



# Geothermal energy of the Mesozoic Basin in the Carpathian Foredeep, Kraków Region, Poland

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## Abstract

Although the most favourable conditions for the use of geothermal energy are found in the Tatra region, in addition, the Foreland of the Carpathians in Poland is rich in low-temperature geothermal waters, both in Cenomanian sandstones and Middle Jurassic sandstones. The geothermal activity is manifested by thermal waters in boreholes situated between the towns of Włoszczowa, Myślenice and Tarnów. Here the Mesozoic waters occur 200 to 2000 m below the surface and their temperatures vary between 20 and 70 °C. The continuous artesian outflow of geothermal waters was observed in many wells during long-term tests. The maximum artesian outflow of fresh water was observed in the zone north of Cracow, i.e. 100 m<sup>3</sup>/h with a temperature of about 20 °C. The results of the analyses which were carried out on the Mesozoic formation confirmed considerable zonation and the existence of local constraints on the reservoir parameters which result from the characteristics of the deposited environment. A distinct relationship was also noted between the total thickness and other reservoir parameters. Moreover, a strong correlation was observed between the degree of water mineralization and the distance from the infiltration zone or depth at which the waters occurred. In the western zones, located close to the recharge areas, waters are fresh or nearly fresh and their temperatures are influenced by surface waters. Favourable conditions for the financial investment in geothermal energy in the Mesozoic Basin of this region are associated with the low mineralization (allowing for exploitation with a single well) and shallowness of the aquifers (i.e. low drilling costs). The paper presents results of analyses of the temperature characteristics of the Mesozoic formation, yields from existing wells and the energy potential of geothermal waters from the point of view of future geothermal projects.

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*Keywords:* Geothermal; Thermal and reservoir parameters; Carpathian Foredeep

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## 1. Introduction

Mesozoic reservoirs present the best opportunities for the utilisation of geothermal water in the area of the Carpathian Foredeep. The primary geological complex for geothermal use in this area is the Cenomanian one that occurs within the area of the Carpathian Foredeep, the Miechowska Trough and the Carpathian Foreland [1,2]. In addition, the Middle Jurassic complex may provide a potential reservoir for geothermal use [3].

The upper seal of the Cenomanian aquiferous level is usually formed by glauconite Santonian marls or compacted Turonian limestone. Depending on the degree of fracturing and karst formation, the underlying Late Jurassic sediments constitute either a bottom sealing of the stratum or a source of intermediate recharge.

Within the Jurassic complex in the central part of the Carpathian foreland, the Dogger sandstone formations exhibit the best reservoir parameters. The direct contact of these formations with fractured and karstic Late Jurassic formations is very favourable, due to the accumulation of thermal waters migrating from the zones of direct and indirect recharge. The geothermal resources here presented may be described as resources of medium and large porosity formations (locally exceeding 30%) under conditions of hydrostatic pressure and artesian pressure as well as of low water mineralisation. The low mineralisation increases the potential for using the water both for consumption and for therapeutic purposes.

## 2. Lithology and hydrogeological parameters of the Cenomanian and Dogger formations

The sandy Cenomanian horizon was prospected in the 1970s. Earlier works on Cenomanian waters were published by Oszczypko and Tomáš [4] and Jawor [2].

The best-developed Cenomanian sediments of the greatest thickness occur along the central zone of the reservoir running through such places as: Węgleszyn, Jędrzejów, Kazimierza Wielka, Koszyce, Szczurowa and between Bochnia and Brzesko towards Połom Duży (Fig. 1).

The distribution of porosity and permeability in a Cenomanian reservoir correlates with the general distribution and the thickness of sediments. In the conglomerate border-zone, porosity fluctuates by several percent and permeability fluctuates from zero to several mD (according to core testing). In sections, where the sandstone thickness exceeds approximately 3 m, porosity reaches a value above ten percent and permeability from several hundred mD to above 1 D. In sections where the thickness exceeds approximately 6 m, porosity is within the range 25–35% and permeability reaches several D.

The depth range of the complex bottom amounts to approximately 2300 m (in the Busko area: +100 m a.s.l., the region of Bochnia: –1000 m a.s.l. and in the region of Połom Duży: –2200 m a.s.l.). Such a significant range of depth has a direct bearing on the range of temperatures in Cenomanian waters in their various zones of occurrence (from 17 °C to 76 °C) and on their mineralisation (0.2–115 g/l, see Table 1).

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