-2, 95°C corresponds to the depth of 3800 m in Vetkhinskaya-4 hole and over 100°C was measured at the depth of 4200 m in the Mikhalkovskaya-3 drillhole. The temperature is even higher at the crystalline basement surface, encountered at depths of 5 - 5.5 km in the northern part of the Pripyat Trough in the vicinity of Borshchevka, Alcksandrovka, Visha, Rechitsa, Svetlogorsk, Sosnovyi Bor, Marmovicni, Parichi towns and settlements. In general, warm water and brines were found everywhere within the Pripyat Trough to the south of the line crossing Gomel, Slutsk till the Belarus-Ukrainian border in the south and Slutsk, Starobin, Zhitkovichi, Stolin towns in its western part.

The Platform cover is thinner within the Brest Depression and temperature reaches only around 35°C here, but the foreign experience shows that the practical utilization of the underground heat could be organized here as well, especially with heat pumps technology. Perspectives of geothermal energy utilization within the Belarussian Anteclise and the Orsha Depression are lower, but it is still possible to extract thermal water with temperatures around 20°C.

Thousands of boreholes were drilled in the course of oil-prospecting works during 30 years within the Pripyat Depression. Many of them are outside oil fields and without an oil were plugged. In principle they could be re-opened and used for production of geothermal water and brines after some repair works. Such an experience was used in Daghestan, Russia (Magomedov, et al., 1998).

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICTY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specifiy)		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in January 2000	No	No					No	No	No	No		
Under construction in January 2000	No	No					No	No				
Funds committed, but not yet under construction in January 2000	No	No					No	No				
Total projected use by 2005	?	?					No	No				

Note: At the moment we have no plans yet for "total projected use by 2005". I try to get money for such a project including the test (pilot) experiment on practical use of geothermal energy.
Please note, this table is not complete at the moment (25th Dec., 1999).

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TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with a University degress)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributied Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
1995	1	No	No	No	No	No
1996	1	No	No	No	No	No
1997	1	No	No	No	No	No
1998	2	No	No	No	No	No
1999	2	No	No	No	No	No
Total	2*	No	No	No	No	No

Note: 2* means the same people were working in previous years in the Laboratory of Geothermics. Institute of Geolc ogical Sciences, Minsk. Nobody graduates special courses in Geothermal energy utilization.

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TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (1999) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling Million US$	Field Development Including Production Drilling & Surface Equipment Million US$	Utilization		Funding Type	
			Direct Million US$	Electrical Million US$	Private %	Public %
1985-1989	N o	No	No	No	No	No
1990-1994	No	No	No	No	No	No
1995-1999	0.05 (for 4 years)	No	No	No	No	0.05

Note: Money were given only to estimate geothermal pot tential (resources) of Belarus. No money were given fc geothermal drilling or other things.

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