

ANTON PORUBSKÝ

## THE MINERAL AND THERMAL WATERS OF SLOVAKIA

Anton Porubský: Les eaux minérales et thermales de la Slovaquie. Geografický časopis, Bratislava 1972, XXIV, 2; 1 tableaux, 10 lit. cit.

Sur le territoire de la Slovaquie, dont la surface est de 49 000 km<sup>2</sup>, il y a plus de 1300 sources à l'eau minérale ou thermale. C'est une richesse unique en Europe centrale. Toutes les sources sont exactement enregistrées, relevées dans les cartes topographiques et les eaux furent soumises à des analyses hydrochimiques détaillées. Selon une classification géochimique et balnéologique, elles furent divisées en 34 types différents, suivant la norme tchécoslovaque en vigueur.

Les eaux thermales et minérales sont actuellement utilisées en 17 lieux de bains et mises en bouteilles, en tant qu'eau potable de table, en 9 localités.

Une telle abondance en eaux minérales et thermales de toutes sortes est liée à la composition géologique favorable et la structure tectonique des unités individuelles géomorphologiques-géologiques. Leur grande majorité est directement liée à l'extension superficielle des roches mésozoïques carbonatées, surtout des calcaires et dolomites. Dans le dernier temps, on avait vérifié sur le territoire de la Slovaquie même des eaux hyperthermales, surtout dans la partie centrale de la Plaine Danubienne.

Slovakia, with its surface of 49 000 km<sup>2</sup>, geographically situated in the centre of Europe, is one of the richest countries in the world as for the occurrence and geographical extension of mineral and thermal waters. In the recent years, all the wells of mineral and thermal waters have been registered, topographically worked and geochemically evaluated by the Ministry of Health of the Slovak Socialist Republic, Inspectorate for the protection of sources. On the relatively small territory mentioned, there are more than 1300 wells (10), exhibiting different geochemical classes and balneotherapeutic values.

From the beginning of this work, it must be emphasized that up to now mineral and thermal waters, as for their geochemical and balneotherapeutical typisation, have no common all-world international norms of uniform classification groups and systematical topological allocation. They are classified according to national directives only, which are different in various states, although striving to approach more or less to each other. The creation of a world classification system is impeded by the manifoldness of mineral and thermal waters, by differing opinions on their origin (genesis), their therapeutic value and exploitation. According to the classification of mineral and thermal waters, valid in Czechoslovakia, 34 geochemical types of Slovak mineral and thermal waters have been determined.

Owing to its geological structure and geomorphological conditions, the Slovak territory is specially predetermined to such abundance and type manifoldness of mineral

and thermal waters. There are geological formations from Paleozoic crystalline areas up to Quaternary loess sediments and Recent river alluvia of powerful thicknesses. Almost the whole geological history of the earth lithosphere evolution and structure, in most various tectonic positions and geomorphological formations, defile here before us. On examining the geographical-geomorphological or geological-tectonic map of Slovakia, we see that this territory is prevailingly of mountainous character, that the area of lowlands and hollows is by far smaller than that of the mountains. The folded structure of Slovak mountains allowed individual folds of entire geological and petrographical-lithographical series to plunge, from elevated mountain parts, deeply under the terrain relief in valleys, hollows or lowlands. On the stratigraphical, lithological and tectonic joints, they are destroyed or deeper sunken, due to manifold tectonic activity which, to a large extent, affected the whole territory of Slovakia from the oldest dislocation forms up to the Quaternary tectonics.

The territory of Slovakia is crossed by a system of faults, oriented in different lines and forming, approximately in chess-board pattern, a tectonic structure of horsts and precipices, elevated blocks and sunken depressions. In the system of faults, most typical are those in the east-west or northeast-southwest directions, called in general as strike tectonic lines; the perpendicular tectonic lines pass in the northwest-southeast or north-south directions.

The uplifted folds, mostly of the carbonaceous Mesozoic era, are favourable infiltration areas for precipitation waters. The descending folds are a favourable environment for their deeper circulation and metamorphosis in mineral or thermal water, and for their main accumulation. The intersections of tectonic lines are appropriate places of their outflow. In Czechoslovakia, considerable importance was, and still is attributed to the thermosiphon theory of descent, metamorphosis and ascent of mineral or thermal waters. But modern research on the relations environment-water-earth, on the origin and accumulation of mineral and thermal waters, seek and strive more to explain— for different areas, regions or entire structures — the interrelations between infiltration zones, descent ways and the laws of the formation and metamorphosis of mineral and thermal waters, of their accumulation recipients and the ways of outflow.

The formation of mineral waters in the region of Western Carpathians is mainly concentrated in Mesozoic carbonaceous rocks, limestones and dolomites of the medium and upper Triassic period. They extend at the borders of kernel mountains and occupy large territories. They also form the basis of Tertiary structural units on extensive areas. They have a very good Karstic permeability, still increased sometimes by the leaching effect of waters saturated with carbon dioxide. They are principally waters of earthy, gypseous types with prevailing Ca, Mg,  $\text{HCO}_3$  and  $\text{SO}_4$  ions.

Cold carbonaceous waters, which largely predominate among the wells, gush from all kinds of geological structures. They also usually concentrate the subsurface outlet of juvenile carbon dioxide, especially at the fault lines. This formation of mineral waters is permanent in most cases. A quite limited or interrupted formation of mineral water is scarce. This mostly occurs at waters of the oil type, e. g. in Číž, Cígelka, Dubová, Smrdáky and elsewhere.

Mineral wells originating from flysch zones and Neogene series of strata attain essentially smaller yields, scarcely of some tens of litres or some few litres only per minute.

In Czechoslovakia a special classification system for mineral and thermal waters is valid, determined by the Czechoslovak State Standard 86 8000. According to this norm, the mineral and thermal waters are divided, evaluated and classified in types

after their solved gases, total mineralization, principal ion components, biologically and pharmacologically significant factors, osmotic pressure, natural temperature at the outlet, and radioactivity. The classification is specified in detail, in the mentioned standard. Based on the above mentioned chemico-physical components, we range the Slovak mineral waters in following types: 1. ordinary acidulae, 2. true salt waters and acidulae, 3. salt basic waters and acidulae, 4. salt basic earthy acidulae, 5. salt Glauberitic earthy acidulae, 6. salt earthy acidulae, 7. basic earthy gypseous acidulae, 8. basic gypseous waters and acidulae, 9. true earthy water, 10. true earthy carbonic acidulae, 11. earthy gypseous acidulae, 12. earthy bitter gypseous water, 13. gypseous waters, 14. gypseous acidulae, 15. ordinary hydrosulphuric waters, 16. salt basic earthy gypseous carbonic acidulae, 17. salt hydrosulphuric, 18. salt basic hydrosulphuric, 19. salt, basic, earthy, carbonic, hydrosulphuric, 20. basic, hydrosulphuric, 21. earthy, carbonic hydrosulphuric, 22. earthy, gypseous, sulphuric, 23. gypseous, hydrosulphuric, 24. ferrous acidulae, 25. salt, basic, earthy, gypseous, ferrous acidulae, 26. salt basic, ferrous, 27. basic ferrous, 28. basic, earthy, ferrous, 29. earthy, ferrous, 30. earthy, gypseous, ferrous, 31. vitriolic, 32. salt iodobromic, 33. salt basic bromic acidulae, 34. salt basic iodobromic.

In Tab. 1, we show the balneological classification system only, exhibiting the criteria according to this table.

The knowledge and methods of recognizing the composition of mineral waters, with regard to the presence of heavy water and its effects, remains a permanent world problem. We know that many chemical reactions proceed by far slower, in the presence of heavy water, and that its content in underground waters increases with the depth, especially at the contact with old metamorphosed rocks, in particular with metamorphosed chlorides, which contain larger amounts of heavy water. This study of mineral and thermal waters will possibly explain the causes, little elucidated up to now, of the curative effects of mineral waters, generated mainly in crystalline rocks or at the contact with them, whereby the presence of heavy water prevents their increased mineralization.

The utilization of mineral and thermal waters, in national economy and, above all, in health service, is conditioned by several fundamental factors. Beside the therapeutic, sanitary and refreshing properties of the sources, in the first place by their exploitable yields. On the territory of Slovakia, in Western Carpathians, this yield usually does not exceed 50 l/s, which only occurs at the localities Piešťany, Bojnice and Kováčová. Further localities with thermal waters are: Ružbachy 40 l/s, Turčianske Teplice 25 l/s, Trenčianske Teplice 23 l/s, Sklené Teplice 15 l/s, Liptovský Ján 30 l/s, Lúčky 30 l/s, Patince 30 l/s, Kremnica 25 l/s, Komárno 17 l/s, and some others such as Ďudince, Santovka, Kalinčiakovo, Štúrovo etc.

The warmest waters in Slovakia are the following ones: Piešťany 69,5 °C, Komárno 27 °C, Sklené Teplice 53 °C, Banská Štiavnica 48,7 °C, Kováčová 48,5 °C, Bojnice 46,2 °C, Turčianske Teplice 44,8 °C, Trenčianske Teplice 40 °C, Liptovský Ján 28 °C, Kalinčiakovo 27 °C etc. The mineral waters of Korytnica (well Klement) of 5 °C, Železnô 6,5 °C and Nová Lubovňa 7,5 °C have the lowest temperatures.

From the gaseous components, the most frequent are those of carbon dioxide (CO<sub>2</sub>), a to a lesser extent hydrogen sulphide (H<sub>2</sub>S). The greatest quantity of carbon dioxide, in mineral waters, has been found at the locality Santovka (up to 4200 mg/l).

At present, in Slovakia, mineral and thermal wells are exploited and therapeutically utilized in 17 spas of all-state importance: Piešťany, Trenčianske Teplice, Sklené Teplice, Turčianske Teplice, Bojnice, Ďudince, Kováčová, Rajecké Teplice, Lúčky,

Table 1

The balneological classification system of mineral and thermal waters

The ionic component	mval/l	The type of water
Na <sup>+</sup> — Cl <sup>-</sup>	17	salt
Na <sup>+</sup> — HCO <sub>3</sub> <sup>-</sup>	12	basic
Na <sup>+</sup> — SO <sub>4</sub>	14	Glauberic
Ca <sup>+2</sup> (Mg <sup>+2</sup> ) — HCO <sub>3</sub> <sup>-</sup>	13	earthy
Ca <sup>+2</sup> (Mg <sup>+2</sup> ) — SO <sub>4</sub> <sup>-2</sup>	15	gypseous
Mg <sup>+2</sup> — SO <sub>4</sub> <sup>-2</sup>	16	bitter
Fe <sup>+2</sup>	mg/l 10	ferrous
J <sup>-</sup>	mg/l 5	iodic
Br <sup>-</sup>	mg/l 5	bromic
S	mg/l 1	sulphuric
The gaseous component	mg/l	The type of water
free CO <sub>2</sub>	mg/l 1000	carbonic acidula
free H <sub>2</sub> S	mg/l 1	hydrosulphuric
Water temperature	in °C	The type of water
up to	20	cold
within	20—50	thermal
above	50	hyperthermal

Ružbachy, Sliach, Korytnica, Nimnica, Brusno, Číž, Smrdáky and Bardejovské Kúpele. Table, refreshing or medicinal mineral waters are bottled in the following localities: Lipovec (world-wide known under the name Salvator), Baldovce, Santovka, Korytnica, Slatina, Záturčie (known as Fatra), Cígelka and Moštinec. Some of the listed areas of medicinal mineral and thermal waters exceed the boundaries of Czechoslovakia, being renowned in the whole world and visited by interested persons from many countries.

In the last year (1971), based on the study of the Geographical Institute of the Slovak Academy of Sciences (6,7), the organization Geologický Prieskum (together with the oil research) found — for the first time in Slovakia — an exploitable amount of hyperthermal water, in the Danubian lowland central part, near Dunajská Streda. The hyperthermal water of this locality comes from the depth of 2500 m and the artesian discharge yields 16 l/s, and has the temperature of 86 °C, at the bed (the bore hole bottom) it attains 106 °C. Such waters can already be utilized as energetical sources in the national economy, in housing economy or agriculture (for various purposes of heating). Their caloric value replaces yearly several thousand tons of coal.

This first greater success in discovering highly thermal water in Dunajská Streda was an impulse, for workers of the fundamental hydro-geological research and geophysics, to elaborate important studies on the possibilities of winning highly thermal waters as sources of energy on extensive areas of Slovakia (1, 5, 9). In these studies, results of the newest geological and geophysical research are utilized and analogically with other world localities, offering hyperthermal waters, the reality of their occurrence in our territory is pointed out. Especially the Danubian lowland

central part, with its layers of gravel and sand in the upper Neogene Pannonian sediments, belongs to the most promising regions of this kind. The same holds for the hollow of Žiar, in which the hyperthermal waters are bound on Mesozoic substrata in the depth of about 3.000 m. The occurrence of such waters is supposed in the lowland of Záhorie, in the hollows of Liptov and Turiec as well. There are geological indications still for other regions, but the reality of these ones has not yet been proved by fundamental exploration.

From the Slovak translated by J. Belaj

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Anton Porubský

#### MINERÁLNE A TERMÁLNE VODY SLOVENSKA

Územie Slovenska je vplyvom svojej geologickej stavby a geomorfologických pomerov zvlášť predučené na bohatý výskyt a pestrosť typov minerálnych a termálnych vôd. Na plošnej rozlohe 49 000 km<sup>2</sup> sa na území Slovenska nachádza vyše 1300 minerálnych a termálnych prameňov s najrôznejšou geochemickou klasifikáciou a balneoterapeutickou hodnotou.

Minerálne a termálne vody v zmysle svojej geochemickej a balneoterapeutickej typizácie nemajú ešte spoločné svetové medzinárodné normy pre jednotné klasifikačné triedy a systemizačné typologické začlenenie. Triedia sa len v zmysle národných klasifikácií, ktoré v rôznych štátoch sú rozdielne — ale snažia sa k sebe viac-menej približovať. V zmysle klasifikácie minerálnych a termálnych vôd, platnej v ČSSR, sa zistilo medzi slovenskými minerálnymi a termálnymi vodami 34 geochemických typov.

Územie Slovenska je poprepletané systémom zlomov, ktoré sa vzájomne križujú v najrôznejšie orientovaných líniiach a vytvárajú približne šachovite rozloženú tektonickú stavbu hrastí a prepádlín — vyzdvihnutých krýh a poklesnutých depresii. V systéme zlomov sú typickejšie zlomové línie smeru východ-západ, ktoré sú všeobecne známe ako smerné tektonické línie a kolmo na ne spadajú tektonické línie smeru severozápad—juhovýchod, resp. sever—juh.

Tvorba minerálnych vôd v oblasti Západných Karpát sa sústreďuje hlavne v mezozoických karbonatických horninách — vápencoch a dolomitoch stredného a vrchného triasu. Rozkladajú sa na okrajoch jaderných pohorí a zaberajú rozsiahle územia. Na veľkých plochách tvoria tiež podklad pre trefohorné štruktúrne jednotky. Majú veľmi dobrú krasovú priepustnosť, ktorá býva zvýšená vylúhujúcim účinkom vôd preplnených kyslíčnikom uhlíčitým. Sú to hlavne vody typu zemitého, sadrového s prevahou iónov Ca, Mg, HCO<sub>3</sub> a SO<sub>4</sub>.

Podľa ČSN 868000 sa minerálne a termálne vody rozdeľujú, hodnotia a klasifikujú na typy podľa obsahu rozpustených plynov, celkovej mineralizácie, hlavných iónových zložiek, biologicky a farmakologicky významných faktorov, osmotického tlaku, prirodzenej teploty na vývere a rádioaktivity. Klasifikácia je podrobne špecifikovaná v uvedenej norme.

Slovenské minerálne vody na základe uvedených chemicko-fyzikálnych komponentov zaraďuje sa do týchto typov: 1. obyčajné kyselky, 2. pravé slané vody a kyselky, 3. slané zásadité vody a kyselky, 4. slané zásadité zemité kyselky, 5. slané glauberovské zemité kyselky, 6. slané zemité kyselky, 7. zásadité zemité sadrové kyselky, 8. zásadité sadrové vody a kyselky, 9. pravé zemité vody, 10. pravé zemité kyselky uhličité, 11. zemité sadrové kyselky, 12. zemité horké sadrové vody, 13. sadrové vody, 14. sadrové kyselky, 15. obyčajné sírovodíkové vody, 16. slané zásadité zemité sadrové uhličité kyselky, 17. slané sírovodíkové, 18. slané zásadité sírovodíkové, 19. slané zásadité zemité uhličité sírovodíkové, 20. zásadité sírovodíkové, 21. zemité uhličité sírovodíkové, 22. zemité sadrové sírne, 23. sadrové sírovodíkové, 24. železnaté kyselky, 25. kyselky slané zásadité zemité sadrové železnaté, 26. slané zásadité železnaté, 27. zásadité železnaté, 28. zásadité zemité železnaté, 29. zemité železnaté, 30. zemité sadrové železnaté, 31. vitriolové, 32. slané jodobromové, 33. slané zásadité bromové kyselky, 34. slané zásadité jodobromové.

V súčasnosti sa na Slovensku exploatujú a terapeuticky využívajú minerálne pramene v 17 kúpeľoch celoštátneho významu: Piešťany, Trenčianske Teplice, Sklené Teplice, Turč. Teplice, Bojnice, Kováčová, Rajecké Teplice, Lúčky, Ružbachy, Sliač, Korytnica, Nimnica, Brusno, Číž, Smrdáky a Bardejovské kúpele. Ako stolné osviežujúce a liečivé minerálne vody sa plnia do fľaš na lokalitách Lipovec (Salvátor), Baldovce, Santovka, Korytnica, Slatina, Záturčie (Fatra), Cígelka a Moštinec.

V minulom roku na základe štúdie Geografického ústavu SAV (A. Porubský) robil Inžiniersko-geologický a hydrogeologický prieskum spolu s Naftovým priemyslom prvýkrát na Slovensku v centrálnej časti Podunajskej nížiny využiteľné množstvo hypertermálnych vôd v Dunajskej Stredě. Hypertermálne vody tejto lokality sú z hĺbky až 2500 m, artézsky výtok a výdatnosť 16 l/s a teplota vody je 86 °C pri ložiskovej teplote (na dne vrtu) 106 °C. Sú to vody, ktoré sa dajú už využívať ako energetický zdroj v národnom hospodárstve. Ich kalorická hodnota nahradí ročne niekoľko tisíc ton uhlia.