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75 localities with geothermal water in Bihor County (Romania) and the potential for the sustainability of balneology

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Abstract: The problem of this research stems from the fact that in Bihor County there are 75 localities that have one or more thermal water wells, of which only 8 locations can provide balneological treatment. The purpose of the research is to evaluate whether the geothermal potential of the region would be sustainable for the development of balneology in other localities as well. In order to meet the above-mentioned requirement, an interdisciplinary methodology was necessary, starting from geophysics and geology, including hydrogeology, chemistry, physics and ending with elements of tourism and balneological potential. The research methods refer to field work, the inventory of all locations that have geothermal resources, the creation of a database, the analysis of the stability and continuity over time of the source of thermalism, the analysis of the stability and time continuity of those physical-chemical properties that are suitable for balneology. In conclusion, out of the 67 locations that still cannot provide balneological treatment, only 20 could fulfil the sustainability criteria and are able to diversify the exploitation of thermal waters. There are 47 other locations that have unexploited boreholes, but despite this, we have come to the conclusion that balneology and tourism based on geothermal waters in Bihor County has a sustainable future in dozens of localities.

1. Introduction

The particularities of the evolution of the Carpathian orogen (Matenco and Radivojević, 2012; Cvetkovic et al., 2016; Balázs, 2017) and of the large basin inside the mountain range, named the Pannonian Basin or the Carpathian Basin (Figure 1), are responsible for the geothermal properties of the deep waters (Horváth et al., 2015).

The Pannonian Basin or the Carpathian Basin is geographically located mostly on the territory of Hungary, northern Croatia and Serbia, the western part of Romania, southern Slovakia and smaller parts of south-western Ukraine, eastern Austria and Slovenia, northern - the east of Bosnia and Herzegovina. Bihor County is located in the western part of Romania. Figure 1 shows that 44% of the landforms of Bihor County is represented by this plain, part of the Pannonian Basin. In all these territories, the presence of geothermal waters close to the earth's surface has been reported since ancient times. The use of geothermal water for baths was the oldest form of utilizing it. They bear witness to the remains of the baths built during the Roman Empire, many of whom nowadays are well known archaeological sites in south-eastern and central

Europe. Historians say that the habit of bathing in thermal water during antiquity was aimed at relaxing, relieving joint pains or improving skin conditions.



Figure 1. The Pannonian Basin, closed by the Carpathians to the north, east, and southeast, by the Dinaric Alps to the south and the eastern limit of the Alps to the west

In many places where the source of the thermal water was close to the ground surface, its use for baths persisted throughout the centuries, although during the Middle Ages it was greatly reduced. On the territory of Romania, in Bihor County, the presence of thermal waters has been noted since the Middle Ages, and the first exploitation drillings were carried out in 1886 at Băile Felix and 1 Mai (Episcopal Baths). Nowadays, the number of localities in the Pannonian Basin that have geothermal water wells is very large. In order to explain the reason why we are studying the potential of these waters at the scale of Bihor County, we will make some special remarks about this county in western Romania. Bihor County includes 95 communes and 75 localities. The ones located in the plain areas notably already have geothermal water drills. On average, for every 100 sq.km. there is a locality that already has a geothermal water well, respectively, one locality for every 9,600 inhabitants (The surface of the county is 7,544 km² and the total population is 575,000 inhabitants). In Bihor county there is a long tradition regarding the local ad-hoc exploitation of geothermal waters for bathing and recreation (Ciurba et al., 2023). As good and beautiful activities are known to become habits, in the future it is very possible that other localities will be included in the list of those that capitalize on geothermal water for spa and tourism purposes. Bihor County is developing rapidly, much faster than many other Romanian counties, both from an economic and social point of view, as well as from the point of view of people's quality of life (Bratu et al., 2010; Axinte et al., 2020). The abundant presence of geothermal spa resources in Bihor complements other existing resources and brings benefits to the life of Bihor residents through the chance to have "at home" a palette of balneological and tourism services for the locals but also for the increasingly numerous tourists. The purpose of the current study is to evaluate to what extent the geothermal waters from Bihor County, intercepted in a large number of boreholes, in 75 localities of the county, could ensure a sustainable development of balneology. Firstly, we intend to explain the origin of geothermal waters and demonstrate that they regenerate continuously, and thus, that they are inexhaustible. Secondly, we want to explain where the physical-chemical characteristics of these geo-thermal waters come from, the fact that their properties do not change over time, and that they meet the specific requirements for the balneological treatment of numerous ailments. Unfortunately, despite the fact that geothermal water resources can be found in several dozen localities of Bihor County,

they are not currently exploited for balneological purposes except in the case of 8 localities. Therefore, our objective is to demonstrate that the thermal waters from the boreholes of dozens of localities have the same physical-chemical characteristics as those from the consecrated resorts, and therefore lend themselves to a balneological valorisation. As we are discussing thermal waters as indicators of sustainability, we will first take into account those of a physical and chemical nature that condition balneology. The indicators for the health status of the population are precisely the benefits that the application of specific balneotherapy procedures based on thermal waters can bring. On the other hand, the indicators specific to the local economy of the village or city can only be partially analysed, as the database with this specificity at the level of the 75 localities is still under development; moreover, given the current context, the economy of the county is progressing very quickly. In Figure 2, we present a diagram of the stages of this study that contains the research problem, the purpose, the interdisciplinary methodology, the main findings, three categories of results, four directions of discussion as well as the main conclusions.

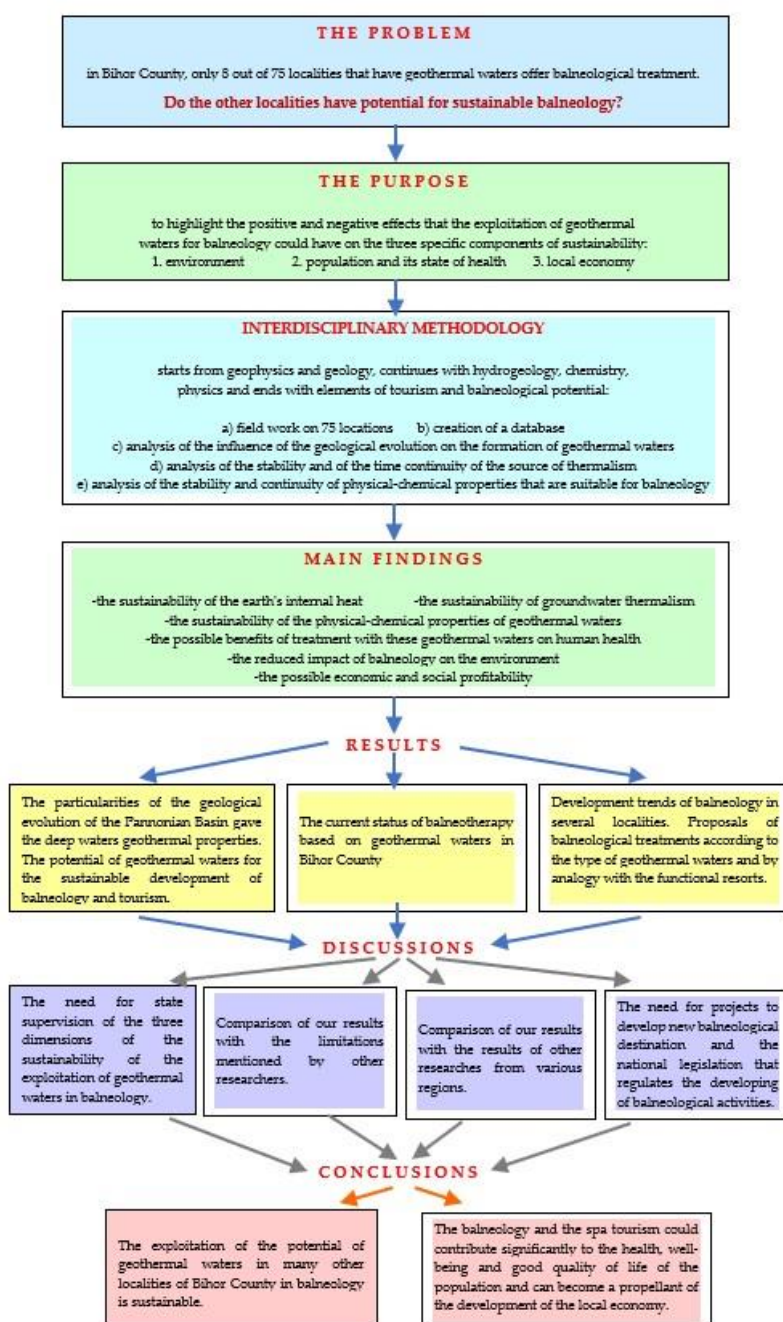


Figure 2. The diagram of the stages of the present study.

2. Materials and Methods

The geothermal balneology resources research in Bihor County involved three years of frequent field trips in order to carry out detailed investigations in the 75 localities regarding the dozens of functional or abandoned swimming pools, the inventory of dozens of boreholes, as well as the interpretation of the physical and chemical properties of the waters delivered. We have built a database regarding the things mentioned above which has already started to be used (Ciurba et al., 2023) and which is continuously supplemented with new data regarding the degree of favourability for balneological capitalization. The work methodology involved the inventory of all the thermal pools in Bihor County, the evaluation of their status, their mode of operation where applicable, and the evaluation of the extent to which they would be sustainable for organized balneology.

In order to evaluate to what extent geothermal waters would have a potential for the sustainable development of balneology, we must analyse the formation of geothermal resources and the functioning of aquifers (paragraph 2.1), respectively, to see if the resources have stability and continuity over time. Then, it is important to evaluate whether the physical and chemical properties of geothermal waters would be suitable for balneological treatments (paragraph 2.2). As a method for evaluating the potential of geothermal waters, we pursued the definition of sustainability evaluation criteria for balneology and tourism and their analysis. The evaluation of the sustainability of the exploitation of geothermal waters in balneology involves the evaluation of the environmental components (exploitation characteristics, the quality of the resources, and the impact on the environment), the economic evaluation (the profitability of the exploitation) and the social evaluation (the benefit for the population). If on the long term, these components remain in harmony, it means that the exploitation of geothermal waters in balneology is "durable" or "sustainable".

At the current stage of our research, some of the above components cannot be treated separately, or in very economic or financial terms, as that would involve dissecting the "whole" that we are presenting. It would also require that for each of the components above, we should develop another article discussing the development of balneology in Bihor County based on thermal waters. However, in the "Discussions" chapter we will discuss aspects related to the validation of the assumptions that balneology and tourism based on thermal waters in Bihor County has a sustainable future in dozens of Bihor localities, and we will also identify the natural, social or economic limitations, as well as solutions for the private or public start-up of the local geothermal potential for tourism or balneological purposes.

2.1. Evaluation of the influence of the geological evolution of the region on the formation of geothermal waters

The formation of artesian or ascent geothermal waters in the Pannonian Basin, including the Western Plain of Romania, was the consequence of geological events related to the evolutionary antagonism between the Pannonian microplate and the Carpathian orogen that largely surrounds it, against the background of the upward movement of the Asthenosphere (mantle upper part of the globe, more "ductile" due to high temperatures). The rising tendency of the Asthenosphere had as a consequence the extension and at the same time the heating and thinning of the lithosphere (Demetrescu and Polonic, 1989; Huisman et al., 2002). For reasons of isostasy, with the rise of the Asthenosphere, an initial subsidence occurs. The crystalline of the Pannonian plate fragmented and descended in the middle of the Neozoic in parallel with the rise of the Carpathian orogen, the consequence being the formation of a so-called "Carpathian Basin" inside the chain described by the Carpathian Mountains. This Carpathian sedimentation basin is based on Mesozoic or older crystalline shale and Cretaceous deposits. The evolutionary antagonism between the Pannonian microplate, which overlies the Transylvanian microplate to the east, resulted in the formation of a crustal

fault in the NE-SW direction (Airinei and Pricăjan, 1976), approximately parallel to the western border of Romania (Figure 3).

The crystalline in the foundation is also faulted in the E - W direction by two major faults, one to the north and the other to the south of the the Western Carpathians. Other secondary faults that intersect the previous ones, many perpendicular to the major ones, but also having other different directions, have transformed the foundation into an alternation of horsts and grabens, which as a whole descend "in steps" from east to west, the greatest depth on the territory of Romania being in the central area, precisely in the plain area of Bihor County (Airinei, 1981; Sandulescu, 1984). Therefore, the foundation appears as a "checkerboard" being covered with a sedimentary blanket (limestone, sandstone, clay, sand, tuff deposited in marine or lacustrine conditions) of variable thickness, 3-5 km in grabens and several hundreds of meters above the horsts. From north to south, we can list six large geothermal anomalies with the potential to heat underground water.

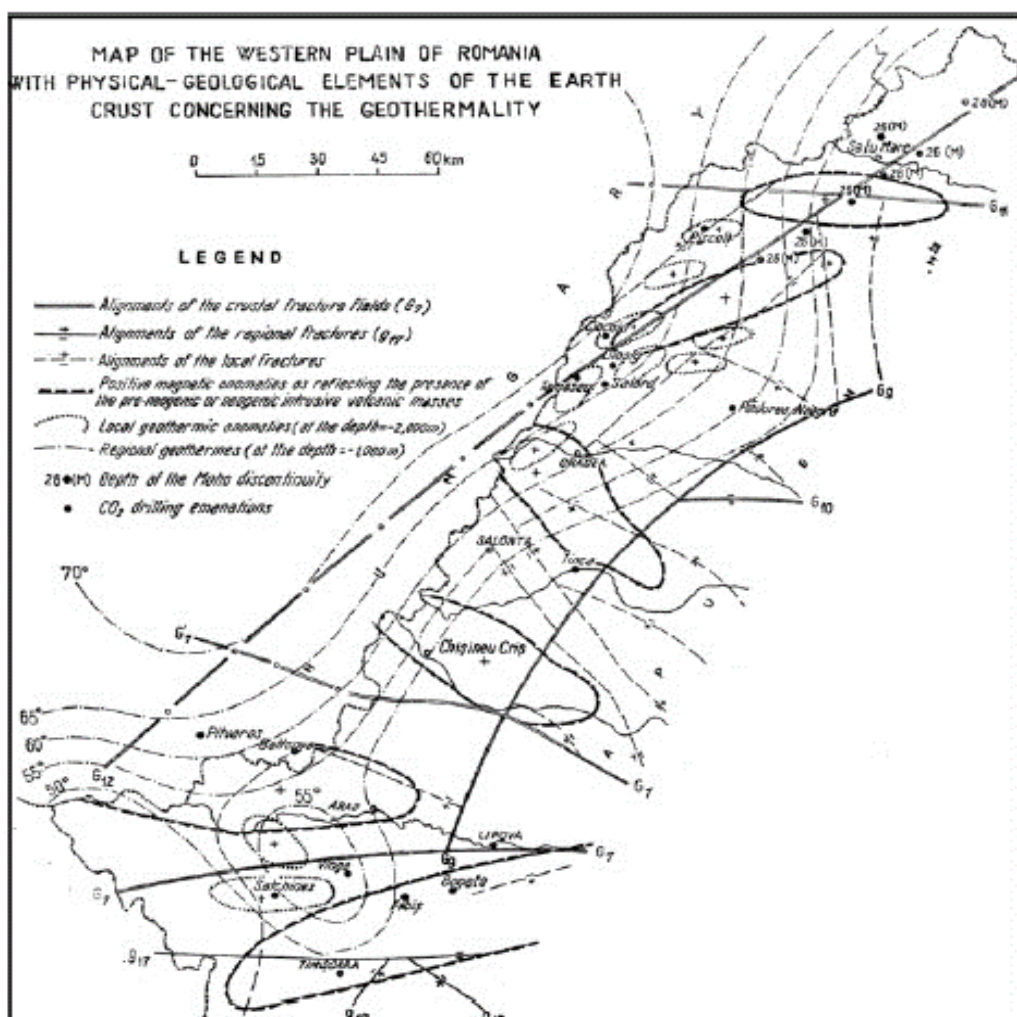


Figure 3. Map of the Western plain of Romania with physical-geological elements of the earth crust concerning the geothermality. (Reproduced after Airinei and Pricăjan, 1976).

The sediments from the Pliocene, being difficult to divide, are known as "Pannonian", a name initiated by the geologist L. Roth von Telegd in 1879, an old name that the Roman Empire assigned to the province surrounded by the Carpathians, and found today in the name of the geological unit Pannonian Basin as well as the relief unit named the Pannonian Depression or Plain. Several deep grabens, located on the territory of Hungary in the trough of the crustal fault, are manifested as areas of neotectonic subsidence (Bodrog, Sárret and Makó) influencing the evolution of the surface hydrographic network

(Bulla, 1962; Posea, 1997) and the major drainage channels of underground water. Linked to Bihor county, the second of these subsidence areas, influences the evolution of the Crisul Repede River and its tributaries, but also the drainage routes of the underground waters (Tenu, 1981).

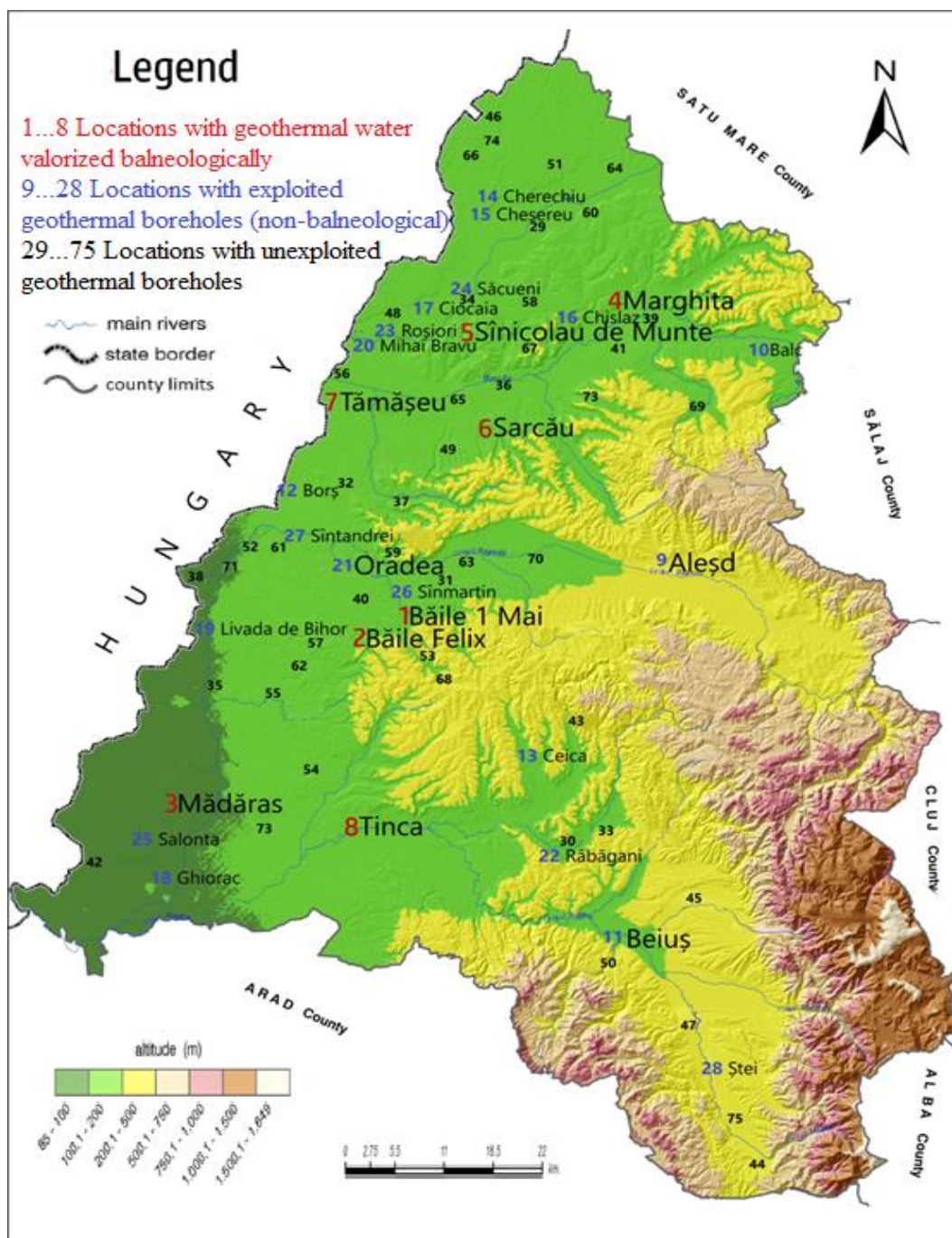
The Mohorovičić discontinuity, which separates the crust from the upper mantle in the Pannonian Depression is at a shallow depth, so geothermal gradients are higher than in other areas 6.2 to 5.6 °C/100 (Airinei, 1987). This explains the presence of a continuous internal heat source (Demetrescu, 1982; Nader et al., 2023), which is transferred to the underground waters, transforming them into thermal waters. The thickness of the crust is 25-30 km in Bihor County and 30-35 km in the the Western Carpathians Mountains (the smallest thickness being 20-25 km in the east of the Pannonian Basin, and in the southwest of Bihor County. The thickness of the lithosphere is 60 km in Bihor County and 80 km in the east of the Western Carpathians. The heat flow is 90-100 mW/m² in the central part of the Western Plain in Bihor county, 80-90 mW/m² in the north and south of the county, and for comparison, in the Western Carpathians it is 50-60 mW/m² (Rădulescu et al., 1982; Demetrescu and Polonic, 1989; Horváth et al., 2001; Horváth et al., 2015; Perşa et al., 2019).

The numerous faults of the foundation, which also influence the sedimentary cover, favour the rise of geothermal waters. The difference in density between the cold waters of precipitation, which drain according to a slope from east to west specific to the aquilude formations at the base, and the thermal waters, gives the latter ascending tendencies, and if it is under pressure, even artesian (Scradeanu and Gheorghe, 2007). The consequences of the peculiarities of geological evolution on the formation of thermal waters are the following: the formation of a heat source and an abundant thermal flow of the foundation of the Pannonian Basin; the formation of high-capacity aquifers based on the porous Pannonian sedimentary and on the altered limestones and dolomites from the Mesozoic; the formation of a fault system of the foundation that facilitates the ascent of geothermal waters. All these consequences show the fact that geothermal water resources are inexhaustible, both quantitatively and in terms of their thermalism, and therefore their qualification as sustainable is justified.

Taking into account the alternation of horsts and grabens that size differently the capacity of geothermal aquifers in Bihor County, a regionalization of geothermal water resources can be attempted. The porous Pannonian sedimentary (sandy formations and poorly cemented sandstones) constitutes the most extensive aquifer system of geothermal waters in the Pannonian Plain. The structure in horsts and grabens of the foundation, which influences the thickness of the sedimentary package above it, allows the contouring of geothermal fields (Figure 4).

In the northern part of Bihor County, there is a geothermal field that extends from Satu Mare County to Cherechiu - Valea lui Mihai and the surrounding villages. Another field linked to the porous sedimentary aquifer of Miocene age from Săcueni can be distinguished, which extends to the east towards Marghita and Balc, being bordered to the south by the Diosig uplift and the Biharea-Mihai Bravu horst, the western extension of the Plopiş Mountains. In the central part of the plain area of Bihor county there is the Oradea aquifer consisting of limestones and altered dolomites of the Middle Triassic and the 1Mai - Felix aquifer consisting of limestones of the Lower Cretaceous (Roba et al., 2012), bordered to the south by the elevation of the foundation Inand - Salonta. In the Beius Depression (Beiuş - Ştei area), the boreholes intercepted artesian or ascent thermal waters also in fractured and altered Triassic dolomites and limestones (Orăşeanu, 2020. In the southern part of Bihor County, there is another geothermal field made up of Pannonian aquifers, Ciumeghiu - Mădăras, which extends eastward to Tinca.

The rising warm waters have a great capacity to dissolve the minerals encountered on their way to the surface, so that the geothermal waters acquire the properties of geothermal mineral waters. Once the geothermal aquifers are intercepted in deep boreholes, it is important to evaluate their physical and chemical properties as well as their degree of favourability for balneology and tourism.



The black numbers indicate: 29-Adoni, 30-Albești, 31-Betfia, 32-Biharia, 33-Căbești, 34-Cadea, 35-Cefa, 36-Cenaș, 37-Cetariu, 38-Cheresig, 39-Chiraleu, 40-Ciheș, 41-Ciulești, 42-Ciumeș, 43-Corbești, 44-Criștioru de Sus, 45- Curățele, 46-Curtușeni, 47-Cusuiș, 48-Diosig, 49-Fegernic, 50-Finiș, 51-Galoșpetreu, 52-Girișu de Criș, 53-Hidișel, 54-Husășu de Tinca, 55-Miersig, 56-Niuved, 57-Nojorid, 58-Olosig, 59-Oșorhei, 60-Otomani, 61-Palota, 62-Păușa, 63-Săcădat, 64-Sălăcea, 65-Sălărd, 66-Șimian, 67-Sîniob, 68-Tășad, 69-Tăuteu, 70-Tileagd, 71-Toboliu, 72-Tria, 73-Tulca, 74-Valea lui Mihai, 75- Vașcău.

Figure. 4. Localities with geothermal water resources.

2.2. Evaluation of the physical and chemical properties of geothermal waters as balneological factors

Evaluating the sustainability of some resources for tourism is a new objective in Romanian geographical research and involves spatial methods (Lakatos et al., 2023; Roșca and Ceuca, 2023) but in the case of the current research, the analogy of the

physical and chemical properties of geothermal waters in different locations, is the basis of the method of selecting sustainable locations for tourism and balneology.

As far as 30-40 years ago, the interest in the exploitation of geothermal waters caused, immediately after the execution of a drilling well, to proceed to their physical and chemical analysis, and therefore, to communicate the results (Țenu, 1981; Airinei, 1987; Cîneti, 1990). More recent summaries for the Western Plain, or for some of its subunits, appear in the following articles (Butac and Opran, 1985; Gheorghe and Grăciun, 1993; Gilău et al., 2001; Stănășel and Gilău, 2003; Roba, 2010; Roba et al., 2010; Setel et al., 2010; Roba, 2012; Orășeanu, 2020; Sebeșan and Sebeșan, 2014; Begy et al., 2023). In order to carry out a synthesis regarding the physical and chemical characteristics of the geothermal waters from the deposits of Bihor County, we have taken into account the individual analyses performed for each drilling, regardless of the period in which they were performed (Table 1). In the last two rows of the table, we have mentioned the current forms of valorisation, as well as the appropriate therapeutic indications depending on the physical-chemical characteristics of the geothermal waters.

A first general remark is the fact that in Bihor County, the characteristics of geothermal waters are quite similar. The similarity is dependent on the continuity or connection between the aquifers, independent of their age. From a qualitative point of view, the common constituents, but still in different proportions depending on the deposit, are Cl^- , NO_2 , NO_3^- , HCO_3^- , CO_3^{2-} , SO_4^{2-} , PO_4^{3-} , Ca^{+2} , Mg^{+2} , Na^+ , K^+ etc. There are, however, some particular notes of the physical and chemical properties, in close connection with the type of drained rocks but also with the influence exerted by the hydrocarbon and CO_2 deposits. Often, the differences between thermal waters are given by small differences between the contents of Mg^{+2} and SO_4^{2-} . Here are some examples (Roba, 2012; Orășeanu, 2020):

- sulfates–bicarbonates–calcium–magnesium, slightly acidic pH = 6.3-7.6 from triassic aquifer of Oradea, petroleum hydrocarbons only 1.5 mg/l.
- bicarbonate–sulfate–calcium–magnesium at Felix and Băile 1 Mai
- sulfate–sodium–calcium–magnesium at Corbesti (as well as iodized character)
- bicarbonate–sodium–chloride and high concentration of metaboric acid from Pontian aquifer of Săcueni, petroleum hydrocarbons 41.1 mg/l, (pH=7.5-8.1)
- chloride–bicarbonate–sodium geothermal water from the Miocene at Balc, mpH=7.3, mineralization 16.6 g/l, 46°C
- bicarbonated–sodium–chloride type at Borș; these have high mineralization (13-14 g/l) and a high content of dissolved gases, mainly carbon dioxide (70%) and CH_4 (30%).

High mineralization 14g/l shows a strong tendency to crust (Stănășel and Gilău, 2003):

- high mineralization rich in sodium bicarbonate and carbon dioxide reserves at Ciocaia
- sulfate–carbonate–calcium–magnesium at Beiuș from Mesozoic carbonate
- bicarbonate–sulpho–sodium at Beiuș from Neogene deposits
- bicarbonated–chloride–sodium thermal waters with high methane content in Ciumeghiu and high mineralization 6-7 g/l, pH is = 7, generally low mineralization 0.4-0.9 g/l with some exceptions.

The water temperature at the mouth of the well is between 37°C and 86°C, the extremes being 105°C at Ciumeghiu and 115°C at Borș. The activities of radon and radium were higher in Oradea (up to 34.82 and 1.82 Bq/L), followed by Săcueni and Felix-Băile 1 Mai.

The particular physical and chemical properties of the deposits exploited by drilling, give them different adaptability for one or another of the diseases that could be treated by balneological procedures, but these aspects will be treated in the next chapter.

Table 1. Physical and chemical properties of geothermal waters, forms of valorisation and therapeutic indications.

Localities/ Properties	Aleşd	Mădă- ras	Sînnico- lau de Munte	Livada de Bihor	Tămă- şeu	Săcueni	Chişlaz	Beiuş	Marghita	Sarcău	Ştei	Chereşeu	Cealof	Valea lui Mihai	Mihai Bravu	Răbăgani	Ciocaia
WT (°C)		46	57		61	90		70	70					20	60	24	67
NTU	2.27			0.31			0.22	0.54			38.9						
Conductivity (µS/cm)	948	1324	4940	772	4139	11350	3450	472	8600	38512	1063	5900	40000	6800	5020		10990
Salinity (%)	0.5		2.6	0.4			1.8	0.2			0.9				7		
Hardness (ΣCa ²⁺ , Mg ²⁺)	17.29		1.51	19.47	1.34	1.26	1.79	12.7	1.96	165.31	60.92	2.02	60.20	2.97	1.54		1.26
pH (unit pH / temp)	7.06	7.6	7.95	6.61	7.82	7.45	8.4	7.4	7.8	6.8	7.3	7.85	6.90	8	7.9		7.8
TDS (mg/l)	457	675	3200	371	2800	4330	1750	225	2052	29910	878	4300	19852		2100		8790
Cation																	
Na ⁺ (mg/l)		328.2	1125.0		791	1640.0	834	41.7	900	10640		1642.0	7400.0	1100	922	62.8	3850
K ⁺ (mg/l)		8.0	16.4		12	17.20	8.20	25	8-18	400.00		19.80	120.00	80	9.5	2.2	23.05
Ca ²⁺ (mg/l)		8.0	32.7	110.07	8.2	4.40	7.60	50.40	3.5-7.8	38512	292.80	7.41	216.03	7.48	3.91	68.5	4
Mg ²⁺ (mg/l)	39.93	2.7	9.9	17.63	5.3	3.89	3.15	24.78	2-5	343.87	86.50	4.26	130.36	8.39	8.6	12.1	2.18
Fe ²⁺ (mg/l)		0.1	0.07		0.156	0.20	0.17	363	0.64	10.39	3.861	0.25	7.40		0.36		0.17
Total iron (mg/l)	0.422			0.051			0.086	0.195									
F ⁻ (mg/l)											1.933						
NH ⁺ ₄ (mg/l)	0.317	2.9	traces	traces	10.33	12.42	12.0	<0.05	6-9	74.14	<0.05	11.54	3.42				
Anion																	
HCO ₃ ⁻ (mg/l)	230.45	805.2	2659.6	297.17	1160	3032.8	1.656	239.7	130-475	5.34	124.44	2945.4	3721.9	1713.5	991	366.1	8091
NO ₂ ⁻ (mg/l)	< 0.02		traces	traces	1.99	0.21	<0.02	<0.02	-	-	<0.02	0.15			0.57		
NO ₃ ⁻ (mg/l)	< 0.1	5.0	7.9	37.54	-	0.10	<0.1	<0.1	0.36	-	0.434	0.12	0.19	0.36	0.34		
SO ₄ ²⁻ (mg/l)	302.5	8.9	11.2	43.12	17	traces	<8	38.80	traces	8.62	1041.2	traces	30.45	10	44	48	12.35
Cl ⁻ (mg/l)	43.91	63.8	278.0	35.28	915	824.44	299.15	<5.0	631.90	16902	<5	886.67	10106	760.4	414	7.1	831
Alkaline (mval/l)	3.77			4.57			27.15	3.93									
H ₂ SiO ₃ (mg/l)		21.7	24.6											33			
HBO ₂ (mg/l)			24.9		31.62	98.50	25.40		15-27	194.13		107.67	103.10	30.25			
SiO ₂ (mg/l)			44.083		41.3	50.44	41.59		40-45	55.04		65.40	38.00				
Free carbon dioxide CO ₂					1190	1570											
Permanganate index (mgO ₂ /l)				0.57			0.9	0.5				<0.5					
Organic substances (O ₂) (mg/l)			1.6		32.46	59.56	0.50		35.44	19.2		59.09	54.18	28.96	38.07		60.5
Phenol			0.73		0.62	5.19	0.30		0.56	1.30		4.65	4.50	0.51	1.14		4.5
Total mineralization (mg/l)			4192.6		4504.7	5704	2932.1	463.2	3047.8	32542		5690.7	24877	3661	2771	597.8	13791

WT - Water temperature; NTU - Turbidity; TDS - total dissolved solids; Na+ - Sodium; K+ - Potassium; Ca2+ - Calcium; Mg2+ - Magnesium; Fe2+ - Iron; F- - Fluoride; NH4+ - Ammonium; HCO3- - Bicarbonates; NO2- - Nitrites; NO3 - Nitrates; SO4 2- Tone; Cl - Chloride; H2SiO3 - Metasilicic acid; HBO2 - Metaboric acid; SiO2 - Silicone dioxide

3. Results

3.1. The potential of geothermal waters for the sustainable development of balneology and tourism

Some references from medical journals specify relatively promising benefits of thermal water. Bathing in thermal water has the effect of increased comfort and a feeling of pleasure and suppleness of the skin (Bacle et al, 1999). The presence of minerals in the thermal water gives them antioxidant properties, neutralizes free radicals and reduces the risk of sunburn (Seite, 2013). Thermal water soothes skin irritation and reduces the effect of eczema (Alirezai et al, 2000; Guerrero and Garrigue, 2007). Thermal water reduces the inflammation caused by psoriasis (Zeichner and Seite, 2018).

The use of geothermal waters in balneology, within Bihor County, is traditional at Felix, Băile 1 Mai and Băile Tinca. But many lessons could be learned from the experience of those who wrote about the balneological tradition of some localities in the Pannonian Basin and other neighbouring countries. The thermal water has multiple uses in the Pannonian Basin (energy, agriculture, tourism, balneology) and it is normal that the future valorisation trend should be directed towards sustainable use.

Taking into account the favourable factors as well as the unfavourable ones, the extraction and treatment of thermal water with the aim of balneological valorization, would become feasible for a sustainable operation (Buday, 2012; Bódi et al., 2015; Buday et al., 2015) if it achieves the protection of used polluting reservoirs, the reduction of dependence on various related economic services, the minimization of the impact on the environment. The example from Hajdúszoboszló and Debrecen in Hungary (Buday et al., 2015) is worth following because it is a very diversified balneological valorisation supported by social insurance: chronic joint inflammations, degenerative joint problems, various acute degenerative inflammatory diseases of the spine vertebral, inflammation of the nervous system, treatment for any paralysis, acute muscle pain, rehabilitation from general and sports injuries, certain locomotor disorders, chronic gynaecological problems, infertility, acute skin problems, constriction of blood vessels, osteoporosis. Balneotherapy, as a method of treatment in medicine based on geothermal waters, has reached a level of functioning in Hungary characterized by efficiency and sustainability, as demonstrated by a synthesis based on 122 studies of this profile (Bender et al, 2014).

Also in the Pannonian Basin, but in Croatia (Borović et al., 2016), starting from 1980, geothermal waters are used for heating and for tourist purposes. It is a fractured and altered Mesozoic limestone aquifer that delivers 50°C carbonated-calcium water, but the perfecting of a sustainable valorisation solution, in balance with the environment and social and economic demands, is not yet finalized. In Serbia, geothermal waters have multiple forms of exploitation, including for tourism and balneology (Todorović et al., 2016; Petrović Pantić et al., 2021).

In Bihor County, the long tradition of harnessing geothermal waters for tourism and balneology (Felix, Băile 1 Mai, Tinca) has proven obvious characteristics of sustainability. Recent research examines, however, to what extent the radioactive potential of the new geothermal water sources, not yet fully entered into the tourist and treatment circuit, could affect the sustainability feature (Roba, 2010; Roba et al., 2010; Roba, 2012; Begy et al, 2023).

3.2. The current status of balneotherapy based on geothermal waters in Bihor County

Balneary tourism is practiced for medical recovery, therapeutic and prophylactic purposes (Stăncioiu et al, 2013), and Bihor county has been offering these benefits since ancient times in the consecrated resorts of Băile Felix, Băile 1 Mai and Băile Tinca, recognized both nationally, as well as internationally, especially the first two. Through this study, we want to provide a mapping of all localities with geothermal spa resources,

analysing the existing situation and future forecasts of sustainable development, based on the socio-economic and geographical situation and the local spa potential. In Table 2, we present the current situation regarding the locations where geothermal water is utilized for balneological purposes.

There are 8 locations where balneological treatments are carried out (Figure 4) and for each of them the temperature of the water, its flow rate, the type of water, the pathologies being treated as well as the total number of accommodation places are specified. We mention the fact that Bihor County currently has a total of 11,026 places to stay for balneological treatments and associated tourism.

The physical procedures associated with the balneological exploitation of the hydrotherapeutic potential are: physiotherapy, ultrasound, robotic therapy, magnetodiaflux, therapeutic massage, electrotherapy, ionization, galvanic baths, TENS, TECAR therapy, occupational therapy, etc. In the towns with geothermal resources exploited for balneological purposes in Bihor County, several types of pathologies can be treated, and namely: inflammatory rheumatism, arthrosis, neurological diseases, post-traumatic conditions, inflammatory gynaecological pathologies, and etc. Balneological treatments are associated with various tourist services and, of course, a developing accommodation infrastructure (see the last column of Table 2). The exception is the thermal bath complex in Tămășeu, which has foreseen, in the immediate development plan, the establishment of a strong accommodation infrastructure. The balneological accommodation infrastructure includes camping caravans, wooden houses in lesser-known rural locations, and hotels up to five stars. All of these are located in the largest spa resort of national and international interest in the county (Băile Felix).

The restaurant infrastructure is well developed and includes fast food places and restaurants. There are also leisure facilities that include children's playgrounds, sports fields, etc. (Ciurba et al, 2023). Concerts and festivals are organized in many locations that utilize geothermal water for balneological purposes: Waves Festival at Băile 1 Mai, Thermal Days at Băile Felix (Stăncioiu et al, 2013); themed parties such as foam party at Marghita; wine tastings at Sînicolau de Munte, or summer camps for children at Sînicolau de Munte. In locations where the restoration infrastructure is above the level of current balneological needs, family events such as weddings, christening parties etc. are often organized. All of these activities increase the number of potential tourists in the geothermal locations of Bihor County, contributing to the development of spa tourism.

3.3. Development trends of balneology (and tourism) in several localities of Bihor County

In Bihor County, there are 75 locations with geothermal water with relatively similar physical-chemical properties, some of which are already very well exploited for spa treatment, but many others (Figure 4) are still not exploited systematically or have only an ad hoc exploitation on a local level. The results of our research indicate that 20 localities have an immediate potential for the balneological exploitation of geothermal waters (Table 3). The last column of the table informs about the types of treatment that could be applied depending on the type of thermal water and its physical-chemical characteristics. We consider that connecting the spa potential of the locations in this table with their natural, anthropic, and socio-cultural potential, in case of systematic and organized capitalization, would lead to a sustainable development of local spa tourism.

In Bihor County there are still 47 localities that have geothermal water wells, carried out in the last 40-50 years by various companies or institutions, but still unexploited (the localities are mentioned in black in Figure 4). In many drillings, the physical and chemical properties of the geothermal water are currently under analysis and some of them already have partial results.

Table 2. Locations with geothermal water in Bihor County, valorised balneologically at the level of 2023. The red colour for numbers and localities corresponds to the indication of the legend in Figure 4.

Locations	T (°)	Flow	Type of water	Treated pathologies	AC*
1. Băile 1 Mai	36-48	50 l/s	oligometallic, bicarbonate, calcium, sodium	degenerative rheumatic diseases; inflammatory rheumatic diseases; abarticular rheumatic diseases; post-traumatic disorders of the locomotor system; neurological disorders; neuromuscular disorders; conditions associated with metabolic disease; gynaecological conditions (chronic metronexitis, minor puberty or menopause disorders); respiratory diseases	3,500
2. Băile Felix	49	196 l/s	oligometallic, bicarbonate, calcium, sodium, oligominerals	degenerative rheumatic diseases; inflammatory rheumatic diseases; abarticular rheumatic diseases; post-traumatic disorders of the locomotor system; neurological disorders; neuromuscular disorders conditions associated with metabolic disease; respiratory diseases	7,100
3. Mădăras	62	21 l/s	bicarbonate, chlorosodic, hypotonic	chronic degenerative rheumatism; abarticular rheumatism; post-traumatic conditions; peripheral neurological disorders	26
4. Marghita	62-70	10 l/s 5 l/s	hypotonic	chronic degenerative rheumatism; abarticular rheumatism; post-traumatic conditions; chronic gynaecological conditions	260
5. Sânnicolau de Munte	70	4-5 l/s	bicarbonate	chronic degenerative rheumatism; abarticular rheumatism; post-traumatic disorders of the locomotor system.	64
6. Sarcău	43	1,5 l/s	brominated, iodized, ferrous, chlorinated, sodic, hypotonic	chronic degenerative rheumatism; abarticular rheumatism; post-traumatic conditions; venous circulatory disorders; gynaecological conditions	76
7. Tămășeu	78-116	3 l/s	ferruginous, bicarbonated carbonated, sodic, hypotonic	chronic inflammatory rheumatism; degenerative rheumatism; abarticular rheumatic diseases; post-traumatic disorders; chronic peripheral neurological diseases.	-
8. Băile Tinca	26	3,4 l/s	Bicarbonate calcium, sodium	chronic degenerative rheumatism; abarticular rheumatic diseases; peripheral neurological disorders; venous circulatory disorders; gynaecological diseases	230

*AC = Accommodation capacity

Table 3. Localities having exploited boreholes with potential for balneological valorisation of geothermal water (The blue colour for numbers and localities correspond to the indication of the legend in Figure 4).

Ref. No.	Geothermal water resources	T°C	Flow	Type of water	Current utilization (non-balneological)	Potential treatments
9	Aleşd	38	12 l/s	bicarbonated, sulphated, sodium	leisure	chronic degenerative rheumatism; post-traumatic disorders; abarticular rheumatism
10	Balc	46	5.5 l/s	brominated, iodized, chlorinated, sodium, hypotonic	thermal baths in ruins	chronic degenerative rheumatism; post-traumatic disorders; abarticular rheumatism
11	Beiuş	86	46 l/s	hypotonic	skin scarring; skin irritations inflammations heating	chronic degenerative rheumatism; abarticular rheumatism; post-traumatic conditions; peripheral neurological disorders
12	Borş	107	30 l/s	chlorinated, sodium, bicarbonated, hypotones	heating balneary reserve fund	chronic degenerative rheumatism; abarticular rheumatism; post-traumatic conditions; peripheral neurological disorders
13	Ceica	19.6	0.19 l/s	bicarbonate, carbogas, iodide, oligominerals	unexploited borehole	chronic degenerative rheumatism; abarticular rheumatism; post-traumatic conditions; chronic gynaecological conditions; peripheral neurological disorders
14	Cherechiu	90	20 l/s	trace minerals, sulphurous, bicarbonated, sodium, chlorinated	experimental exploitation	chronic degenerative rheumatism; abarticular rheumatism; post-traumatic conditions; peripheral neurological disorders
15	Cheşereu	88	no info	bicarbonated, chlorinated, sodium, hypotonic	balneary reserve fund	chronic degenerative rheumatism; abarticular rheumatism; post-traumatic conditions; peripheral neurological disorders
16	Chişlaz	59	8 l/s	hypotonic	leisure	chronic degenerative rheumatism; abarticular rheumatism; post-traumatic conditions; peripheral neurological disorders

17	Ciocaia	72	no info	hypotonic, bicarbonated, ferruginous, sodium	balneary reserve fund	chronic degenerative rheumatism; abarticular rheumatism; post-traumatic conditions; peripheral and central neurological conditions; gynaecological conditions
18	Ghiorac (Cighid)	70	4-5 l/s	not analysed yet	heating	not evaluated yet
19	Livada de Bihor	80-82	20 l/s	bicarbonated, calcium, chlorinated, sodium, hypotonic	heating leisure agriculture	chronic degenerative rheumatism; abarticular rheumatism; post-traumatic conditions
20	Mihai Bravu	67-98	4.5 l/s	oligominerals	abandoned thermal baths	chronic degenerative rheumatism; abarticular rheumatism
21	Oradea	74-105	5-45 l/s	hypotonic	Heating Leisure	chronic degenerative rheumatism; abarticular rheumatism; post-traumatic conditions; peripheral neurological disorders
22	Răbăgani	24	12 l/s	iodized, brominated, oligominerals	discontinued thermal baths	chronic degenerative rheumatism; abarticular rheumatism; post-traumatic conditions
23	Roșiori	60	4.5 l/s	oligominerals	balneary reserve fund	chronic degenerative rheumatism; abarticular rheumatism; post-traumatic conditions
24	Săcueni	82-84	10 l/s	bicarbonated, ferruginous, sodium, hypotonesic	heating thermal baths	chronic degenerative rheumatism; abarticular rheumatism; post-traumatic conditions; peripheral neurological disorders
25	Salonta	101	15 l/s	oligominerals	experimental exploitation	chronic degenerative rheumatism; abarticular rheumatism; post-traumatic conditions
26	Sînmartin	35	8 l/s	hypotonic	thermal pool	chronic degenerative rheumatism; abarticular rheumatism; post-traumatic conditions
27	Sîntandrei	80	40 l/s	not analyzed yet	fish farming	not evaluated yet
28	Ștei	70	5-7 l/s	bicarbonate, calcium, sulfuros	heating	chronic degenerative rheumatism; abarticular rheumatism; post-traumatic conditions

Thus, Cadea (bicarbonated geothermal water), which once hosted thermal baths, Ciumeghiu (hypotonic, 95°), Corbești (sulphurous and sulfated, 34°), Crișcioru de Sus (trace minerals and ferruginous), Diosig (70°), Oșorhei (sulphuric and trace minerals), Palota (47°), Tulca (sodium and ferruginous) and Valea lui Mihai (68°), are localities with promising resources to evaluate in the future if they have a real potential to exploit geothermal waters in balneology. Starting from 2020, several localities with geothermal resources (Marghita, Săcuieni, Salonta, Borș, Beiuș, Ștei, Mădăras) have been certified as tourist resorts. This status facilitates their access to European funding sources, which could further contribute to the development of spa tourism, but also of other forms of tourism in these localities.

Regarding the identification of the perspectives of sustainable development of balneology and balneological tourism in the Bihor County, the main peculiarity is the similarity of the geothermal water dependent on the connection between the aquifers, independent of their age. The profitability of the exploitation of geothermal water could be sustainable through any form of exploitation, because its source is inexhaustible and its physical-chemical characteristics are quite constant. The utilization for heating is well known and the great advantage is given by the low cost of green energy. Capitalizing for leisure and for the purpose of spa treatment involves the arrangement and maintenance of swimming pools and the development of a specific infrastructure by creating stable jobs and, consciously, increasing the local budget by paying taxes. Thus, the quality of life of local residents could increase, especially in rural areas.

Of great importance for sustainable development could be informing professional doctors about the benefits of each therapeutic feature of geothermal water, according to the indications established by the National Institute of Recovery, Physical Medicine and Balneology (the specific structure for approving organized treatment in Romania), regardless of whether the location is included or not in the national balneological circuit. This institute should proceed to determine the therapeutic recommendations of the geothermal water, by analysing the physical-chemical indicators, for the benefit of the public or private administrative entities that have custody of the geothermal resource. The advantages could be even greater for the population, if agreements were signed between the existing balneological resorts or those in the process of formation and the National Pension House, respectively the National Health Insurance House (from Romania), which would give patients and social security rights and access facilities to prophylactic, therapeutic and recovery spa treatments, by allocating subsidy or free vouchers for the spa treatment. This measure could be extremely beneficial for the development of locations with local spa potential and their inclusion in the national circuit.

4. Discussion

Our article provides concrete arguments in support of proving the fact that balneology based on thermal waters in Bihor has a future and that its potential meets sustainability conditions. However, the transition from finding that there is potential, to the higher level of organized and efficient practice of thermal water-based therapies, still requires the fulfilment of some conditions.

Firstly, the state, through laws and regulations, should intervene concretely to supervise the three dimensions of the sustainability of the exploitation of geothermal waters in balneology: environmental protection, economic development and social development. Secondly, we can imagine that the balneological activity based on geothermal waters would work as a system. The inputs are known, meaning the geothermal water, we also know the objective, and that is the balneological treatments. However, as regards the outputs from the system, it is obvious that the analysis of the natural and social-economic limitations regarding the sustainability of balneology based on geothermal waters is required. Thirdly, the results of this study should be compared

with the conclusions reached by various Romanian or international experts, who have analysed the effectiveness of balneology based on geothermal waters, depending on the desire to improve health, wellness and good health, and quality of life of the population.

Fourthly, we propose to discuss the ways through which certain local developers, either based on the state administration or based on private administration, could transform a location with geothermal potential into a balneological destination, which should become a national or even an international destination.

4.1. The justification of the need for state supervision of the three dimensions of the sustainability of the exploitation of geothermal waters in balneology

The most important premise for exploiting thermal water is that the source of water is renewable. Nevertheless, its discharge into nature, after it has been used, must be done without jeopardizing the sustainability of the quality of the environment, therefore, a precautionary principle must be respected first. Any ecological system has a certain capacity for resilience, and with regard to the extraction of thermal waters and the development and operation of an infrastructure with a touristic or balneological purpose, it must not diminish the capacity of resilience of the system. Therefore, the Bihor County local or national authorities must implement a package of principles adapted both to the optimum functioning of the process of optimal utilization of thermal waters in tourism and balneology at the local level, as well as strict rules for preserving the resilience of the system and inhibiting activities pollute. Environmental costs are difficult to estimate in the long term, but national institutions must impose, through appropriate legislation, clear rules regarding the exploitation of thermal waters, because their exploitation in tourism and for balneology generates both value and costs. In this way, the state ensures that it supervises the three dimensions of the sustainability of the exploitation of thermal waters in balneology and tourism at the local scale of human settlements, villages or cities: economic development, social development and environmental protection.

4.2. Possible limitations of the sustainable development of balneology

The thermal waters coming from the Triassic aquifer from Oradea and used for heating show an inadmissible concentration of sulphate ion (Călborean and Roba, 2011). This result suggests the need to be careful about the risk of pollution caused by the geothermal waters used in swimming pools and for balneotherapy.

The discharge of used thermal waters in the surface emissions of the hydrographic network can cause the infiltration of pollutants, which, although it is a very slow process, may at some point intersect the thermal aquifer. The hydrographic basin of the Ier river overlaps the area of the Săcueni geothermal aquifer and in the analysed samples a high proportion of chlorine ions of petroleum hydrocarbons and phenolic compounds was found (Călborean and Roba, 2011). The same study mentions that sometimes the temperature of the thermal waters at the discharge, even after their use, is too high.

It is also known that intensely mineralized thermal waters favour the development of crusts on the surface of wet metals (probes, pipes, various installations, heat exchangers). These crusts identified in the installations from Bihor County (Stănăşel and Iovi, 2006; Sebeşan et al., 2013) are composed of alkaline deposits of calcium carbonate and magnesium hydroxide, magnesium silicate, zinc silicate, ferric oxide, ferrous sulphide and calcium sulphate. They are very difficult or almost impossible to remove despite the use of chemical or mechanical techniques. Geothermal waters can also contain gases, especially N_2 , CO_2 , H_2S , which if they are in high proportions, it is indicated to re-inject the waters into aquifers to reduce the duration of contact with the environment and to prevent them from reaching the atmosphere.

Another limitation that could appear by chance can be caused by possible sudden changes in the volumetric distribution ratios between the aquifer layers. Although geothermal water is considered to be a renewable resource, in some places even inexhaustible, reservoir modelling is particularly important. When a short-term profit is

sought through the exaggerated exploitation of large volumes, it could be followed by the reduction of production in the future.

Changing the administrative factor could be an impediment in the sustainable development of balneology. By selling the location with a spa resource, where the administrative entity is private and the purchasing administrative factor is not concerned with the maintenance or development of services for the exploitation of the natural resource, for various reasons, financial or other priorities. If the geothermal natural resource belongs to a public administrative entity, its sustainable development could be jeopardized by the termination of the mandate and the change of position of the person representing the entity (the mayor). This fact can negatively influence the sustainable development of the spa resource, by channelling financial and human resources towards other priorities, considered important in the life of the community.

4.3. The importance of the formation of spa tourism destinations for the benefit of the hosts as well as the visitors

As we have shown in the previous paragraphs, Bihor County has important geothermal water resources, but their exploitation for spa tourism is not yet up to the potential proven in this study. That's why, in this paragraph, we will present some arguments of internationally renowned specialists, who prove their expertise in terms of the role of the development of spa tourism for society, for the local economy, and last but not least, for the health of the population.

Erdeli et al. (2011), underlines the evolution of the concept of spa tourism in Romania, which has awakened people's interest, since ancient times, in spa therapy. With the passage of time and the advancement of technology, natural spa factors have been combined with physical procedures, using more and more performing devices for an increased efficiency of spa therapy and the concept of wellness. Thus, it has contributed to the increase of the quality of life and the local socio-economic development through the development and practice of spa tourism. The authors discuss the issue of how medical spas could be better promoted to increase their visibility. Romania is one of those European countries with impressive potential from a balneological point of view, having a great diversity of natural factors that allow the treatment of several medical conditions in the same resort.

Nistoreanu et al. (2021), highlights the importance of illustrating geothermal resources on the official websites of the resorts/localities, in order to increase their visibility. This fact could contribute to supporting the implementation of water management in spa towns, thus contributing to the sustainable development of local balneology. The idea of implementing some management procedures with the aim of effective communication of spa benefits and for international promotion is supported. An important advantage is the location of Bihor County in northwest Romania, as a border county. This position gives it the possibility of fast external connections with Central and Western Europe, which offers opportunities for development and collaboration favourable to the sustainable development of balneology and spa tourism.

Turtureanu and Chitu (2020) referred to the evolution of spa tourism, emphasizing the important role of the retrospective analysis of this type of tourism, related to several factors such as the specifics of the field and market, the importance of spa tourism in shaping society and the implications for the environment and sustainability this one. Marin et al. (2019) mentioned the importance and development of spa tourism in Romania, highlighting certain ways to maximize the potential of sustainable tourism development in balneoclimatic resorts. They list a number of possible activities that could be carried out in order to further develop spa tourism.

At the international level, this theme is debated by several authors, including Torres-Pruñosa et al. (2022) which evokes both the economic and social value of balneotherapy and spa tourism in Maresme, a region of Catalonia, Spain. The theoretical

implications of the economic and social benefit of spa tourism are discussed, as well as certain political findings to promote and encourage investments in spa tourism.

Vovk et al. (2021) report on the identification of factors for the development of medical tourism in the world. They show how important it is for the formation of medical tourism destinations to be done in a balanced and unidirectional manner, because in this way, it will contribute to the formation of resources for further socio-economic development.

Quintela (2023) conducted a comparative study between Portugal and Hungary regarding the contribution of spa tourism to the health of the population. The results of this study should also be followed by the developers of spa tourism in Bihor County because the related examples prove that balneotherapy contributes significantly to health, well-being and the good quality of life of the population.

4.4. Justification of the need for projects to transform a location with geothermal potential into a balneological destination

The results of the study and tables 2 and 3 show the fact that in Bihor County 45 locations with geothermal water wells executed are not yet exploited. In Romania, geothermal water resources are considered to be useful mineral resources, subject to the Mining Law no. 61 of March 5, 1998. Since the drillings have already been executed, but in 47 locations they are not yet exploited, there would be a need for projects to transform a location with geothermal potential into a balneological destination. Whether it is a private developer or a state company, the acts of giving in administration or in concession, after the drilling has already been executed, are mentioned by the letters d - h of Article 6 of the Norms for the application of the Law of Mines from 25.09.1998:

- d) the license to have in administration for exploitation
- c) concession licence for exploitation
- f) exploitation permit
- g) the agreement of the National Agency for Mineral Resources regarding the association of the license holder with other legal entities, in order to carry out the mining activities provided for in the management or concession license;
- h) the approval of the National Agency for Mineral Resources regarding the transfer of an exploration or exploitation concession license to another legal entity.

On the basis of the operating license, specific works can be performed: the arrangement of swimming pools, the construction of buildings, the installation of equipment, and so on. On the basis of Article 11 of the Mining Law, quantitative evaluations of geothermal resources, physical-chemical analyses and environmental protection measures can be established, and all these together outline the hydrogeological documentation. The balneological operation is conditioned by the establishment of the list of therapeutic indications by the National Institute of Recovery, Physical Medicine and Balneology. In the next phase of the project, which is about transforming a location with geothermal potential into a balneological destination, the technical, economic and medical conditions for utilizing geothermal water for balneological treatment will be set up.

Article 19 of the Law's Application Norms specifies that public institutions and Romanian or foreign legal entities, which express their interest in receiving the exploitation license, can exercise their right of initiative throughout the calendar year. Article 24 shows that the exploitation license is granted to Romanian or foreign legal entities, under the law, based on an application accompanied by a feasibility study that ensures the exploitation of reserves of useful mineral substances and the protection of the deposit, the exploitation development plan, the study of impact on the environment (environmental balance sheet and restoration plan), approved according to the law and accompanied by a bank guarantee for the restoration of the environment.

5. Conclusions

In the Pannonian Basin, respectively, the Western Plain of Romania, the presence of geothermal waters has been known for many centuries. But, in order to assess whether this resource has sufficient potential for the sustainable development of balneology in Bihor County, it was necessary, first of all, to determine the origin of these waters and to understand to what extent they have sustainable volumes and physical-chemical characteristics suitable for balneotherapeutic treatment. Our conclusion is that the peculiarities of the geological evolution of the studied region conferred a genetic link between the formation of the Pannonian Basin, the rising tendency of the Asthenosphere, the heating and thinning of the crust and the high geothermal gradient. An important role was played by the formation of high-capacity aquifers due to the porous Pannonian sedimentary and altered Mesozoic limestone and dolomites, as well as the presence of a fault system that facilitates the ascent of geothermal waters and their enrichment with dissolved minerals. Thus, these waters acquire the characteristics of geothermal mineral waters, and therefore their qualification as sustainable for their use in balneotherapy and tourism, in general, is justified. Moreover, the example from Băile Felix, Băile 1 Mai, Tinca or from the neighbouring country from Hajdúszoboszló and Debrecen or many other localities from the countries bordering the Pannonian Basin should be multiplied.

In Bihor County, out of the 75 locations that have geothermal resources, only a number of 8 can provide different balneological treatments, 20 locations capitalize on this potential only for recreational thermal pools, but many of them have developed strategic projects in order to diversify the exploitation of waters in the direction of organized balneology. There are 47 other locations in Bihor County with geothermal water wells executed that are not yet exploited.

Our research analyses the conditions of sustainability in order to make more use of geothermal water resources in Bihor County, justifying the need for state supervision of the three dimensions of sustainability related to balneology: economic development, social development and environmental protection. Some possible limitations of the sustainable development of Bihor County balneology are mentioned, related to the risk of aquifer pollution, the effect of hypermineralized waters that form crusts on watered installations, the risk of the release of some harmful accompanying gases, or the possible errors of the administrative factor that manages the process exploitation of geothermal waters.

We have also come to the conclusion that the geothermal waters in Bihor County, with proven therapeutic qualities if more intensively utilized in other locations, could contribute significantly to the health, well-being and good quality of life of the population and of course, can become a propellant of the development of the local economy of some villages and towns. That is why certain projects promoted by state or private investors would be very welcome, aiming to transform a location with geothermal potential into a spa destination. Finally, we present a simple guide that explains the legislative steps to follow so that the 47 locations that have boreholes, still unexploited, gradually join the spa tourist circuit.

This study is interdisciplinary, as it starts from geophysics and geology, continues with hydrogeology, chemistry, physics and ends with elements of tourism and balneological potential. The results and conclusions are aimed at researchers who belong to the mentioned fields but also to local or county authorities, as well as to potential entrepreneurs or entrepreneurs who are ready to invest in this sector. The next phase of research would involve the development of a territorial planning project focusing on the capitalization infrastructure for balneological and touristic purposes of one or another of the locations that prove to have such potential.

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