The possibilities of diverse use of geothermal energy in Lithuania

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Abstract

Lithuanian's territory with regard to its geology and tectonics belongs to the western edge of the Precambrian East European platform. The sedimentary formations (from Vendian upto Quaternary) lie ontop of the Precambrian basement rocks. According to the depth of basement three large tectonic structures are determined in the territory of Lithuania: the Baltic Syneclise (Craton) and its slope, the Mosurian-Belarusian Anteclise, and the Latvian Saddle. Research of geothermal energy started in 1988. First of all (since year 1994) the shallow geothermal resources have been used in developing individual heating systems with heat pumps. The geothermal resources up to 100 meters depth are very attractive. It is very easy to use: they are spread everywhere and are renewable. The main deep-hydrothermal resources are related to aquifers of regional Cambrian and Devonian. Usage of geothermal resources from Devonian for the centralize heating started at 2000. The first geothermal demonstration plant in Lithuania was built in Klaipeda. The total capacity is 41 MW. Two production and two injection wells were drilled. The geothermal water (38^{o}C and salinity ~98 g/litre) is pumped from 1100 m depth. Petrothermal resources are related to the Hot Dry Rocks (the temperature is 150-180^{o}C at the depth 4-5 km). The legal and economical-technical problems hinder realization of usage of geothermal energy in Lithuania.

Keywords: *Lithuania, geothermal energy, Cambrian and Devonian aquifers, Klaipeda geothermal demonstration plant, balneological health-resorts.*

1 Introduction

In the context of the western part of the Eastern Europe Platform (with average density of heat flow of 40-50 W/m^2) Western Lithuania has higher heat flow of 90-100 W/m^2 in the area over 42400 km^2 on land besides offshore to the West in the Baltic see. Qualifying geologically, Western Lithuania must be considered a rare phenomenon (heat deriving from altered mantel) among those in old geological platforms. According to geothermal parameters it can be compared to areas of young orogeny (Kepezinskas et al, 1996).

In Lithuania geothermal data were being collected together with oil explorations. Since 1988 independent investigations of geothermal conditions have been carried out. Mostly by institutes of Geology (recently Geology and Geography) and Energy. Practical work is done by company "Geoterma", which was consulted and financed by the Danish government to build Klaipeda Demonstrational Geothermal Plant with capacity of 49,3 MW. Since 1994 shallow geothermal resources have been used, mostly in household sector. These geothermal resources laying in depth up to 100 m are very attractive because they are easy to reach and technically simple to use. There are really favorable perspectives for development in this field (Suveizdis et al., 2000).

There are ideas to produce electric power using hot dry rock technology in Lithuania.

There is still no evaluation of possibilities to use thermal water for the spheres of health care, recreation and tourism developing them for business.

2 Methods

Geothermal investigations are a sort of geological exploration and are closely related with oil explorations. The first temperature measurements of geological section started with drilling deep wells. The first geothermal wells were drilled in Vydmantai (2 wells) and Klaipeda (4 wells). Geothermal plant is built in Klaipeda. Geological, geophysical, laboratorical and experimental data are being analyzed and generalized.

3 Regional hydrogeothermal aquifers

There are three regional hydrogeothermal complexes in geological section of Lithuania: Cambrian, Lower/Middle Devonian and Middle/Upper Devonian. In Eastern Lithuania Cambrian aquifer interconnects with Vendian aquifer, and Cambrian with Ordovician in Western Lithuania. All above mentioned aquifers have not only accumulated heat, but they are also rich in chemical elements. Up to now these qualities of underground waters are not utilized for human sake. The table shows generalized results of thermal water chemical analysis and collates them to those of famous spa resorts. Lithuanian thermal waters could be used for bathing, therapeutic purposes, recreation. The culture of balneology has been prestigious in Central Europe and Japan. According to historical sources it is aware that Grand Duke of the Great Duchy of Lithuania Stephen Bathor (XVI century) vested palace doctor M. Bucelli with the privilege to extract salts from mineral springs. It is still not available for everybody in our time, despite the fact that mineral waters were used for healing for centuries. Balnelogical culture in Lithuania is still not so well developed like in Central Europe. Natural and geological circumstances are favorable for this field. There are two places in Lithuania with people willing to utilize thermal waters not only for producing heat, but also for healing and recreation – Vilkaviskis and Baisogala.

The Mayor of Baisogala is taking an initiative to fund a geothermal heat plant and health, rehabilitation and recreation complex. Baisogala is a small town in Middle Lithuania with over 5000 inhabitants. It has old and noble past. Komarai manor house extant from XIX century is one of most beautiful places here. In Baisogala there is Lithuanian Institute of Animal science in which would be possible to carry out scientific research on underground mineral water use for cattle growing.

Vilkaviskis is situated in Southwest Lithuania and has population of over 15.000 inhabitants. The German engineering company Geothermie Neubrandenburg GTN and Lithuanian Institute of Geology in 1996 prepared the balneology-geothermal project for Vilkaviskis. Within the framework of a first study, the geothermal potential was evaluated and planning of heat recovery for energetic purposes was started. In the course of the investigations, the chemical composition of the deep waters was analyzed. It is known that Cambrian waters of similar composition are suitable also for balneological purposes. Water use for medicine is basically determined by the salt content (predominantly NaCl) and the contents of trace elements such as iodine, iron and others, as well as the temperature.

3.1 Cambrian hydrogeothermal aquifer and characterization of thermal water

The Cambrian deposits are one of the oldest sedimentary rocks in the Baltic basin. Mostly they lie on the top of Proterozoic basement, and only in the eastern part of the basin they cover Vendian. The Cambrian exists everywhere except for southern Lithuania and in some local geologic structures (Plunge, Veiverzenai, Baubliai). The thickness of Cambrian siliciclastic rocks varies from 0 to 177 m (Zemyte-1). The boring depth in western Lithuania is more than 2 km. Representative sections of Cambrian succession of Lithuania are in Figure 1 (at the end of the paper). The Cambrian rocks could be utilized as a source for energy and minerals, and as a reservoir. Existing data suggest the usage of Cambrian as follows:

Cambrian rocks are most important oil and gas bearing rocks in the region and economically profitable deposits have been found. Oil field exploration is one of the main aims of Cambrian studies in Lithuania.

In the frame of oil researches, higher temperatures (40-90°C) of Cambrian rocks and pore fluids have been found. Exploitation of terrestrial energy in western parts of Lithuania is important not only from energy point of view, but also from environmental aspects (low pollution in case of use renewable energy source).

After extraction of heat, the groundwater could be directed to extract chemical elements and compounds, which are dissolved in the water. Unfortunately, chemical composition of deep waters was formerly studied in connection with oil search and mainly only these components were analyzed which lead to hydrocarbon appearance. Presently the need for geothermal energy has grown and deep groundwater studies have been activated. The content of insoluble residue decreases from about 200 g/l in western Lithuania to about 100 g/l in the eastern part. Characterization of thermal water are presented in Table 1.

Table 1: Chemical composition of thermal water in Lithuania and in the famous resorts.

Parameters	Units	Cambrian	L-M Devonian	M-U Devonian	Blue Lagoon	Dead See	Tiberias	Baden-Baden	Sea water
pH		3-5,9	4,7-7,4	6,9	7,37			8,2	
TDS	g/l	107,6-202,9	20,5-110	5,0-35,0	24,4	310	26	3,1	35,82
K	mg/l	340-936	80-554	167	1030	7560	291	32,9	392
Na	mg/l	22515-40260	1735-28218	5245	6910	34940	5600	851	10800
Ca	mg/l	6426-30395	971-12353	1218-1856,7	1100	15800	2752	144	411
Mg	mg/l	275-5291	234-3023	60,8-358	0,81	41960	595	58	1290
Fe	mg/l	11,6-226,4	1,06-174	-	-	-	-	-	3400
NH_4	mg/l	8,1-139,5	9-72	29	-	-	-	-	-
Cl	mg/l	66690-126647	3617-60030	14317,92	13550	208070	15051	1442	19400
HCO_3	mg/l	3-294	24-314	120,78	-	-	-	-	-
Br	mg/l	261-1109	67-407	50-78,59	44,5	5,6	133	1,6	67,3
J	mg/l	0,41-3,81	0,16-1,65	0,21	-	-	-	-	-
SO_4	mg/l	33-2323	1409-3536	2390,9	31	0,5	695	209	-
B	mg/l	4,4-100	2,3-44	8-27,85	-	-	-	-	-

3.2 The Middle/Lower Devonian hydrogeothermal aquifer and characterization of thermal water

In its upper part the Piarnu sandy layers (20-40 m thick) are singled out. In the middle part of aquifer there are Viesvile (Kemeri) layers (100-130 m thick), which upper part (about 35 m) is composed of clayey rocks mainly. These are Viesvile layers lying over the sandy Sesuvis layers (100 m thick). In the lower part of aquifer there is Gargzdai series reaching 200 m in thickness. All aquifers are with greatly varying lithology: sandy and sandstone light gray, fine-medium grained, some silt and clay, some gypsum, siltstone and claystone.

In the area near to the Baltic Sea the roof temperature of the Parnu horizon exceeds +40°C, and at the foot of Lower Devonian it even exceeds +50°C. In the central part Lithuania the roof temperature is +20°C. Water mineralization is varying from 20 to 110 g/l (Table 1). The upper part of M/L Devonian aquifer – Kemeri (Viesviles) horizon is used as productive in Klaipeda geothermal demonstration plant. The geological actual section and construction of geothermal well Klaipeda-4I is presented in Figure 2 (at the end of the paper). Klaipeda geothermal demonstration plant has two production and two injection wells. The depth of wells is 1128 to 1228m. Low-temperature geothermal heat is extracted from geothermal water (38^{o}C) using an absorption heat pump and transferred to district heating network of Klaipeda. Total thermal capacity of plant – 41MW: 17MW geothermal heat and 24 MW heat from boilers. Total amount of heat produced by KGDP in year 2002 was – 189000 MWh, but plant is still not handed over by State Commission because of problem gypsification in a pipeline system.

3.3 The Middle/Upper Devonian hydrogeothermal aquifer and characterization of thermal water

The Middle/Upper Devonian (Upninkai-Sventoji) hydrothermal aquifer consists of two stratigraphically isolated, but hydraulically related terrigenous variegated rock horizons. Their total thickness ranges from 170 to 200 m. Layers of Upninkai and Sventoji are composed of similar terrigenous deposits sand, weakly cemented sandstone, aleurite, clay, sometimes dolomitic marl.

Weakly cemented aleuritic sandstones with lenses and interlayers of fine and very fine sand represent the collecting layers. These deposits have accumulated rather high quantities of geothermal water. Aquifers (1-25 m thick) alternate with impermeable layers (3-25 m thick). Mean open porosity is rather high and ranges from 16 to 25%. Lithological composition of this aquifer (D2up-D3sv) is present in Figure 2.

Characterization of thermal water is present in Table 1.

3.4 Overview of the possibilities to produce electric power

In 1995 prof. Y.D. Diadkin (Sankt Peterburg) asked by Institute of Geology of Lithuania performed economical-mathematical simulation and presented tentative technological parameters of abyssal circulating system for producing electric power from geothermal heat in Klaipeda city. Using for calculations basic data (the thickness and the geothermal gradient of sedimentary cover - 2330m and 0.035 C/m; the geothermal gradient of crystalline basement rocks -0.03 C/m) it was assumed that the lowest temperature acceptable for electricity production must be 140^{o}C and, in this

case, the depth of well was find 4103m. The price of produced power would be 12.3 ct US/kWh and price of produced heat 2.04 USD/GJ (0.734 ctUS/kWh).

In year 2001 average electricity tariff in Lithuania was 6.07ctUS/kWh (excl. VAT) and heat tariff - 2.73 ct US/kWh (excl. VAT).

4 Conclusions

Existing theoretical studies and practical results show that in Lithuania:

1. Shallow geothermal resources already are used in individual heating systems with heat pumps.
2. Hydrogeothermal resources of Cambrian, Middle/Lower Devonian and Middle/Upper Devonian aquifers could be used for heating, hot water supply, and balneological and therapeutic purposes,
3. Petrothermal resources could be used for heating and electric power production.

5 References

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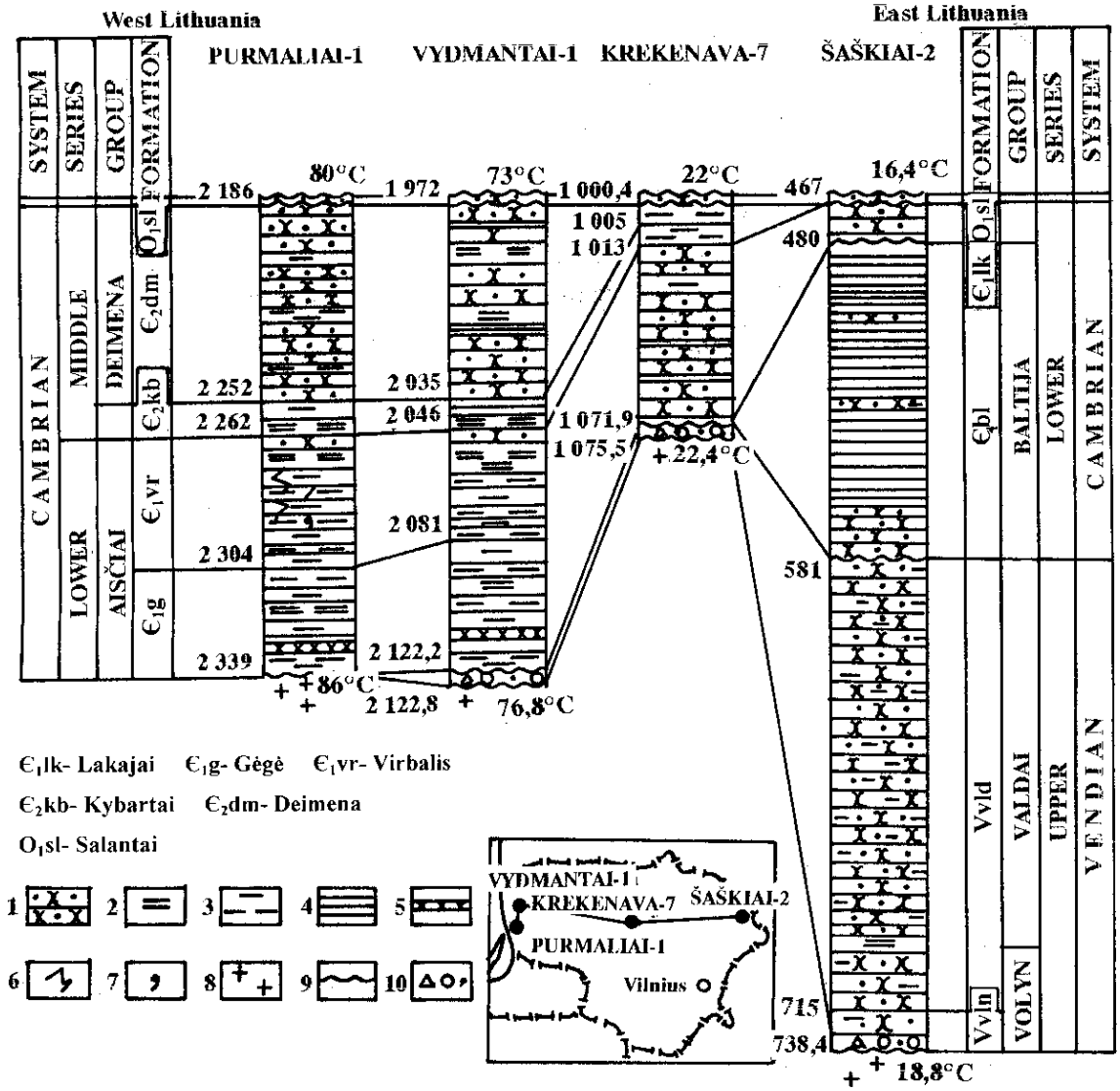

1-sandstone; 2-sandy siltstone; 3-siltstone; 4-argillite; 5-sandstone interlayer; 6-fractures; 7-glauconite; 8-crystalline basement; 9-unconformity;10-conglomerate, brecia

Figure 1: Representative sections of Cambrian succession of Lithuania.

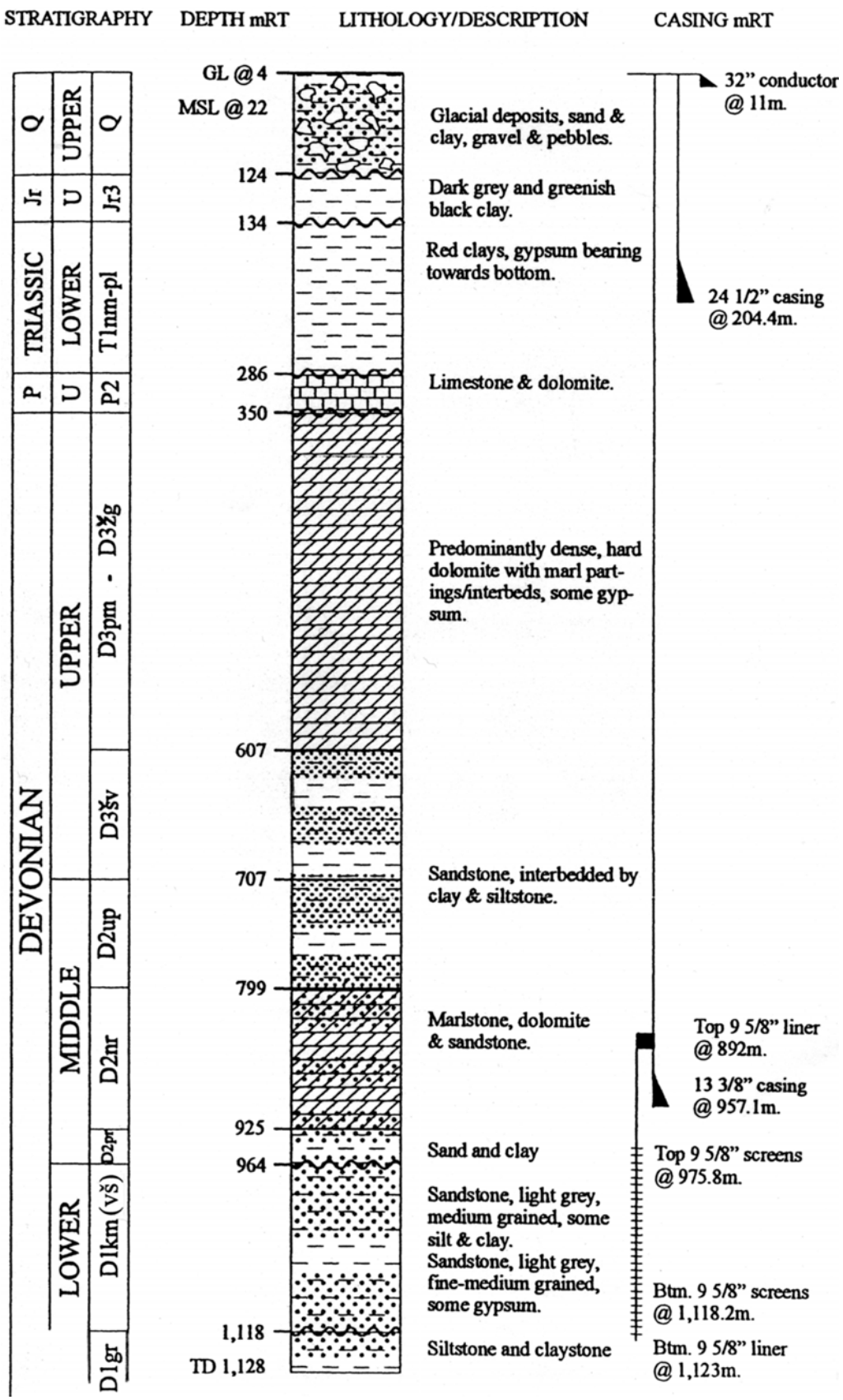

Figure 2:Geological actual section of Klaipeda geothermal well KGDP-4I. (prepared by Petroleum Geology Investigators Aps, Denmark).