

HYDROGEOLOGY OF THE MINERAL WATER RESOURCES IN BARDEJOV SPA

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The written history of Bardejov Spa dates back to the first half of the 13th century, when the Cistercian religious order described the local healing springs under the name of Burcouth. At the same time, in 1247 was issued the donor charter thanks to the well-known natural springs to the city of Bardejov by the King of Hungary Belo IV. In the 14th century, Bardejov is becoming a spa town thanks to the building up of the first spa buildings designed for therapeutic purposes. The period of rapid growth during the 18th and 19th century was subsequently replaced by long-term stagnation in pre-war, inter-war and war times (1914-1945). The modern era of a major spa town from the second half of the 20th century and the first decade of the 21st century meant gradual reconstruction of facilities and transformation from state to stock ownership (Uličný, 1998).

Geographical and geomorphological characteristics of the area

From the geographical point of view, Bardejov Spa is located in the Prešov region in Bardejov district and the cadastral area of Bardejov. The location is situated in the valley of the Kvašný brook on the southwest slopes of Ondavská highlands, and the center of the village is at an altitude of 325 m. n. m.

Geomorphologically, the locality is subdivided as follows: the system: Alpine - Himalayan, subsystem: Carpathians, province: Eastern Carpathians, sub-province: Outer East Carpathians, area: Low Beskydy, unit: Ondavská highlands (Mazúr and Lukniš, 1978).

Generally, the relief in the vicinity of the Bardejov Spa is orientated to the west, preserving its preferential slope in the range of 5 - 12 °. The macrographs of the relief point to the gradual passage of the highly rugged hills to the medium to heavily rugged hills, which is typical for faulted and folded Karpaty, so called Flysch Carpathians, respectively for the morphostructural transversal depression of the Low Beskids. Representative microforms of the relief in Bardejov Spa are U-shaped valleys, landslides, structural rigidities and mineral springs (Tremboš and Minár, 2004).

Hydrogeology and climatology

Hydrologically, the Bardejov Spa is situated in the valley of the Kvašný stream, which is part of the Topľa river basin, and they are globally part of the the Black Sea drainage area. The hill-to-mountain relief, along with the geographical location of the area, are a conditional factor of local climatic conditions. In general, the area is slightly warm with an average number of summer days less than 50, characterized as a slightly warm and slightly humid climatic region (Lapin et al., 2004). Correspondingly, the average annual air temperature is 6 - 7 ° C (Šťastný et al., 2004), which is reflected in an average of 240 - 280 heating days per year.

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Geological structure of Bardejov Spa area

From the geological point of view, the area of Bardejov Spa belongs to the Neo-Alpine units of the Outer Western Carpathians. Flysch Belt zone, The Magura group of nappes, represented by the Bystrica unit, plays an important role in the composition of the area. In close proximity to the north of the village there is a tectonic contact between the Bystrica and Rača unit (Nemčok et al., 1990, Fig. 1).

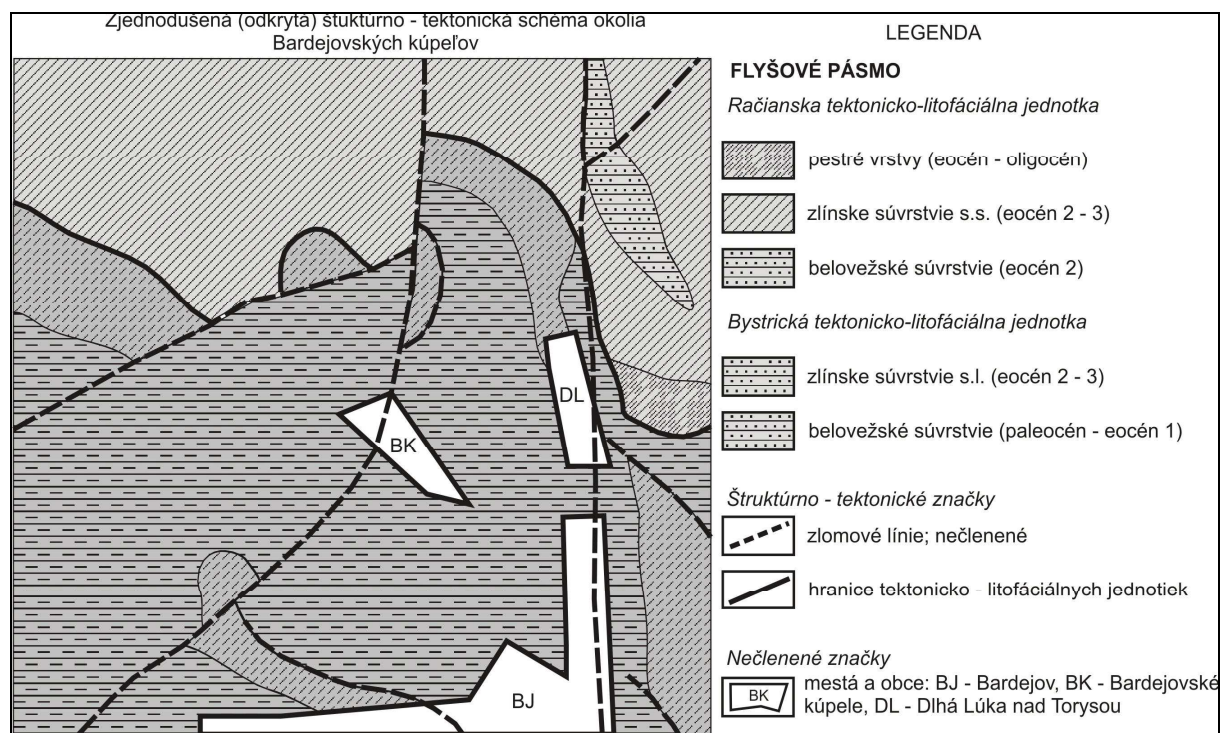


Fig. 1. Scheme of geological and tectonic situation in the surrounding of Bardejov Spa. Modified by: (Bezák et al., 2004, Nemčok et al., 1990)

The youngest salient formations in the vicinity of Bardejov Spa are alluvial quaternary fluvial deposits, reaching a thickness of 4,8 – 17,2 m. The predominant abundance is represented by clay and sandy gravels with weak to medium worked cobbles. In the eastern part of the spring zone there is a 1.5 m thick coarse peat position with clay admixtures.

Quaternary fluvial deposits passes directly into the rock bed. The most prominent representative of the Bystrica unit is the Lackov strata (middle eocene) made up of light-colored polymictic conglomerates of a pseftic to psamitic structure with fragments of slates, quartzites and melaphyres. The matrix is detritic, siliceous, or calcareous. For the occurrence of mineral waters, the presence of light fine grain sandstone, which are representing collectors of local importance.

The oldest, by hydrogeological boreholes captured tectonic unit is the Beloveža formation (paleocene - the lower eocene). Characteristic lithotype are greenish-gray, greenish-blue, brownish-grey to-red-purple calcareous claystone. In extremely predominant pelite stand out of the 30-70 cm thick arkosic sandstones bank.

It is highly probable, that in the subsoil of Beloveža Formation are exposed Tvarožec sandstones (Paleocene), presence of which is derived analogously. The complex is represented by bright, massive sandstone, strongly stained with red-rusty brown limonite. Unique are the peaks of strongly sandy clay. In the direction of the base, the massive sandstones pass into the position of the silicious small rythmited sandstones and the sandstones and shales (Nemčok et al., 1990).

Hydrogeological conditions

On the basis of the regional hydrogeological division, the area of Bardejov Spa falls under the hydrogeological region of the Low Beskids in the Topľa river basin, which is characterized by a fissure type of permeability (Malík and Švasta, 2004). Due to the litofacial type of collectors (conglomerates or fine sandstones), fissure permeability (the result of tectonic activity and exogenous factors, dislocation of rocks, derating and gravitation) is mediated by transverse permeability. The direct dependence of fatigue fill and hydrogeological characteristics reflects variability, mild to high hydrogeological productivity, ranging from $1 \cdot 10^{-4} - 1 \cdot 10^{-2} \text{ m}^2 \cdot \text{s}^{-1}$ (Malík et al., 2004).

Geological and tectonic conditions have influenced the occurrence of many natural springs of point, line and area character (wetlands) in the whole area. Since the infiltration zones are located on the surrounding slopes, the gradual development of local and intermediate flow subsystems towards the spring zones points to the complete openness of the local hydrogeological structure. In the area of Bardejov Spa is a relatively high concentration of natural springs (Figs. 2 and 3), which is supplemented by hydrogeological boreholes extending into the rock bed and collecting the storage-accumulation segment of the migration paths of mineral waters. Although the predominant genetic type is petrogenic (carbonatogenic), mineral water, a high proportion of the chloride component in some springs points to the mixing of waters with pertogeneuous and relic marinogenic mineralization (polygene water). According to Struňák et al. (1969), it is possible to divide the mineral water in the spring area into three groups:

- *the first group* is represented by Klára source, with a natural spring on the tectonic slip line, which is called Bardejov fault, respectively caught by hydrogeologic borehole BJ-20. Cold mineral water in this group is thinned in quaternary formations with precipitation water, with a hydrogen carbonate-sodium-calcium chemical character and with hypotonic properties, generally with a minor total dissolved solids in comparison to the others ($1800 - 2000 \text{ mg} \cdot \text{l}^{-1}$),
- *the second group* represent the wells Alžbeta (BJ-24), František (BKH-1), Herkules (BJ-33), Napoleon (BJ-18) and Colonnade Spring (BJ-19). The mineral waters of this group do not come into direct contact with precipitation, respectively with plain water.
- *the third group* represent the sources of Medicinal Spring, Anna (BJ-21), and Main spring. A common feature is the complex process of migrating water to the spring. The water does not spring from the rock bed, but breaks into the alluvial fan at the fault between the Main Spring and the borehole BJ-19, where it is mixed with ordinary groundwater in individual stratified collector positions of different permeability, separated by isolators of local importance. In the subsequent migration to the hydraulic barrier, the individual mineral waters do not communicate hydraulically.
 - the cold mineral waters of the second and third group are hydrochemically identical despite the different shaping conditions and the different nature of the spring parts. In both cases, the water is hypotonic, moderately mineralized hydrogen carbonate-chloride-sodium, with an increased content of lithium and boric acid.

- the exception is the Herkules spring - cold mineral isotonic water of bicarbonate-chloride-sodium character, which has the highest content of dissolved salts within Bardejov Spa.

In terms of predominant chemical formation processes, the dominant elements are: carbonate dissolution, gypsum dissolution and sulphide oxidation (in the case of SO₄ component) and hydrolytic decomposition of silicates in mineral waters of the shallow circulation. As the depth in case of mineral waters of the Bardejov Spa increases, the impact of ion-exchange processes and the hydrolytic decomposition of silicates increases, especially at the expense of sulphide oxidation, which is manifested by pushing to the elimination of the component S₂ -SO₄ (Vrana et al., 1990).

Balneology and indications

Wide range of mineral waters of different chemical composition, mineralization and properties (the active sources are Hlavný, Liečebný, Anna, Alžbeta, Ľudový, Klára, Napoleon, Kolonádový, Nový, Herkules, František and Alexander) is providing the national status for Bardejov Spa as a spa where different diseases can be treated, indications including: oncological diseases, locomotor disorders, circulatory and digestive diseases, metabolism disorders and endocrine glands diseases, non-tuberculous respiratory diseases, kidney and urinary tract diseases or occupational diseases.



Foto 1: Balneotherapy

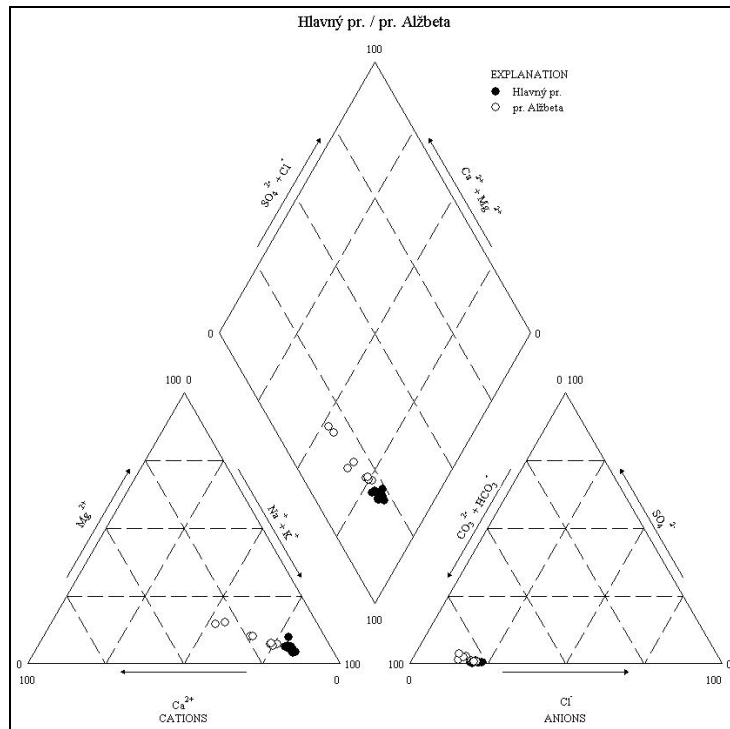


Fig. 2: The chemical composition of Main mineral spring and spring Alžbeta

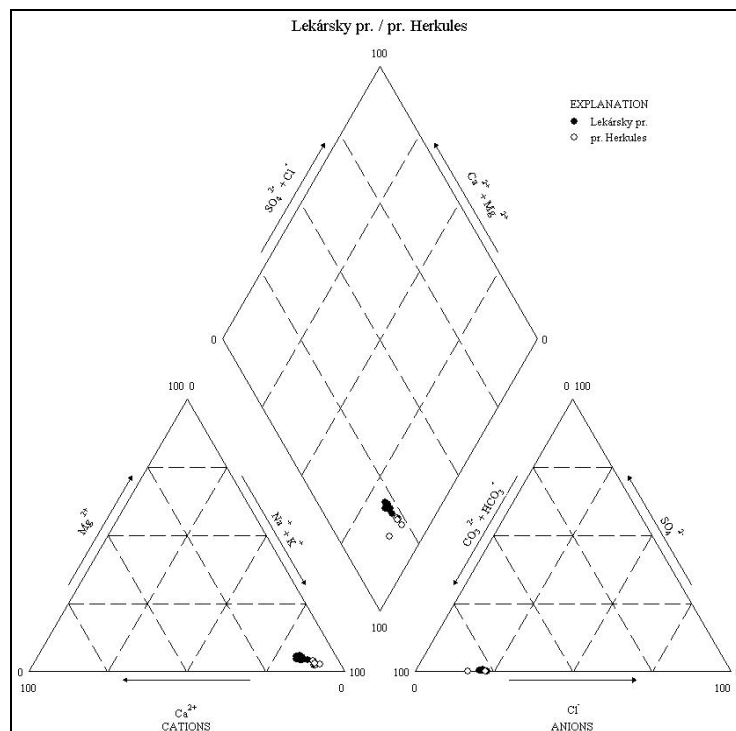


Fig. 3: The chemical composition of mineral springs Medicinal and Herkules

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