GEOTHERMAL ENERGY RESOURCES IN BELARUS

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ABSTRACT

Republic of Belarus is located within the western part of the Precambrian East European Platform. In geologic respect it represents a junction of crustal blocks of different age and origin. The crystalline basement within the whole territory of the country is covered by sediments of variable thickness. In result of recent investigations a contrast pattern of the terrestrial temperature field was revealed within the sedimentary cover of the country. Heat flow density distribution in the whole region varies in the wide range from 20 to 70-80 mW/m^2 and it increases up to 100-120 mW/m^2 within salt domes, widely developed within the Pripyat Trough (PT).

The platform cover within the trough and the Podlaska-Brest Depression (PBD) is the most warmed up. Temperature reaches up to 100-115°C within the PT at the depth of 4-4.5 km and up to 40-42°C within the PBD. The Orsha Depression is the third deep sedimentary basin within the considered area. Temperature at the crystalline basement here doesn't exceed 30-35°C at the depth of 1.5-1.7 km. The Belarusian anteclise (BA) is a vast positive structure with a thickness of sediments up to 500 m with observed lower temperature values (10-20 °C).

Estimates of geothermal resources available in the platform cover of Belarus were based on the approach used in the Atlas of Geothermal Resources in Europe. Results show that resources of geothermal energy existing within sediments are varying in a wide range from first dozens of kg.o.e./m2 within the Belarusian anteclise to 300 – 350 kg.o.e./m^2 within the PBD. The highest values for the Orsha Depression reach approximately 100 kg.o.e./m^2. The so-called Intersalt sediments, the thickness of the Upper Salt, Devonian deposits, overlaying the Upper Salt, and the Jurassic accumulations, comprising the geologic crossection within the PT, were considered as geothermal horizons. Calculations show that the density of geothermal resources within the Intersalt Complex range from 0.1 to 1.75 t.o.e./m^2. Maximal values correspond to the northeastern part of the PT. In the southern part of the unit they are lower (0.25-0.65 t.o.e./m^2). Within the Jurassic and Devonian deposits, overlying the Upper Salt, the density of geothermal resources usually corresponds to a few dozens of kg.o.e./m^2. Within the impermeable Upper Salt Complex they are much higher and reach in some blocks of the PT up to 2-4 t.o.e./m^2. Their utilization is possible by means of borehole heat exchangers.

There are already 8 small geothermal installations under exploitation in the country. They use heat pumps with the total installed heat capacity of them around 1.5 MWt. Works were undertaken to construct the first in Belarus geothermal station for the greenhouse complex "Berestye" in the Brest

town. Here the Republican Unitary Enterprise “Belgeologiya” recently finished to drill and test a borehole to recover warm water. Its bottomhole is at the depth of 1.5 km.

Dozens of deep holes, drilled in the process of oil prospecting works outside oil fields, are available within the PT. It is possible to use them as a basis to create geothermal installations for heating of dwelling, as well as to satisfy demands of agricultural and industrial users. Terrestrial heat is a perspective renewable and ecologically clean resource in Belarus. Its utilization represents an important national goal for the economics of the country.

1. GEOLOGICAL BACKGROUND

Republic of Belarus is located within the western part of the Precambrian East European Platform. In geologic respect it represents a junction of crustal blocks of different age and origin. The crystalline basement within the whole territory of the country is covered by sediments of variable thickness, Fig.1.

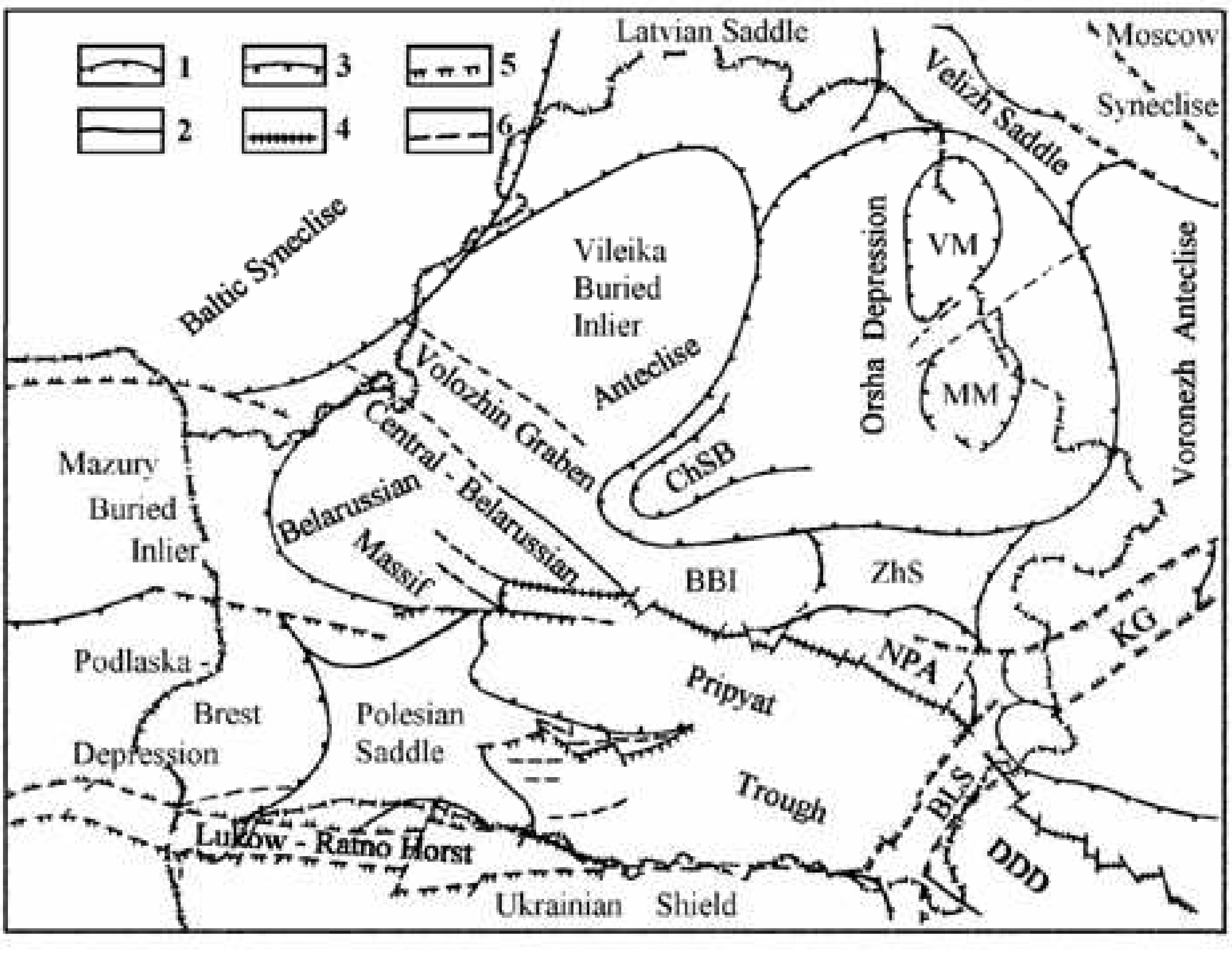

Figure 1. Main geologic units located within the territory of Belarus.
Legend: DDD – Dnieper-Donets Depression; KG – Klintsy Graben; BLS – Bragin-Loev Saddle; NPA – North Pripyat Arch; BBI – Bobruik Buried Inlier; ZhS – Zhlobin Saddle; ChSB – Cherven Structural Bay; VM, MM – Vitebsk and Mogilev muldes, respectively.

The Pripyat Trough is the deepest sedimentary basin in Belarus. Its crystalline basement represents a system of blocks, limited by deep faults with varying thickness of the overlying platform cover. Tectonic movements along faults produced developed salt tectonics, (Geology..., 2001). The trough is limited by the North-Pripyat, South-Pripyat super-regional faults, the Bragin-Loev and Mikashevichi-Zhitkovichi salients. A thin sediments overly the latter one. Its thickness usually ranges here from 200 to 400 m. The thickest cover up to 5-5.5 km corresponds to the northern and southern zones of the trough.

The Pripyat Trough has a complex geological structure with two salt bodies within its platform cover. Brines, filling the pores and cracks in rocks overlying the crystalline basement have the dissolved chemicals content up to 400-420 g.p.l. (grams per litre). The intersalt deposits separate the Upper Salt and Lower Salt complexes within the trough. The depth to its surface is on average 2.0 – 3.0 km. High salinity brines were observed within this complex. The content of dissolved chemicals reaches on average up to 200-300 g.p.l., which is lower than in the subsalt sediments, which gives better conditions to exploit it for the geothermal energy use. A thickness of the permeable intersalt deposits ranges from 100 meters in the western part of the area up to 1000 meter observed in a few wells.

The main tectonic activity, which formed the Pripyat Trough, took place during the Devonian time. It was accompanied by the Devonian volcanism within its north-eastern part and explosion pipes, discovered recently, were formed within the Zhlobin Saddle, separated from the trough by the North-Pripyat Arm, see Fig.1. The Pripyat Trough has its continuation through the Bragin-Loev Saddle into the Dnieper-Donets Depression located within the territory of the Ukraine. The Ukrainian Shield, Poleskaya Saddle and the Bobruisk Buried Salient adjoin it in southern, western and north-western directions, respectively, Tectonics (1979).

2. TEMPERATURE DISTRIBUTION MAPS

2.1. Temperature distribution at the depth of 100 m

In result of recent investigations a contrast pattern of the terrestrial temperature field was revealed within the sedimentary cover of the country. But the lack of temperature-depth profiles for deep boreholes didn't allow preparing the detailed temperature distribution maps for horizons deeper than 400-500 meters for the whole territory of the country. To be able to describe the main terrestrial temperature field features for all geologic structures of Belarus, we compiled the map of temperature distribution for the depth of 100 meters using the most of available data, Fig. 2. Around 320 temperature-depth profiles accumulated during the last 30- 40 years for the whole territory of the country both for shallow (50-250 meters) and deep boreholes were used to construct this map. Only around 10 diagrams of the standard logging were, recorded by drilling companies, were added after the careful selection of them for those boreholes, where enough time elapsed after the drilling was finished before temperature measurements. In other words, the temperature equilibrium between the wellbore fluid and the surrounding massifs of rocks at the moment of measurements was reached.

Temperature isolines were drawn by means of an interpolation within the territory of Belarus. Outside its borders they were extrapolated and their configuration is very preliminary one, as no reliable temperature-depth diagrams were available for the territory of Poland and the Ukraine. We had only a few diagrams for territories of Lithuania, Latvia and Russia adjoining the border of Belarus. The interval 0.5 °C was used to draw isolines, which is acceptable, keeping in mind that the calibrated thermistor thermometer, used for borehole temperature measurements, had the error of absolute temperature readings around ±0.03 °C.

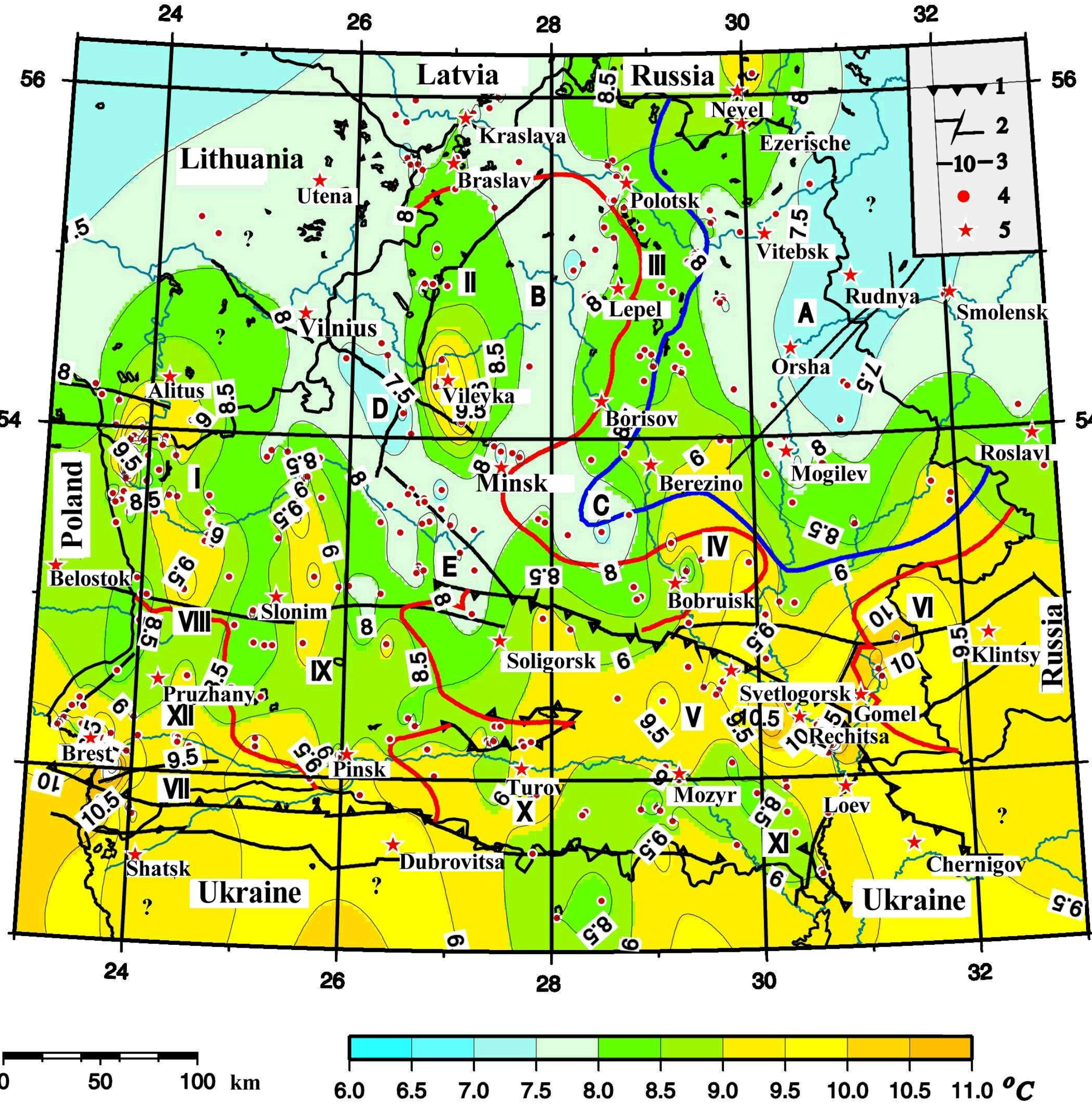

Fig.2. Temperature distribution map at the depth of 100 m within Belarus.

Legend: 1, 2 – Superregional and regional faults within the crystalline basement, 3 – Isotherms, ˚C, 4 – Studied boreholes, 5 – Towns and settlements. Anomalies of increased temperature: I – Grodno, II – Molodechno-Naroch, III – West Orsha, IV – Chechevichi-Rechitsa, V – Pripyat, VI – Western slope of the Voronezh Anteclise, VII – Podlaska-Brest, VIII – Mosty, IX – Lyakhovichi-Elnya, X – Turov, XI – Vystupovichi-Elsk, XII – Kobrin-Pruzhany. Low temperature anomalies: A – East-Orsha, B – Eastern part of the Belarusian Anteclise, C – Cherven Structural Bay, D – Central part of the Belarusian Anteclise, E – Central Belarusian Massif. Red heavy lines indicate margins of positive structures: Belarusian Anteclise, Polesian Saddle and the Voronezh Anteclise (outlined by –500 m isoline). The blue line traces margins of the Orsha Depression (outlined by –700 m isoline).

The depth of 100 m wholly belongs to the fresh water zone (a zone of active water exchange). An influence of the filtration reflects in the shape of thermograms. In other words, a convective component of heat transfer is pronounced here.

The temperature at the depth of 100 m varies in the range 7 – 11.5 °C. The difference between them is 4.5 ºC. Temperature values above 8 ºC are typical for the northern zone of the Pripyat Trough and the Podlaska-Brest Depression. The isotherm of 9 ºC has the continuation beyond the North Pripyat marginal fault and is traces into the North Pripyat Arch, Zhlobin Saddle and the western slope of the Voronezh Anteclise. We have a lack of reliable thermograms in the northern part of the Pripyat Trough at the considered depth of 100 m. It reflects in smooth course of isotherms. The temperature field within the whole territory of the country has a contrast pattern at the studied depth. Regional and local anomalies are clearly distinguished. A part of them was revealed recently.

In the eastern part of the Orsha Depression within a triangle of Orsha – Smolensk – Cherikov towns exists the *East Orsha anomaly* of low temperature values 6.5 – 7.5 ºC. It includes almost the whole area of the Mogilev Mulde. Its shape within adjoining area of Russia is very preliminary because of a lack of reliable thermograms.

A strip of increased temperature of meridian orientation crosses the whole territory of the Orsha Depression. This *West Orsha anomaly* was traced in the western part of it and partly within the eastern slope of the Belarusian Anteclise along the line joining towns: Rechitsa – Svetlogorsk – Klichev – Belynichi – Berezino – Borisov – Lepel Chashniki – Ezerishche – Nevel. Its north continuation in the vicinity of Ezerishche and Nevel has very preliminary shape as only one termogram was available in the adjoining area of Russia. The temperature within the *West Orsha anomaly* ranges from 10.0 to 11.5 ºC within the northern part of the Pripyat Trough. The local Belynichi-Chechevichi-Rechitsa anomaly of increased temperature above 8.5 ºC was jbserved in its southern part. The isoline of 8 ºC along the eastern slope of the Belarusian Anteclise separates it from the Cherven Structural Bay of the Orsha Depression.

The *Chashniki-Polotsk anomaly* of low temperature values exists in the north-eastern part of the country. Its western part at the latitude of Polotsk town is joined with the anomaly of the eastern slope of the Belarusian Anteclise and the Cherven Structural Bay of the Orsha Depression.

The isotherm of 9.5 ºC along the eastern part of the Podlaska-Brest Depression is traced along the Belarus-Ukraine border through the Polesian Saddle reaches the longitude of Stolin town and continues into the territory of Ukraine. The isotherm of 9.0 ºC of this anomaly as well through the Polesian Saddle has its continuation within the Pripyat Trough. Then it is continued into the Belynichi-rechitsa anomaly and is traced to the western slope of the Voronezh Anteclise and continues into Russia (Zui, 2004a; Zui, 2005).

The Grodno anomaly of increased temperature above 9 °C is stretched in the meridian direction and has its continuation into the territory of Lithuania. A lack of reliable data there doesn't allow to trace its northern part.

The Molodechno-Naroch anomaly of elevated temperature above 8 ºC of meridian orientation in its northern part reaches the junction area of the Belarus, Lithuania and Latvia borders. It subdivides the anomaly of low temperature of the Belarusian anteclise into two parts. They are the *anomaly of the eastern slope of the anteclise* and the *anomaly of its central part (the Central-Belarusian Anomaly)*. The local Kobrin-Pruzhany as well as the Mosty and Lyakhovichi-Elnya anomalies of elevated temperature, exceeding 9 ºC have also the meridian orientation.

2.2. Temperature distribution at the depth of 400 m

A number of extrapolations of temperature-depth profiles were used to compile this temperature map. As a not drilled part of the geologic section was a priory unknown. The same concerns thermal properties of rocks comprising those intervals. It result, we used the linear downward extrapolation of thermograms. Only 214 temperature-depth diagrams were used to prepare the considered map. Almost 50% of them were extrapolated ones. Around 20 reliable curves of standard logging were used as well. They were recorded in boreholes of adjoining areas of Russia, Lithuania and the north-eastern Belarus.

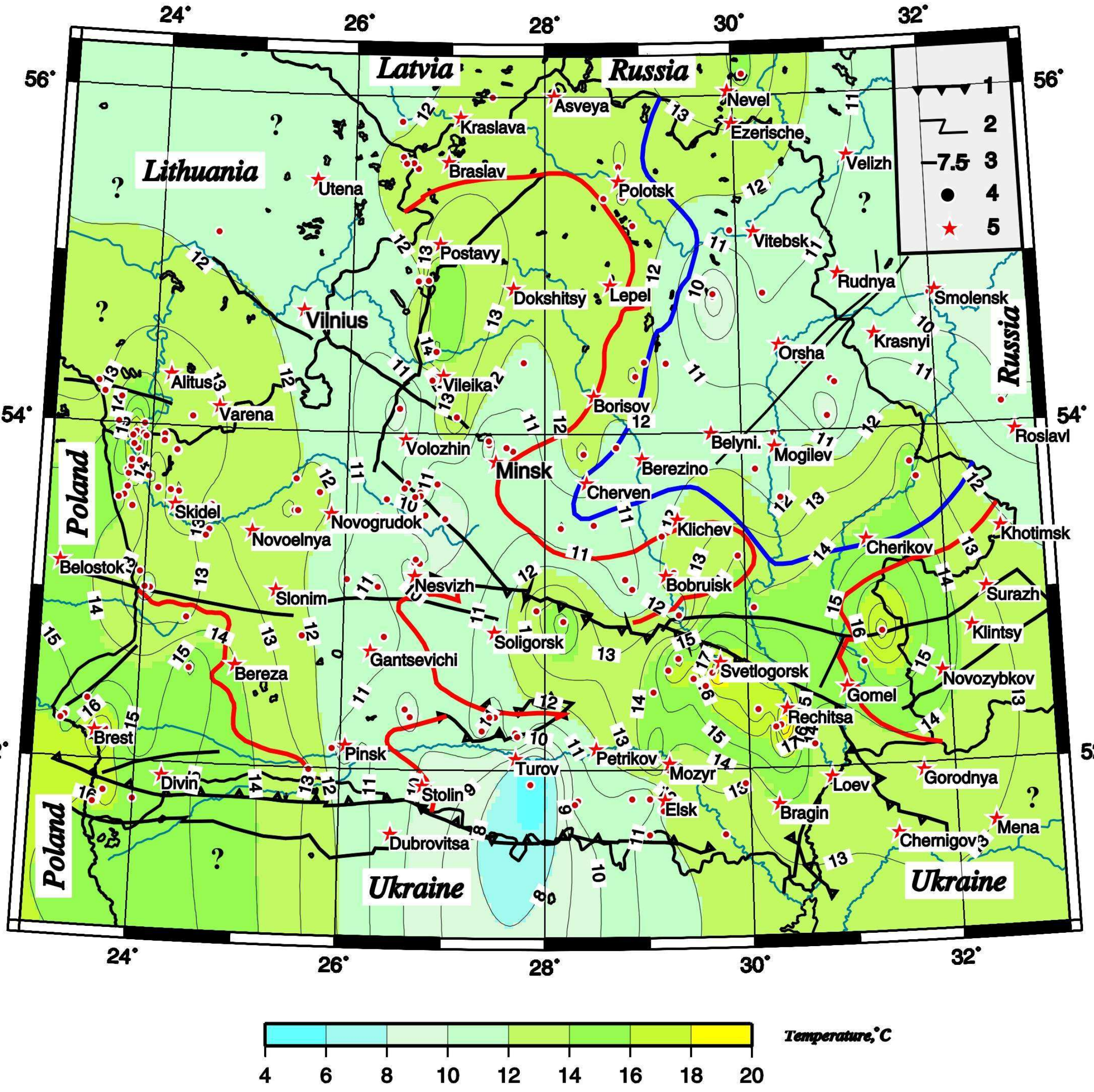

Fig.3. Temperature distribution map at the depth of 400 m of Belarus (compiled by V. Zui). See Legend in Fig. 2.

The temperature field contrast continues to grow with depth relatively to those, shown in Fig. 2. But the mail features described for the temperature map for the depth of 100 m remain similar. The results are shown in the Fig. 3. The temperature ranges here from 8.5 to 19ºC.
The East - Orsha anomaly of low temperature below 11 ºC is clearly distinguished to the east of the line, crossing the following towns: Roslavl – Belynichi – Vitebsk – Velizh. It occupies a smaller area, which is also the result of reduced number of reliable thermograms used to compile this map.

Temperature values in the southern part of the country exceeding 12ºC are typical for the Pripyat Trough, Zhlobin Saddle, as well as the western slope of the Voronezh Anteclise. The West-Orsha anomaly with the temperature range of 11 – 19ºC is traced from Rechitsa in the south to Nevel towns in the north. The higher values are typical for the northern zone of the Pripyat Trough oriented along the Northern Fault. It is possible to reveal besides this anomaly another one within the trough. It has the SSW – NNE direction along the Perga deep fault within the crystalline basement, which crosses the Pripyat Trough. Its main axis crosses the towns: Mozyr – Rechitsa – Svetilovichi – Mstislavl.

The Belynichi – Rechitsa anomaly has the same position, but its shape is very preliminary as within the triangle of Klichev – Belynichi – Borisov towns studied boreholes were absent. It has the continuation through the Zhlobin Saddle and joins with the positive anomaly of the western slope of the Voronezh Anteclise. At the map the low temperature anomaly limited by the isotherm of 11 ºC of the Cherven Structural Bay, the Osipovichi Uplift is distinguished. A small low temperature anomaly near a junction of the Belarus – Lithuania – Latvia borders was traced very preliminary because of a lack of reliable thermograms within this area.

A positive temperature anomaly exists in the eastern part of the Podlaska-Brest Depression. It has a continuation into Poland. The Grodno anomaly is observed at the depth of 400 m as well, but its limits are shown without details because of a lack of thermograms available. In general, it is necessary to note when the depth increases more and more small details disappear within the whole studied territory mainly because a lack of reliable data.

The Molodechno – Naroch anomaly of increased temperature (12 – 14ºC) remains the same shape. At the same time the Lyakhovichi – Elnya anomaly, distinguished in the temperature map for the depth of 100 m, “disappears” at the depth of 400 m as the available thermograms of shallow boreholes within its limits couldn’t be extrapolated to the depth of 400 m. Isolines of 12 and 13ºC join the Grodno anomaly together with the anomaly of increased temperature, existing within the Polaska – Brest Depression.

Heat flow density distribution in the whole region varies in the wide range from 20 to 70-80 mW/m^2 and it increases even up to 100-120 mW/m^2 within salt domes, widely developed within the Pripyat Trough.

2.3. Temperature distribution at the depth of 2 km

It is possible to compile terrestrial temperature maps for depths deeper than 700 – 1,000 m in Belarus only for the Pripyat Trough territory which represents the best studied area in geothermal respect among other sedimentary basins of Belarus. As it was indicated above, when the considered depth increases within this unit, small details disappear, because the number of available thermograms also decreases. For instance, for the depth of 4 km the number of reliable thermograms doesn’t exceed 20.

The temperature field pattern for the depth of 2 km is shown in Fig. 4. It has a distinct contrast. In the northern zone of the trough the temperature is in average two times higher than in its southern and western colder parts. To the left of the isotherm of 35°C exists a wide zone of reduced temperature. Only a few thermograms were available here and they didn't allow distinguishing small details within this area. The highest temperature exceeds 60 – 70°C within the northern and north-eastern local zones of the trough. The mail oil fields were encountered namely within this warm area.

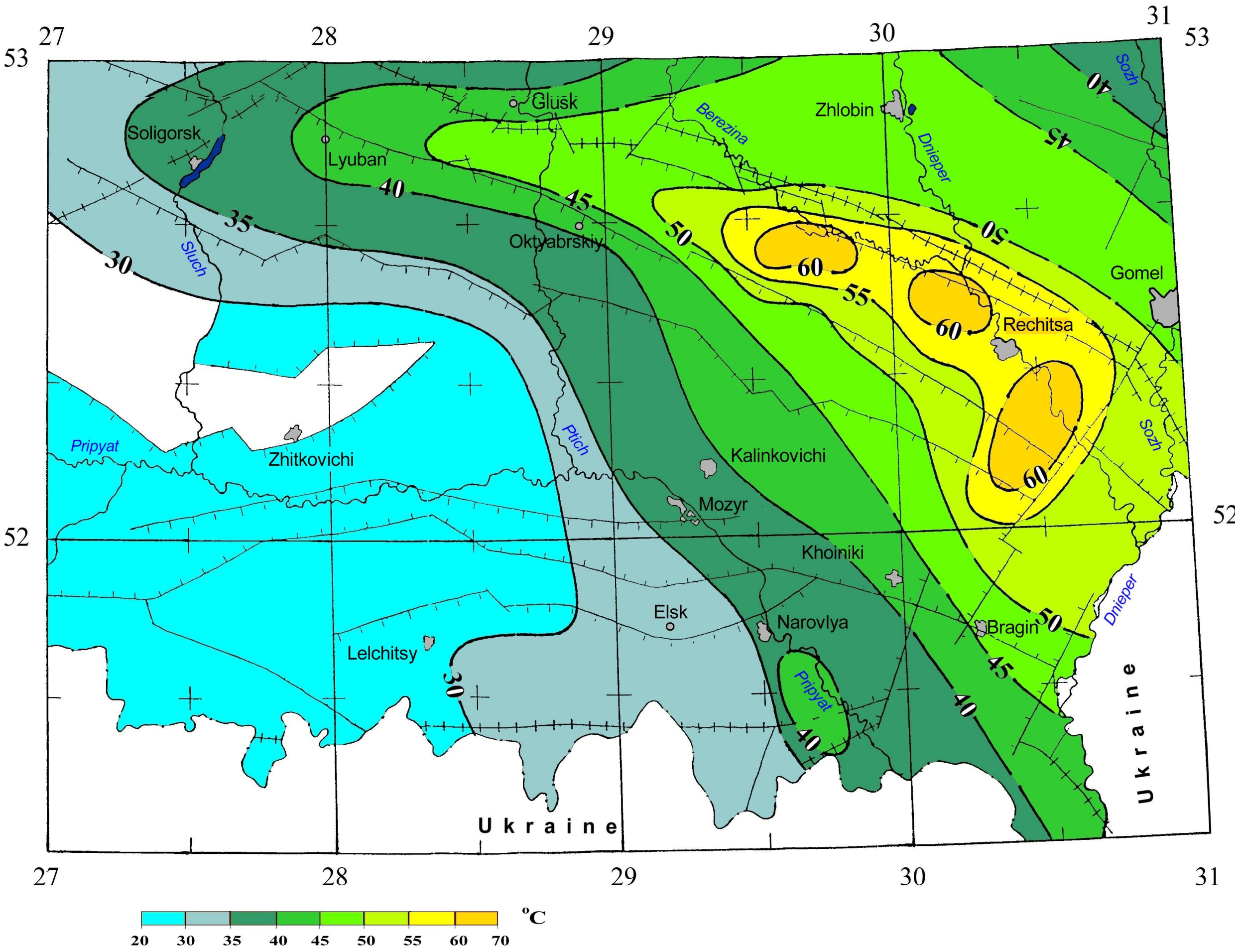

Fig.4. Temperature distribution map at the depth of 2 km within the Pripyat Trough (compiled by V. Zui).

The central part of the anomaly existing in the northern zone of the trough is limited by the isotherm of 50 °C. This zone of increased temperature is traced in the western direction till Luban town and continues in the south-east into the Gremyachy Buried Salient, Russia and the Dnieper-Donets Depression, the main part of it is located in the Ukraine. In northern direction it was traced into the North Pripyat Shoulder. Local anomalies within the Elsk Graben and the Vystupovichi Step are shown by the isotherm of 40 °C. They are based on three thermograms of deep boreholes drilled within the Karpovichi and Zhelon structures, located in the southern part of the trough. The background temperature values here range from 35 to 40 °C.

The platform cover within the trough and the Podlaska – Brest Depression is the most warmed up among other tectonic units. Temperature reaches up to 40 – 42 °C within the Podlaska – Brest Depression and up to 100-115 °C within the PT within Pervomaisk, Barsuki and some other local structures. Maximal recorded temperature, for instance, recorded in the hole Basuki – 63 was 115 °C at the depth of 4 km.

3. HEAT FLOW DENSITY

Heat flow density distribution within Belarus is shown in Fig. 5. Around 500 heat flow data determined for individual boreholes were used to compile this map (Zui, Zhuk, 2006).

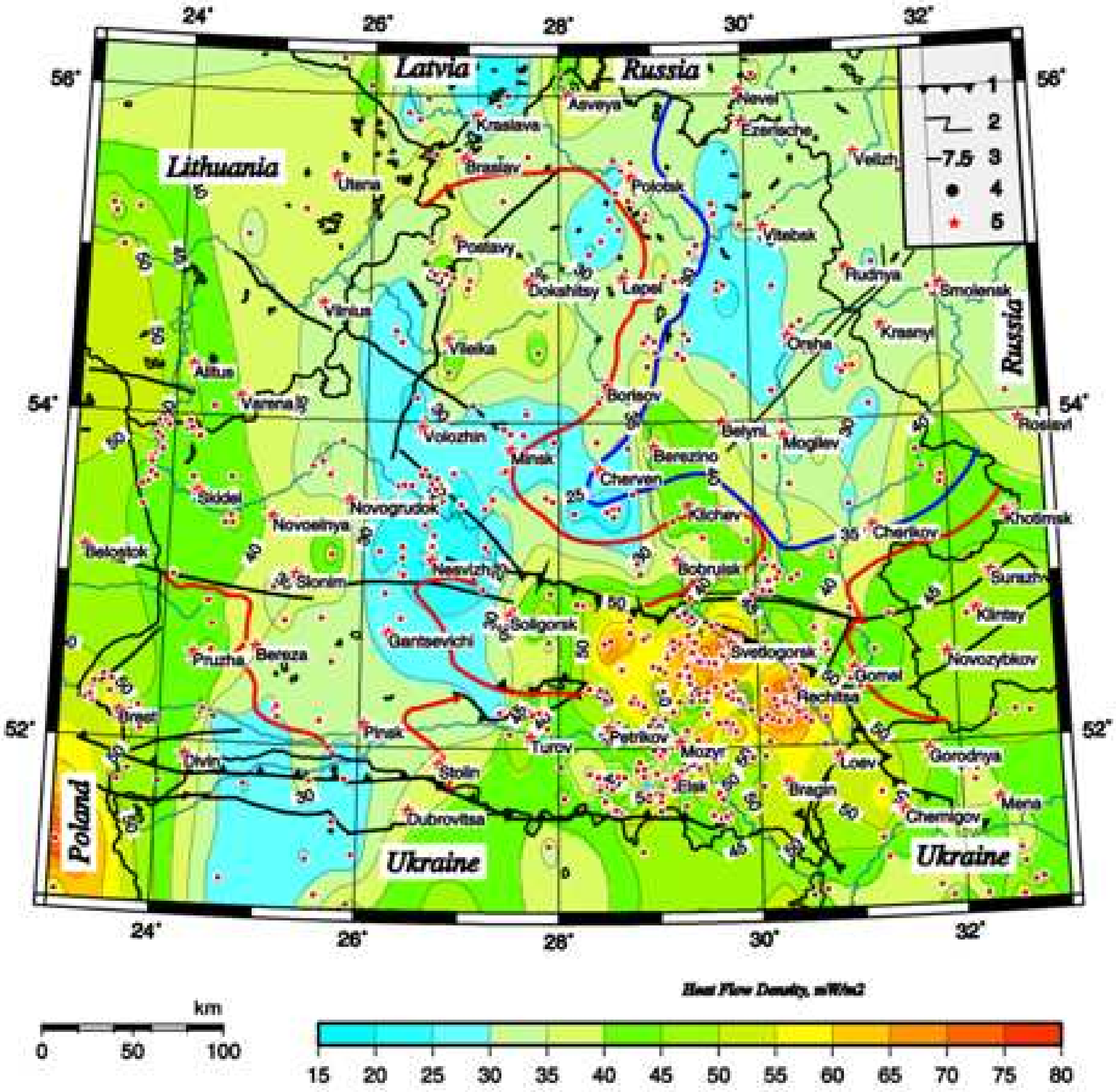

Fig.5. Heat flow density map of Belarus (compiled by V. Zui). See Legend in Fig. 2.

All available heat flow density data were used to compile this map (Zui et al., 1993; Urban, Belyashov, 2003; Zhuk et al., 2004; Zui, 2005; and new its determinations), as well as published data for adjoining areas of Poland, Lithuania, Latvia, Russia and Ukraine. Its distribution is sufficiently differentiated. At the background of its low values (30 – 40 mW/m^2) positive anomalies are distinguished within the Podlaska-Brest Depression (50 – 55 mW/m^2) and the Pripyat Trough where it exceeds 60 mW/m2 within its northern zone. Heat flow density of 40 – 50 mW/m^2 was observed not only within these tectonic units, but also as local anomalies of the Belarusian Anteclise, Orsha Depression, Nort Pripyat Shoulder, Zhlobin Saddle, and the western slope of the Voronezh Anteclise. The Pripyat Trough represents the best studied geologic unit within the whole territory of Belarus. More details of heat flow distribution within its limits is shown in Fig. 6 (Zhuk et al., 2004).

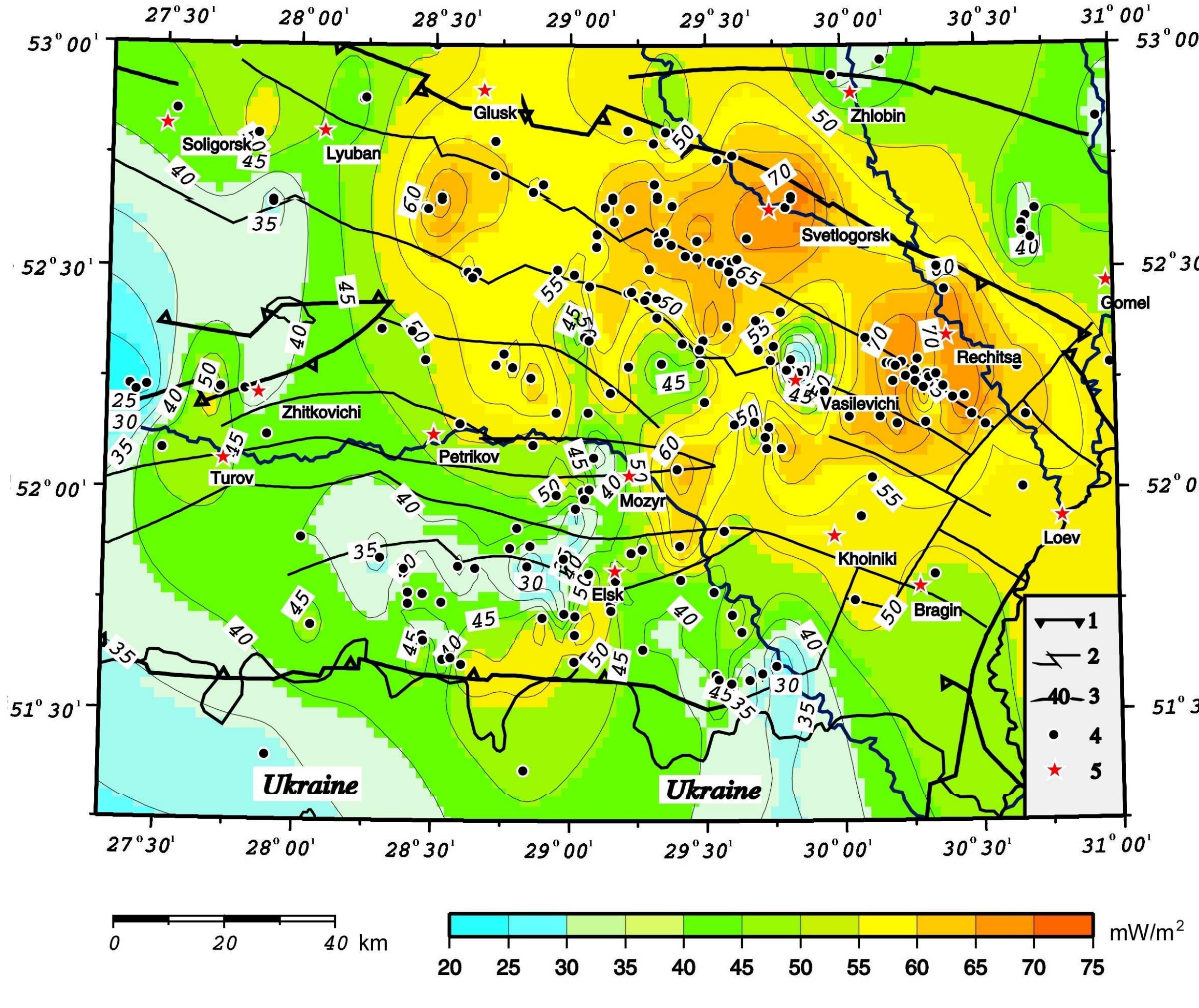

Fig. 6. Heat flow density map for the Pripyat Trough. See Legend in Fig. 2.

Besides the main orientation of heat flow density isolines along the North Pripyat Fault, it is clearly distinguished their another direction with neat low values 50 – 60 mW/m^2, traced along the line joining Elsk – Mozyr – Rechitsa – Svetlogorsk towns. It is orthogonal to the main stretching of the anomaly in the north zone. It follows the Perga crustal fault, penetrating into the upper mantle. Heat flow density within the Pripyat Trough varies in a wide range from less than 40 mW/m2 in its western part to more than 100 mW/m2 within nuclei of salt domes. ([Tsybulya, Levashkevich, 1990; Zui et al., 1991; Zhuk et al., 2004). Interval heat flow values are dependent on the depth. This fact evidences on the influence of many factors: thermal conductivity variation for rocks comprising the platform cover, groundwater and other fluids filtration, varying tectonic conditions and others (Zhuk et al., 2004). A considerable influence on the considered heat flow has the salt tectogenesis, especially within near-the-fault zone of the Rechitsa – Visha Swell. Salt domes are good studied within the Pripyat Trough both by drilling and by geophysical methods. Within the most of them were fulfilled geothermal measurements and heat flow determinations. In the vicinity of the Vasilevichi settlement a heat flow was calculated for shallow depth intervals (above-the-salt deposits). The influence of near-the-surface factors is noticeable here. It resulted in lower heat flow comparably to adjoining areas of the Pripyat Trough.

Heat flow density values below 30 mW/m2 form a chain of small anomalies, partly located along the Volyn – Orsha – Krestsy Paleodepression (Paleotectonics…, 1983), having as a rule, the longitudinal orientation. One of them, occupying the largest area, is traced from the northern part of the Polesian Saddle and the Mikashevichi – Zhitkovichi Salient to the northern part of the Belarusian Anteclise in the direction of Gantsevichi – Nesvizh towns. At the latitude of Minsk a strip is separated into the Cherven Structural Bay and the Osipovichi Uplift. Low heat flow is typical for the Bobovnya Salient of the Belarusian Anteclise.

The isoline of 40 mW/m2 joins the Grodno and the Podlaska Brest anomalies with heat flow values in their central, parts exceeding 50 mW/m^2. In has the continuation in its northern part into the territory of Lithuania and probably joins with the high heat flow anomaly in western Lithuania. But a lack of thermograms doesn't allow tracing it more reliable. A heat flow density pattern within the adjoining area of Poland was also studied only in a few locations.

4. GEOTHERMAL RESOURCES

4.1. Resources of the Pripyat Trough

The density of geothermal energy resources were studied mostly within some horizons of the Pripyat Trough and the eastern part of the Podlaska – Brest Depression. We used the approach described in (Atlas..., 2002) to calculate them. Recoverable resources, accumulated within the Intersalt Complex, deposits of the Upper Salt, Devonian sediments, overlying the Upper Salt Complex and the Jurassic rocks of the Pripyat trough were determined. The map of the density of geothermal resources, within the Intersalt Complex shows that low values 0.2-0.4 tons of oil equivalent (t.o.e.) per square meter are typical for the western part of the area, Fig. 7. Though there is a small area, corresponding so-called Turov Depression, where this value increases to 0.5 t.o.e./m^2. The isoline of 0.5 t.o.e./m^2 has the general longitudinal orientation and separates the whole considered area into the western and eastern parts. Maximal density of geothermal resources up to 1-1.25 t.o.e./m^2 and higher corresponds to the northern and north-eastern parts of the Pripyat Trough. It is stretched sub-parallel to the North Pripyat Marginal Fault. It is the most promising area for the geothermal energy utilization within the trough.

The results show that the Intersalt Complex of the Pripyat Trough represents the interest for recovery of its geothermal resources especially in the northern and partially in central zones. Dozens of abandoned deep wells, drilled originally for oil prospecting and plugged later, represent the interest for geothermal energy extraction. They could be opened, repaired and put into operation to extract warm and hot geothermal liquids. The feature of the Pripyat trough is rather high salinity of brines. It reaches in some localities up to 300 – 400 g.p.l. of dissolved chemicals which requires to pump the used geothermal brines after heat pumps into the same underground horizon. They also can be used as borehole heat exchangers to recover geothermal energy. Their use allows to reduce sufficiently expenses to construct geothermal systems and will increase the economic feasibility of such projects.

The Upper Salt Complex is spread practically within the whole area of the Pripyat Trough. The depth to its roof sufficiently varies even at small lateral distances from first hundreds of metres (mainly within the western part of the paleorift) to more than 2 km in some local parts of the trough. The salt tectonics is created the most differentiated roof relief within the central part of the rift. Such wide range of the depth variation to the salt roof resulted in the temperature distribution and, finally in the density of geothermal resources. We used 108 thermograms to calculate these resources. As before, the most of they are concentrated within the northern oil-bearing area and partly in its central zone. Only thermograms of single holes were available in the western, south-western part of it, as well as along the Bragin – Loev Saddle.

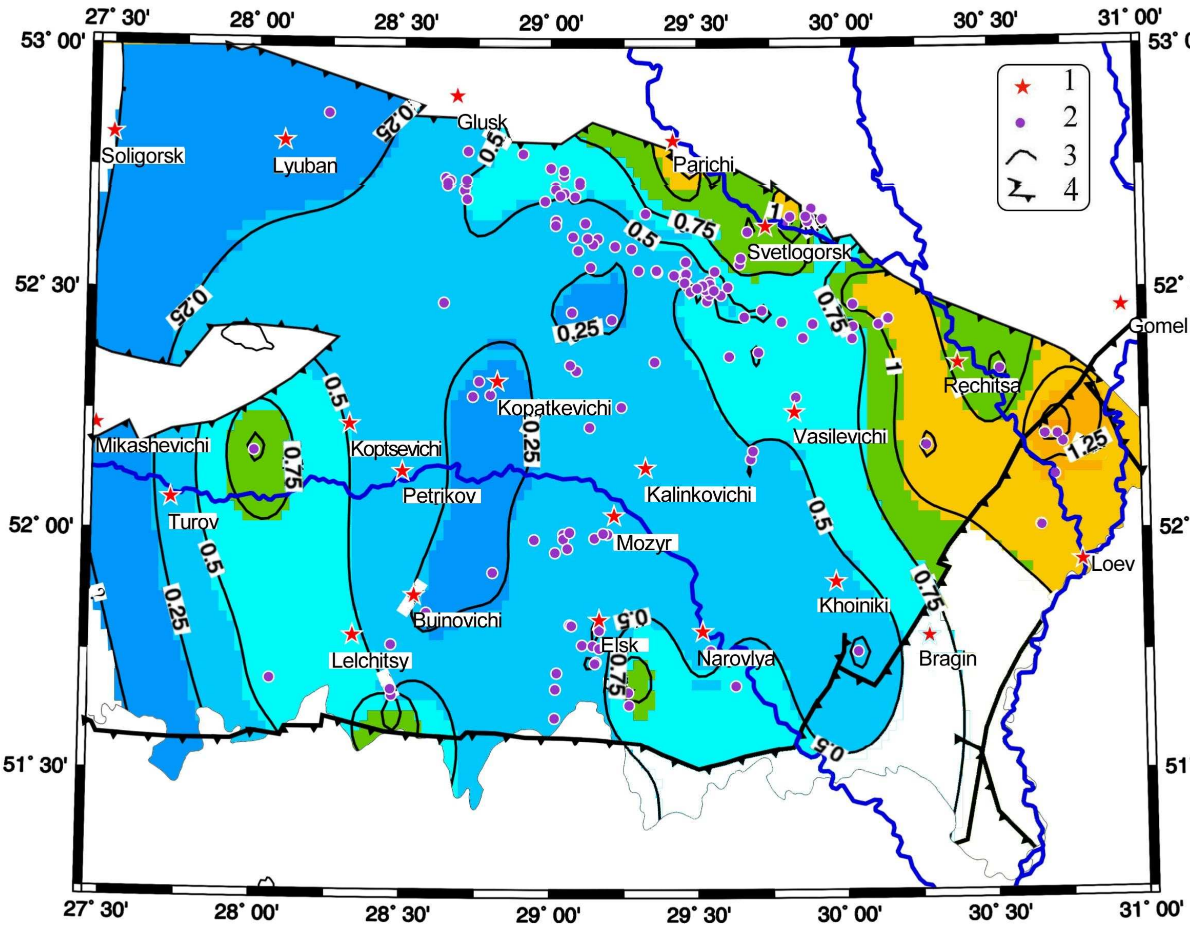

Fig. 7. Density of geothermal resources of the Intersalt Complex within the Pripyat Trough. Isolines are in t.o.e./m^2 (Zui, 2004b; Zui, Mikulchik, 2005;). Dots show the position of studied boreholes.

The temperature at the roof of the Upper Famennian salt ranges from 18 – 20 to 40 – 45 °C. Its lower values correspond to the western part of the trough. Resources distribution within the Upper Salt Complex of the Pripyat Trough are rather differentiated, Fig. 8. The main feature of the map is much higher density of geothermal resources within the Upper salt Complex relatively to the underlying Intersalt deposits, considered above, as well as in the overlying Devonian terrigenous rocks. It results first of all both from a higher volumetric heat capacity of the rock salt and the higher thickness of this complex

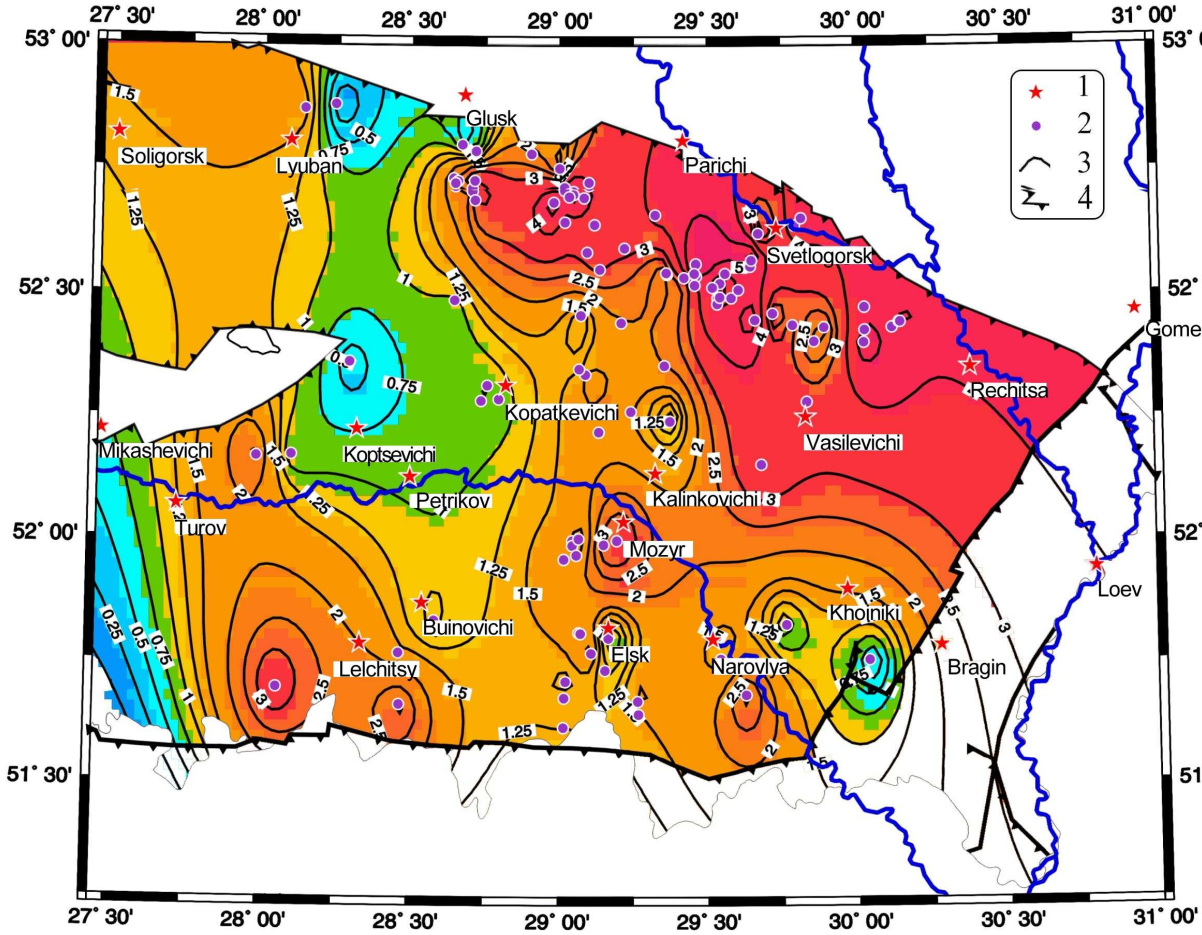

Fig. 8. Density of geothermal resources of the Upper Salt Complex within the Pripyat Trough. Isolines are in t.o.e./m² (ZuMikulchik, 2005;). Dots show the position of studied boreholes. Legend: 1 – Towns; 2 – Studied boreholes; 3 – Isolines of geothermal resources density, t.o.e./m²; 4 – Faults.

The density of geothermal resources varies in a wide range from less tan 0.5 to more than 4 t.o.e./m² depending on the thickness of the complex and its temperature. The northern zone of the Pripyt Trough has higher density of resources relatively to its other parts. The isoline of 3 t.o.e./m² is limiting here a wide area stretched along the North Marginal Fault. Prevailing values 1.25 – 2 t.o.e/m² correspond to the central and southern zones of the trough. Within the Turov depression the density of geothermal resources doesn't exceed 1 – 1.5 t.o.e/m². The same concerns the western part of the Pripyat Trough.

4.2. Resources of the Podlaska-Brest Depression

Similar investigations are undertaken now to estimate the density of geothermal resources for the eastern part of the Podlaska – Brest Depression, stretched into the territory of Belarus ().

The elongated Podlaska-Brest Depression is stretching from the longitude of Drogichin town in Belarus to the edge of the East European Platform limiting by the Teisseyre – Tornqvist Zone crossing the territory of Poland in the SSE-NNW direction. We consider only the Belarusian part of this structure. Geothermal resources were studied for the Cambrian and Proterozoic geothermal complexes. The former one contains practically fresh water and a pore volume within the latter one is filled in by water with the dissolved chemicals content up to 2-0 – 30 g.p.l. We consider only the most promising Cambrian Complex here. The summary of our preliminary estimates of the density of geothermal resources within Belarus is shown in Fig. 9 (Zui, 2007).

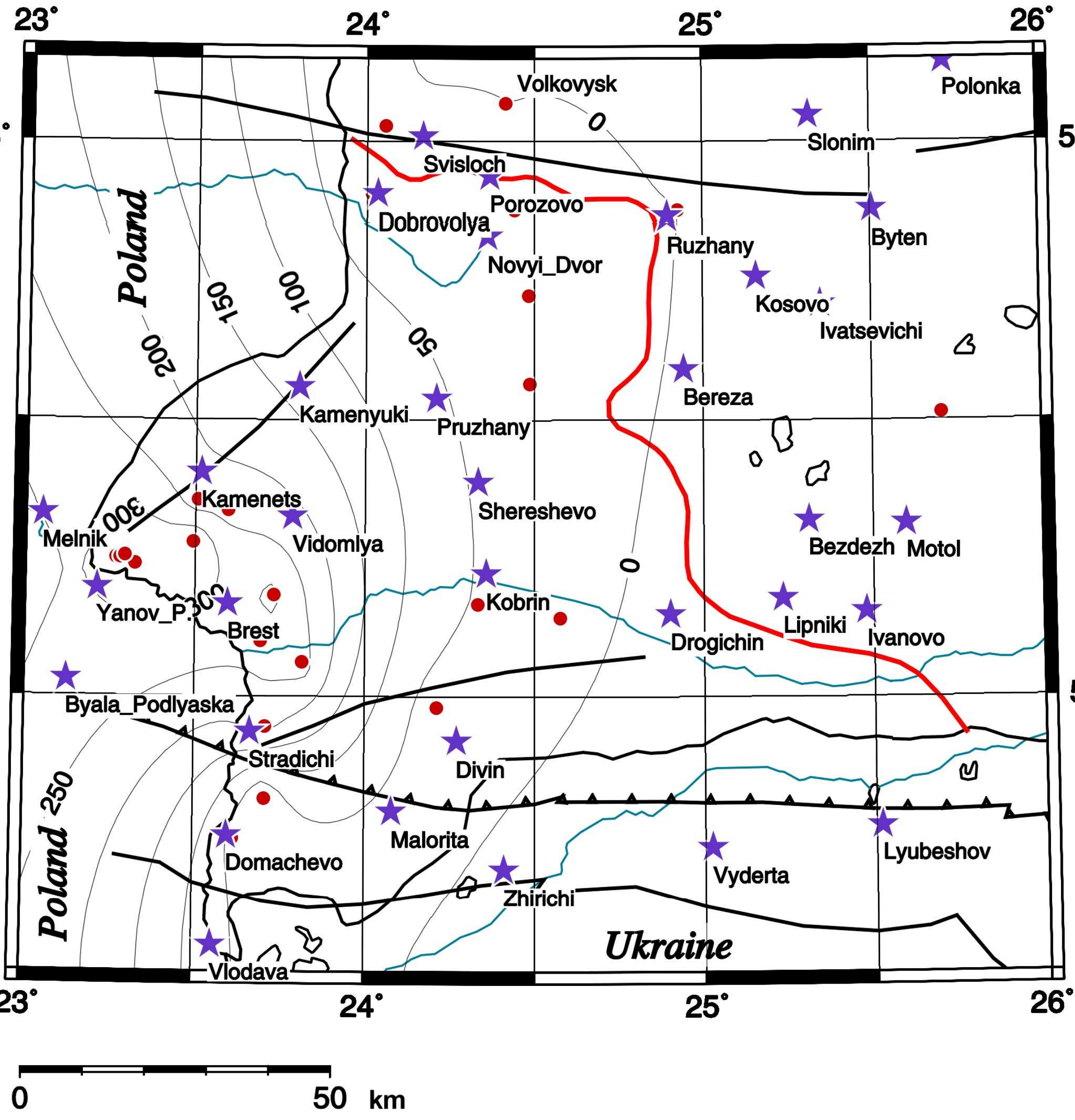

Fig. 9 – A distribution of the density of geothermal resources within the Cambrian rocks of the eastern part of the Podlaska – Brest Depression (Zui, 2007).
Legend: The red line show limits of the Podlaska – Brest Depression; black lines show the position of tectonic faults. Isolines are shown in kg.o.e./m^2.

To the north of the line crossing Kaments – Kamenyuki – Pruzhany – Kosovo towns and settlements the isolines were drawn by an extrapolation as studied boreholes absent there. The resources vary in a wide range from 0 to more than 350 kg.o.e./m^2. The zero isoline represents the margin, to the east and north of which Cambrian deposits absent

Maximal values of the geothermal rsources density is observed to the north-west of Brest within the area adjoining the Belarus – Poland border. In particular, the Pribugskaya Structure well studied in geothermal respect belongs to this area. In the direction to outer borders of the depression was observed deceasing of the geothermal resources density. It results from both the shallower position of the roof of Cambrian deposits and a reduction of their thickness. Within the area around Brest town the density varies from 250 to 300 kg.o.e./m^2. In general this parameter is mostly subjected to the depth of the productive horizon and its thickness. The former factor influences the temperature at their roof, which on average is proportional to this depth.

In southern part of the considered region near the Lukow – Ratno Fault we observe rather rapid reduction of the resources density of the Cambrian geothermal horizon to values below 50 kg.o.e./m^2. For instance, in boreholes of the Berestye Sanatorium these deposits absent at all and in the Domachevo 1 hole their thickness is only 78 m. The density of geothermal resources drops to 31 – 50 kg.o.e./m^2 In the vicinity of Kobrin town these parameters are 136 m and 46 kg.o.e./m^2, respectively. Within the triangle of Kamenets – Dobrovolya – Shereshevo settlements studied boreholes absent. Respectively, the position of isolines was extrapolated.

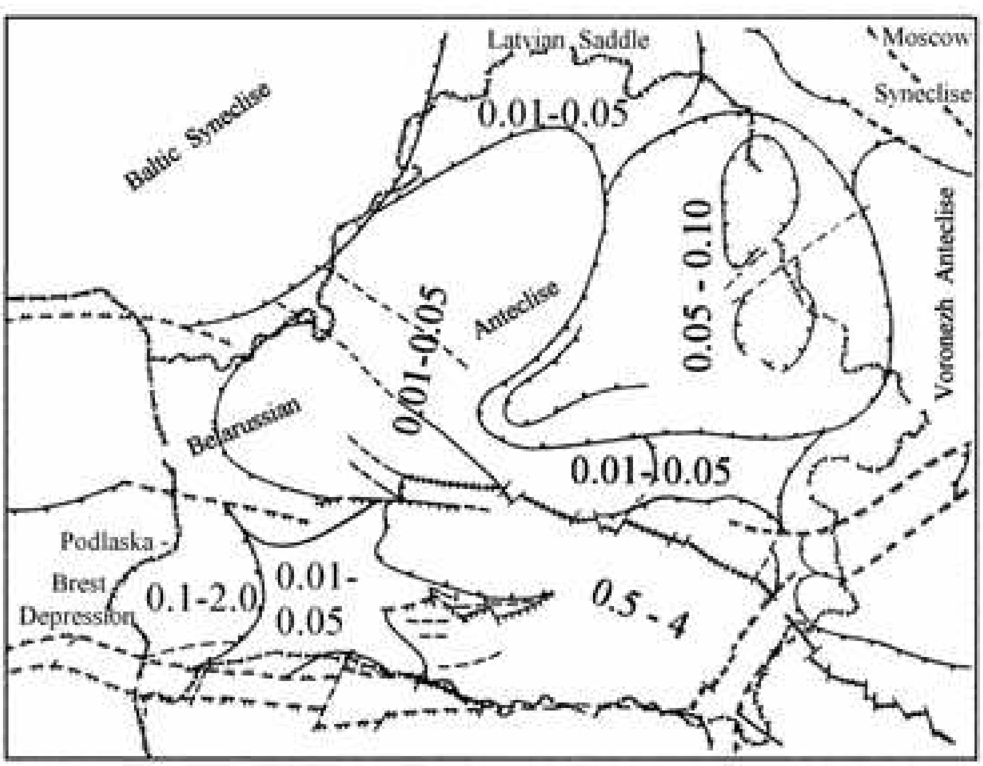

Fig. 10: Simplified chart of the density distribution of geothermal resources within the territory of Belarus in t.o.e/m^2.

The Orsha Depression is the third deep sedimentary basin within the considered area. The temperature at the crystalline basement here doesn't exceed 30-35 °C at the depth of 1.5-1.7 km. The Belarusian Anteclise is a vast positive structure with a thickness of sediments ranging from 100 to 500 m. Low temperature values (8 – 20 ºC) were observed here. Only very preliminary information is available now on the density of geothermal resources within the Orsha Depression. The same concerns the Byelorussian Anteclise adjoining saddles and inliers.

A chart of the estimated density of geothermal resources is shown in Fig. 10. Results show that geothermal resources, existing within the platform cover of the country, are varying in a wide range from first dozens of kg.o.e./m^2 within the Belarusian Anteclise and its saddles to approximately 100 kg.o.e./m^2 for the Orsha Depression. They are higher (300 – 350 kg.o.e./m^2) within the Podlaska – Brest Depression. The density of geothermal resources as high as 3 – 4 t.o.e/m^2 correspond to the Upper Salt Complex of the Pripyat Trough.

Dozens of deep unused holes were drilled in the process of oil prospecting works outside oil fields within the Pripyat Trough, which were later plugged and abandoned. It is possible to use them as a basis to create geothermal installations for heating of dwelling, as well as to satisfy demands of agricultural and industrial users.

There are 8 small geothermal installations which are already under exploitation in the country. They use heat pumps with the total installed heat capacity around 1.5 MWt. At present works are undertaken to construct the first in Belarus geothermal station for the greenhouse complex “Berestye” in the Brest town. The Republican Unitary Enterprise “Belgeologiya” recently finished drilling a deep borehole to recover warm water. Its tests showed the flow rate of 42 m^3/h and the temperature at the drill hole mouth is around 24 – 24 °C.

CONCLUSIONS

Both the temperature and heat flow field parameters very in a wide range within the whole territory of Belarus. In result, both these fields represent a sufficient both the lateral and vertical changeability. These variations are especially pronounced within areas of differentiated salt tectonics, like salt swells and domes which exist within the Pripyat Trough.

Terrestrial heat is a perspective renewable and ecologically clean resource of energy in the country. Its utilization represents an important national goal for the economics of Belarus. Low-enthalpy geothermal energy could be used practically within the whole territory of the republic. But the density of geothermal resources varies in a wide range from 0.01 to 4 – 5 t.o.e/m^2. Low values are typical for the main part of the Belarusian Anteclise and adjoining Latvian, Polesian and Zhlobin Saddles. These values are slightly higher for practically the whole territory of the Orsha Depression (0.05 – 0.1 t.o.e/m^2). All these structures, except the Podlaska – Brest Depression and the Pripyat Trough, are still sporadically studied in the sense of their geothermal potential. This work could be done in the nearest years.

The so-called Intersalt sediments, the thickness of the Upper Salt, Devonian deposits, overlying the Upper Salt, and the Jurassic accumulations, comprising the geologic crossection within the Pripyat Trough, were considered as geothermal horizons. Calculations showed that the density of geothermal resources within the Intersalt Complex range on average from 0.1 to 1.75 t.o.e./m^2.

Maximal values correspond to the north-eastern part of the trough. In the southern part of this unit they drop to 0.25 – 0.65 t.o.e./m^2.

Within the Jurassic and the Devonian deposits, overlying the Upper Salt, the density of geothermal resources usually corresponds to a few dozens of kg.o.e./m^2. Within the impermeable Upper Salt Complex they are much higher and reach in some blocks of the trough up to 2 – 4 t.o.e./m^2. Their utilization is possible by means of borehole heat exchangers.

The first order most promising geologic units within the territory of Belarus for practical utilization of geothermal energy are the Pripyat Trough and the Podlaska-Brest Depression. The geothermal conditions of the trough are similar to those in the western part of Lithuania, where the pilot Klaipeda Geothermal Plant is used during a few years. The northern and north-eastern parts of the trough, as well as the Podlaska-Brest Depression represent the paramount interest to construct there a pilot geothermal plant, which would be useful to stimulate the practical utilization of geothermal resources in the country, though the rest area of the country has the density of geothermal resources, acceptable for practical utilization using both vertical and horizontal heat exchangers coupled with heat pumps.

Many boreholes were drilled within the Pripyat Trough outside oil fields in the course of oil prospecting works. Dozens of them could be repaired and used to exploit the geothermal resources. Their reanimation will increase the economic feasibility of such projects.

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Acknowledgements

This paper became possible partly due to the grant No. X06B-002/2 of the Belarusian Republican Fund for Fundamental Investigations, allocated to V. Zui.