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Mineral and thermal water

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Geothermal resources

title: **The most prospective areas of use of thermal waters for heating purposes in the Polish Lowlands**

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Poland is characterized by significant low-enthalpy geothermal resources, connected mostly with the Mesozoic sediments. Space heating represents the most important type of direct uses. Five geothermal heating plants are in operation. The biggest one is located in the Podhale Trough in the Carpathians Mts., while the remaining operate in the Polish Lowlands: Pyrzyce, Mszczonów, Uniejów, Stargard Szczeciński (Fig. 1). Total installed geothermal power is estimated at about 44.8 MWt with annual production of energy ranging about 480 TJ/a (Kępińska, 2005).

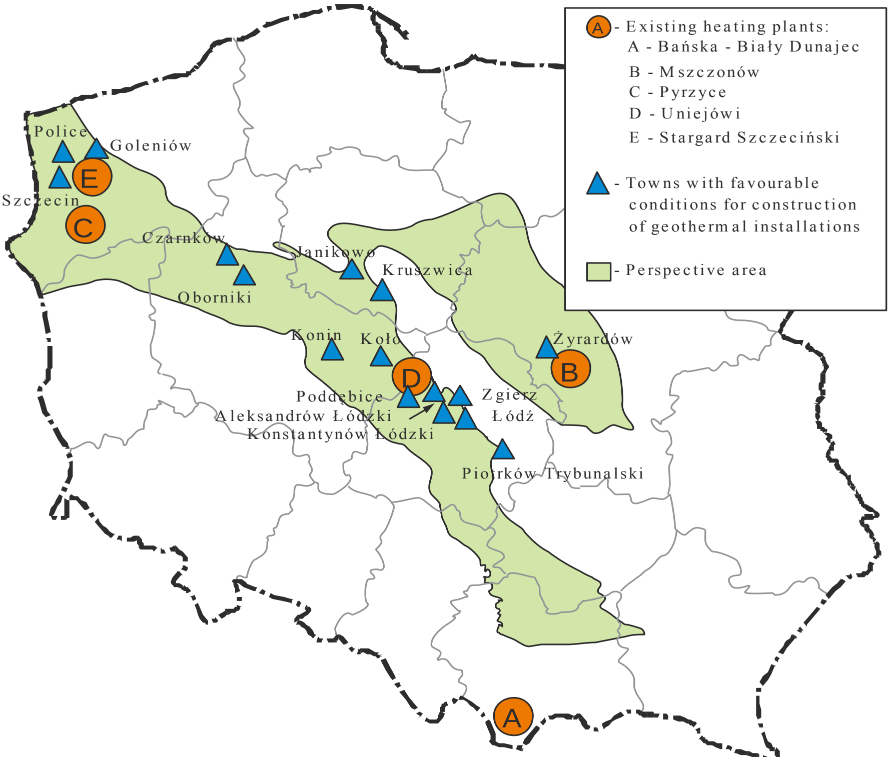

Figure 1. Location of towns with favorable conditions for construction of geothermal installations in the Polish Lowlands and existing geothermal heating plants in Poland.

Within geological sections of the Polish Lowlands, in the Early Paleozoic through Early Cretaceous formations, a number of layers which indicate possible occurrence of good geothermal aquifers can be distinguished. Hydrogeological and thermal parameters that characterize aquifers in the Polish Lowlands indicate possibility of complex utilization of thermal waters, as well for energy production as balneotherapy and recreation.

The paper presents results of assessment of geothermal energy resources accumulated within nine Paleozoic and Mesozoic aquifers in the Polish Lowlands, made within the framework of the project entitled "Geothermal atlases of the Mesozoic and Paleozoic formations — geological analysis and thermal water and energy resources in the Polish Lowlands" (Górecki (ed.), 2006a, b). The project had been commissioned by the Polish Ministry of Environment and was carried out in the years 2004–2006 by a research team composed of specialists from several scientific and commercial institutions with the AGH University of Science and Technology as a leader of the team.

The calculation area measured approximately 270 th. km^2 that represents more than 87 percent of the territory of Poland and comprises nine major aquifers in the Polish Lowlands: Lower Cretaceous, Upper Jurassic, Middle Jurassic, Lower Jurassic, Upper Triassic and Lower Triassic aquifers of the Mesozoic formation, and Lower Permian, Carboniferous and Devonian aquifers of the Paleozoic formation. The distinguished geothermal aquifers were characterized, among others, from the point of view of their geological setting (lithology, stratigraphy and tectonics), extent and depth of the aquifers, their thickness, temperature, water mineralization, discharge of water intakes and calculated resources of energy.

The calculations were made with regard to the classification of resources, in accordance with the McKelvey's diagram. The accessible, static and static-recoverable geothermal energy resources had been distinguished (Haenel, 1982; Muffler, 1975; Muffler, Cataldi, 1979; Sorey et al., 1983).

Considering the extent of the Mesozoic and Paleozoic geothermal aquifers in the Polish Lowlands, that expresses also the area of calculation (rounded up to 1 th. km^2), they can be arranged in the following order: Lower Triassic (229 th. km^2 — 73% of the territory of Poland), Middle Jurassic (205 th. km^2 — 66%), Upper Jurassic (198 th. km^2 — 63%), Upper Triassic (178 th. km^2 — 57%), Lower Jurassic (160 th. km^2 — 51%) and Lower Cretaceous (128 th. km^2 — 41%). The largest calculation area among all Paleozoic geothermal aquifers is occupied by the Lower Permian aquifer: ab. 102 th. km^2, which constitutes 37% of total area of the Polish Lowlands and 33% of the whole territory of Poland.

According to the McKelvey's diagram, the total accessible geothermal resources accumulated in the rock formations down to 3 km depth or down to the top surface of the crystalline basement amount to 7.753×10^{22} J, which is an equivalent of 1.85×10^{12} TOE (*1 TOE* — tonne of oil equivalent, 1 toe = 41.868 GJ).

The principal resources of thermal waters in the Polish Lowlands are reservoired in the Mesozoic groundwater horizons. Thermal waters are accumulated first of all in the Lower Jurassic and Lower Cretaceous formations but significant resources of geothermal energy are reservoired also in the Upper Jurassic, Middle Jurassic, Upper Triassic and Lower Triassic formations.

Total static geothermal resources which express the amounts of free (gravitational) thermal water hosted in pores, fractures or caverns expressed in m^3 or km^3 of water, recalculated after taking the water temperature into the energy units — Joules, accumulated in thermal waters of the Polish Lowlands sedimentary formations are estimated at 1.45×10^{22} J, which is an equivalent of 3.47×10^{11} TOE. The largest static geothermal resources are accumulated in the Lower Jurassic aquifer and were estimated at about 6320 km^3 of water with temperature ranging from 20 to up to 120 degC (Fig. 2).

Energy accumulated in waters of the Lower Jurassic aquifer was calculated to be 2.99×10^{21} J (7.14×10^{10} TOE). Considering the distribution of static resources per area unit, the best parameters among the Mesozoic aquifers are revealed by the Lower Jurassic aquifer — 1.86×10^{16}J of energy per 1 km^2. Mean unit static resources for the Mesozoic aquifer are equal to 9.41×10^{15} J/km^2 (Hajto, 2006).

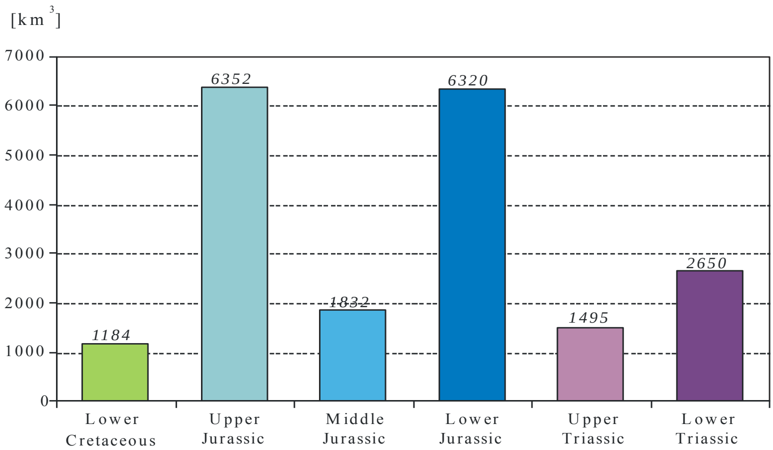

Figure 2. Static resources of thermal water within particular geothermal aquifers of Mesozoik age in the Polish Lowlands.

The amount of static-recoverable resources gives information on the fraction of geological (static) resources that can be theoretically recovered under specified technical parameters of exploitation and utilization of the geothermal medium, i.e at given cooling temperature and with given exploitation method (Gringarten, 1975, 1979). The value of Ro index depends on an exploitation method (single- or double-well system) and on relationships between the reservoir temperature, injection temperature (in doublet system) and mean annual temperature at the Earth's surface. For the calculations it was assumed that waters are exploited by a doublet and the injection temperature does not exceed 25°C. Averaged values of the recovery index calculated for all aquifers of the Polish Lowlands are ranging from 12.8% for the Upper Jurassic to 26.7% for the Lower Permian aquifer. Average Ro value calculated for all nine geothermal aquifers of the Polish Lowlands are estimated at 19.9% (Hajto, 2006).

These results demonstrate that under geological and temperature conditions dominating in the Polish Lowlands it will be possible to recover less than 20% of geological resources of accumulated geothermal energy. Total static-recoverable geothermal resources are equal to 2.9×10^{21} J. The largest geothermal resources which are possible to be produced are accumulated in the Lower Triassic aquifer and are estimated at 6.13×10^{20} J (1.46×10^{10} TOE) (Hajto, 2006).

Additional estimation of energy accumulated in particular temperature classes of thermal waters enables preliminary evaluation of ways of thermal water utilization. Application of the methodology of factor evaluation of the economic effectiveness of heat recovery (the power factor) enabled preliminary assessment of the geothermal energy utilization profitability at the regional scale and indication of prospective areas within particular aquifers, but for this purpose the appropriate market of heat consumers for a geothermal plant construction should be specified.

The area of potential locations of the new geothermal projects corresponds with the area revealing the most favourable geological and hydrogeological conditions within the main aquifers in the Polish Lowlands (Fig. 1). As regards the amount of accumulated energy, the most interesting and promising areas occur in the Warsaw Trough, Mogilno - Łódź Trough (in the central part of Poland) and Szczecin Trough (in the northwestern part of the Polish Lowlands). Utilization of thermal waters for heating purposes in particular voivodships and towns of central Poland should, first of all, be based on the resources of the Lower Jurassic aquifer. Possibilities of geothermal energy utilization in remaining areas are rather low and related to limited areas.

The Atlases were elaborated with application of digital processing of geological data and digital mapping. All calculations were run with the use of the OpenWorks integrated geological data processing system developed by Landmark Graphics Co. The software is licensed under the conditions of educational license No. 2003-COM-020272 and 2003-COM-020273.

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