4.5. THE CARBONATE HYDROTHERMAL RESERVOIR FROM MONEASA (THE CODRU MOMA MOUNTAINS)

by **Iancu ORĂȘEANU**
Romanian Association of Hydrogeologists, ianora@hotmail.com

1. Morphological data

The area of Moneasa is placed in the Codru Moma Mountains, its Northern section being part of the Codru Mountains, while the Souther one of the Moma Mountains.

The plots of land North to Moneasa Valley are of a diverse relief, their major peaks and valleys being directed North-South, in parallel with the direction of the geological structure. The morphology of this sector is dominated by the Izoi ridge, over 1000 m (1097.7 m at Izoi peak), and from that place the relief falls to the East with over 500 m, up to internal drainge areas such as Brătcoaia and Tinoasa-Izoi, and then it continues its fall to the East up to Megheş valley, at around 350 m average height.

The plots to the South of Moneasa are exclusively shaped by the hard Permian deposits of Moma Mountains and have a steepy relief, with deep torrential valleys and sharp mountain sides.

The waterside of Moneasa stream in the juncture of Megheş and Băilor streams, at an average 275 m height, is 100 m maximum wide and partially hosts a spa.

Băilor stream has its main source in Bear's cave (Grota Ursului cave, Moneasa cave), a resurgent cave, and has downstream a narrow valley of a clearly pronounced erosive character. Upstream the cave, the valley, also known as Feredeului valley, is dry, covered with grass and stabilized mountain slopes. The Bear's cave is 250 long and was found by G. HALASI following a series of explorations in a 20 m long siphon from where the Bear's cave spring emerges. The cave later came later into access via a mining gallery, as a tourist destination, a project which was not achieved so far.

The morphology of the karstic fields is dominated by depressions of lythologic contact such as Brătcoaia and Tinoasa-Izoi, plus other exokarstic numerous forms (karrens, sinkholes) and endokarstic ones (caves, potholes). The karst waters from Izoi slope inflitrate in the underground through impenetrable ponors, while depressions lack a main collector.

The climate of Moneasa areal is moderate continental, specific to medium high mountains, of Mediterranean influence. Between 1951-1960, there was a weather station in Moneasa, and an annual average data of 1122.63 mm precipitations and 9°C temperature were recorded. Starting with 1972, the hydrological and meteorological observables were recollected by setting up the Moneasa hydrological representative basin (MIŢĂ P., 1996) and Izoi weather station, the later being suppressed in 1990.

2. The geological and structural setting of Moneasa area

From a geological point of view, the Moneasa area is situated in the border where the Moma Nappe thrust over the Finiş Nappe (Fig. 1). The formations of Finiş Nappe represent a homoclime relatively positioned on the North-South line, with permian rhyoliths and werfenian quartz sandstones at the bottom. All these support a thick layer of predominantly carbonated deposits made of black dolomites (Anisian), black limestones with cherts – Roşia Formation (Anisian-Carnian), white dolomites and violet-coloured brecious limestones in the Tisa Formation and siltites, lime sandstones and black limestones in Codru facies (Norian), clays, red and green sandstones, Carpathian-Keuper (Rhaetian), limestones, black and red marls limestones (Lower Jurassic), sandstones and siltites (Tithonian and Neocomian).

The S5 (4666) well, drilled in the centre of the spa, indicates a rapid disappearance of the limy formations of the Finiş Nappe to the South, under the Permian silty shales and basalts of the

Moma Nappe. They raise in steps to the South, under Permian deposits, and the thickness of the Triasic limestones is gradually reduced, reaching 65 m only in the area of the above-mentioned well.

The deposits of the Finiş homocline close to Moma Nappe are strongly tectonized and divided in a series of blocks by two fault systems: an older one, from NNW to SSE along the geological structure and a second and later one, from NE-SW, perpendicular to it.

In the area of Moneasa, the overthrust front of the Moma Nappe is placed at North of Moneasa valley and goes from East to West, up to the junction of Băi stream with Pietros brook. From there it suddenly turns the direction to South, and it is later re-found on the left shore of Moneasa valley relatively close to Moneasa village, while downstream the village it simply goes alongside the valley, being covered by alluvial deposits.

Seismic and geoelectric research done by A. APOSTOL et al. (1975) and data provided by hydrogeological drilling present this contact as having various incliantions, of a 55° average to the South. Close to the surface, the inclination is higher, being met by well 4664 (S4) under 70°. F3 drilling in Camping area penetrated deep to the bottom up to 197 m Permian deposits only, indicating for the overthrust plane over 70° (Fig. 2).

The second tectonic key element of Moneasa is Moneasa fault. It is directed from East to West, perpendicular on the Finiş homocline which is sectioned, bringing Triasic limestones in the Southern area South of Izoi ridge, and moved to the West, in direct contact with Werfenian quartz sandstones in the Northern area. The fault continues under the deposits of Moma Nappe, being responsible for lifting the sandstones and limestone deposits, which is pointed out by S5 well (4666).

Quarternary deposits are represented by alluvional plain along Moneasa stream, by cones of dejection at the bottom of brooks, by old and present deluvial deposits and slope detritus.

Covering deposits of Brătcoaia and Tinoasa-Izoi karstic depressions are made of residual clays with limestones, dolomites and quartz sandstones blocks.

On the Eastern side of the main ridge of Codru Mountains, between Izoi and the mouth of Pietros brook, for about 3 km, there are slope detritus made of Werfenian quartz sandstones boulders resulted from an intense gelifraction from glaciary eras.

Figure 1. Hydrogeological map of Moneasa area (geolgical data after M. BLEAHU et al., 1979, M. BLEAHU et al., 1981, M. BLEAHU et al., 1984).

Legend:

1 - Mesozoic carbonate series, highly fractured and karstified, characterized by very high effective infiltration and prevalently conduit porosity with intensive groundwater flow. Important water resources in large karst systems;
2 - Werfenian molasse deposits (sandstones, conglomerates and less frequently shales) with double porosity. The groundwater flow providing a continuous and important supply to streams and to binary karst systems;
3 - Paleozoic rhyolites (a) and basalts (b), with extensive fracture networks and well developed weathering zones;
4 - Marly and argillaceous deposits (a-Permian), devoid of groundwater flow, and flysch-like series (b-Rhaetian, c- Tithonian-Neocomian) including rock-complexes of variable permeability (marls, shales, sandstones, limestones);
5 - Holocene (a) and Pleistocene (b) deposits (marls, shales, sands, gravels), hosting discontinuous water accumulations in the more permeable terms;
6 - Course of perennial stream;
7 - Course of temporary stream;
8 - Geological boundary;
9 - Fault;
10 - Overthrust front;
11 - Boundary of internal drainage area;
12 - Boundary between internal drainage areas;
13 - Watershed;
14 - Proved groundwater flow direction;
15 - Boundary of diffluence surface;
16 - Perennial (a) and temporary (b) ponor;
17 - Perennial spring;
18 - Temporary spring;
19 - Bear's cave outlet;
20 - Temporary outflow cave;
21 - Perennial inflow cave;
22 - Fossil pothole;
23 - Pothole tapping an underground stream;
24 - Hypothermal spring;
25 - Well with hypothermal water;
26 - Well with mesothermal water;
27 - Group of springs and wells with hypo and mesothermal water;
28 - Karst depression;
29 - Quarry;
30 - Diffuse losses in streambed labelled with tracers;
31 - Direction of hydrogeological cross section.

3. The historic of hydrogeological research

Moneasa village is first recorded in historic documents at 1200, on a sketch found in the Ţara Crişurilor Museum in Oradea, and the thermal springs there, known from Roman times, are mentioned in 1597 in a letter addressed to the commander of Dezna fortress, a fortified area of the Transylvanian army organised by Sigismund Bathory, a supporter of Michael the Brave (L. COŢOI, 1974).

In 1865, NENDTVICH KAROLY undertakes a first chemical analysis of the thermal springs in Moneasa, and one year later KERY (BITTNER) IMRE describes the springs for the first time and suggests how they could be used.

Between 1890-1895, a first well for thermal waters was drilled up to 316 m (340 m), a well having an initial debit of 16.6 l/s and a 25°C temperature. In 1891, once pavillion no.1 on Băilor stream is built, first treatments of stomach-related affections and rheumatism take place (S. MARKI, 1985). In 1927, early tests of radioactive activity are done by G. ATHANASIU, and in 1932, E. ŢEPOSU and V. PUŞCARIU mention in their "România balneară şi turistică" (Spa and touristic Romania) that there were 4 springs featuring a temperature of 20-30°C and a debit of 14-15000 hectoliters. The therapeutic character of Moneasa is noticed by above-mentioned authors, the thermal qualities of those waters, the climate conditions and the chemical characteristics making the waters to be seen as "indifferent waters."

The Institute of Balneology and Physiotherapy in Bucharest publishes in 1951 the first full chemical analysis of Moneasa waters, and in 1958 M. PAUCĂ points out, in a synthesis of the thermal springs in Apuseni Mountains, that the waters in Moneasa are "a combination of deep waters of hundred of meters rising under the pressure of vapous and karstic cold waters", the author underlining the difficulty of clarifying the protection perimeter of the springs.

From various hydrogeological research undertaken in the last 50 years in Moneasa, we mention complete measurements of waters radioactivity taken by A. SZABO in 1967, the first tracer markings in 1970 by I. ORĂŞEANU, E. GAŞPAR and D. I. SLĂVOACĂ, the first hydrogeological detailed study by I. ORĂŞEANU in 1973, drilling 4 new wells (S2, S4, S5 and S6- Şmelţ) by I.F.L.G.S in between 1972-1987 (G. VASILESCU, N. AVRAMESCU, 1972, MARIA PÂRVU, 1975,), and a complete geophysical research by A. APOSTOL et al. (1975).

In 1987, I. ORĂŞEANU publishes a hydrogeological synthesis of Moneasa area and in 2000, together with J. MATHER, an article on the genesis of thermal waters.

In 1978, G. HALASI publishes two works on the endokarst in Moneasa, and in 1985, with GISELA HALASI and G. BIRTALAN, presents the exploration and morphology of Bear's cave.

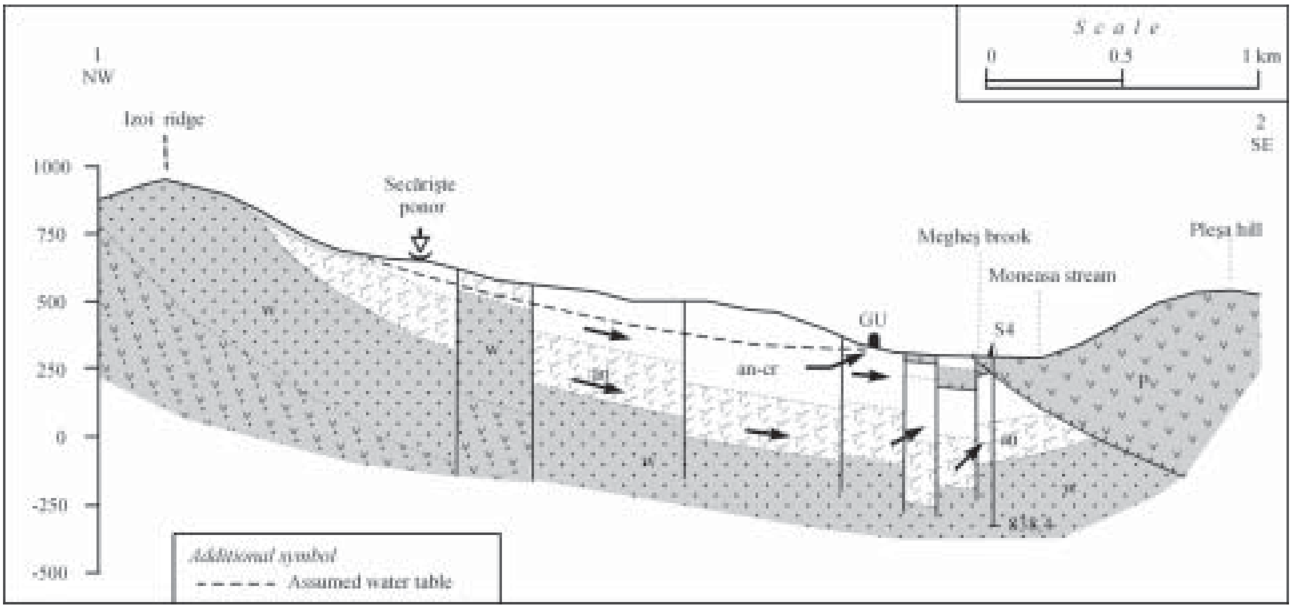

Figure 2. Hydrogeological cross section 1-2, Izoi ridge-Moneasa spa.
Legend as in Figure 1. Line of section shown in Figure 1.

4. The hydrogeology of Moneasa area

The Triassic limestones and dolomites in the area, at North of Moneasa, is 1-2 km wide and has a monoclinal structure, with quartz sandstones at the bottom and flysh-like sediments at the top. At North, the structure continues in the watershed of Finiş stream (I. ORĂŞEANU, present volume, cap. 3.13.4) and to the South is abruptly interrupted by a overthrust plane of the Permian deposits of the Moma Nappe (Fig. 1).

There are major aquifer reservoir in carbonate deposits whose discharge to the South is mainly done through Bear's cave resurgence and secondly through the springs of Răchitarul, Megheşul Sec and Pietros brooks. In order to find the direction of flow for underground waters and their dynamics, I. ORĂŞEANU undertook tracer markings with E. GAŞPAR, D. I.. SLAVOACĂ, NICOLLE ORĂŞEANU, E. ANGHEL, M. MIDOIU and T. TĂNASE (see Table 1).

Labelling no.	Drainage no.	Insurgence$^{1)}$	H m	Resurgence$^{1)}$	H m	L m	ΔH m	Tracer	T, hours	V m/s	Date
1	1	Izoi ponor (6)	680	Bear's resurgent cave (10)	320	2110	360	HTO	6	355.0	1970
	2			Hypothermal spring "a"	295	2180	385		6	363.0	
2	3	Secărişte ponor (7)	685	Bear's resurgent cave (10)	320	1840	365	HTO	5	368.0	1970
3	4	Teia pothole (16)	400	Piatra cu Lapte spring (17)	310	650	90	I	25	41.0	1972
4	5	Tinoasa ponor	657	Răchitarul spring	525	1075	132	F	43	22.0	1973
5	6	Tăul Bivolilor ponor (18)	294	Peştera cu Apă de la Moară cave (19)	250	630	44	F	8	80.0	1974
6	7	Losses of Haiuga Veche brook (4)	669	Megheşul Sec spring (9)	440	1200	229	I	1	1200	1974
	8	Losses of Pârâul dintre Pietre (12)	560	Piatra cu Lapte spring (17)	310	2680	350	R	70	38.3	1987
8	9	Losses of Scăriţa brook (13)	540	Piatra cu Lapte spring (17)	310	1700	230	F	48	35.4	1987
9	10	Losses of Blidăriţa brook (14)	630	Piatra cu Lapte spring (17)	310	3100	320	In	72	43.0	1987
10	11	Dosul Varului ponor (1)	720	Feredeu spring (Huta, Finiş)	415	6000	305	I	58	103.0	1977
	12			Bear's resurgent cave (10)	320	5800	400		48	120.0	
11	13	Dosul Varului ponor (1)	720	Finişului spring (Huta, Finiş)	490	4050	230	In	168	12.5	1986
	14			Feredeu spring (Huta, Finiş)	415	6000	305		96	62.5	
	15			Mesothermal spring nr. 1	294	5900	426		600	9.8	
	16			Well no. 4, Megheş brook	297	6250	424		480	13.0	
	17			Mesothermal spring nr. 2	303	6150	427		460	13.4	

H - elevation, in meters a.s.l., L - horizontal distance between ponor and spring, ΔH - vertical drop; T - time of first arrival of tracer; V - apparent velocity. Tracers: F = Fluoresceine, R = Rhodamine B, I = I-131,In = In-EDTA

Note 1: The following labellings were performed by the author in cooperation with: E. Gașpar, D. I. Slăvoacă, M. Midoiu, T. Tănase and Nicolle Orășeanu – no. 1 and 2; E. Gașpar, E. Anghel, C. Stanca, T. Tănase and Nicolle Orășeanu – no. 6; E. Gașpar, M. Midoiu, T. Tănase and Nicolle Orășeanu – no. 10, E. Gașpar–no. 11. Labelling no. 4 was performed by Tănăsescu and other.

Note 2: In brackets number of sites on Hidrogeological map in Figure 1.

Tabele 1. Results of tracer tests performed in Moneasa area.

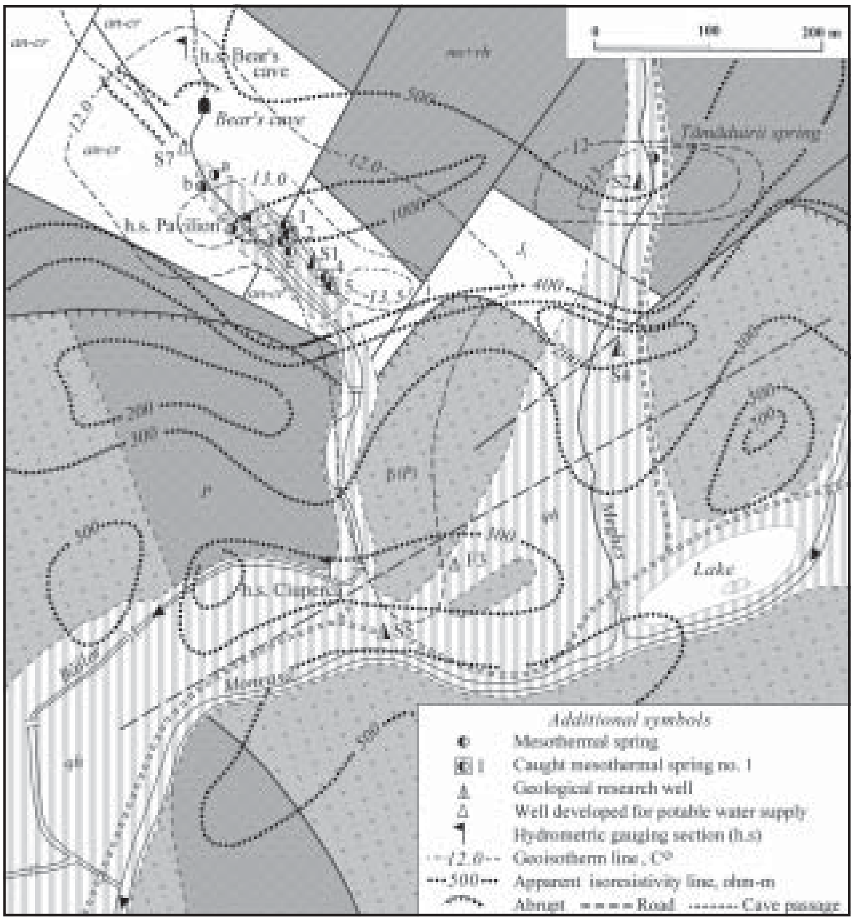

Figure 3. Hydrogeological map of Moneasa spa (geolgical data after M. BLEAHU et al., 1979, geophysical data after A. APOSTOL et al., 1975). Legend as in Figure 1.

Labellings taking place in 1977 and 1986 in Dosul Varului ponor, the Northern area of Brătcoaia depression (Fig. 1, no. 1), pointed out a major underground diffluence, the used tracers, Iodine-131 and Indium-EDTA, being both involved in a flow to the North, to Finiş and Feredeu springs, as well as to the South, in Bear's resurgent cave, thermal spring no.1 and thermal wells S2 and S4 in Moneasa (I. ORĂŞEANU, 1987, I. ORĂŞEANU, 2010).

Overall, the karstic area between Brătcoaia, Tinoasa, Izoi and Moneasa and its side watershed spread to the West up to Izoi ridge, make up a unique binary type karst system, partially thermalised in its Southern end, mainly directing underground waters from North to South, with a dominant discharge through Bear's resurgent cave. The karstic aquifer feeds from the runoff on the Eastern slope of Izoi ridge, from the aquifer located in Werfenian sandstones and the rainfalls on limestones and dolomites outcrops.

Băilor brook comes from the resurgent Bear's cave, is about 1 km long until it flows into Moneasa stream and gets downstream the cave the waters of thermal sources. Its debit is constantly monitored in the National Institute for Hydrology and Water Menegement (NIHWM) hydrometric gauge sec-

	Băilor brook h. s. Ciuperca	Băilor brook h. s. Ciuperca	Băilor brook h. s. Pavilion	Băilor brook h. s. Bear's cave
	X.1976-IX.1997	X.1997-IX.1998		
Q mean, l/s	198.2	141.1	40.1	58.0
Q min., l/s	50	54.0	6.0	17.0
Q max., l/s	5520	900	640	656
Q maxim / Q minim	110.4	16.7	106.7	38.6
Bf	0.56	0.43	0.17	0.40

Table 2. Characteristic discharges of Băilor brook measured in hydrometric sections (h. s.).

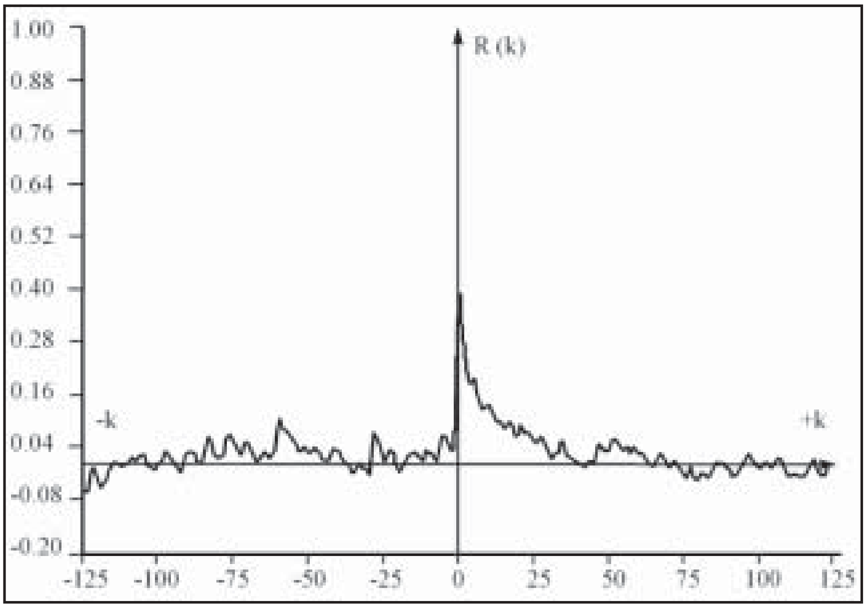

Figure 4. Analysis of discharge time series of the Băilor brook in the period 1986-1988. Cross corelation between rainfall at Izoi and stream discharge in Ciuperca gauging station.

tion (h.s. Ciuperca) placed on Băilor brook, downstream thermal waters, when the stream leave the carbonate area (Fig. 3). The station works since 1976, in between 1976-1997 having a multiannual average flow rate of 198 l/s, with extremely values in between 50 and 5.520 l/s.

For the study of the relations of cold and thermal waters on Băilor brook, there were placed, in between X.1997-IX.1998 period, two additional hydrometric gauge stations on this stream, upstream the thermal spring no.1 (h.s. Pavilion) and in the Bear's cave, on the active course placed near the terminus point of the mining gallery (h.s. Bear's cave). For those stations and the Ciuperca one, besides hydro measurements other pentadal temperature and electrical conductivity (EC) measurements were undertaken. Pentadal measurements of temperature and EC were also done for most of thermal water supplies. The results of the hydro measurements are presented in Table 2.

In the mentioned hydrological year, Băilor brook had recorded losses on the h.s. Bear's cave – h.s. Pavilion interval sections ($Q_{\text{Pavilion}} = 0.549\ Q_{\text{Bear's cave}} + 2{,}6$; $R^2 = 0.84$), as well as inflow between h.s. Pavilion and h.s. Ciuperca ($Q_{\text{Ciuperca}} = 1.68\ Q_{\text{Pavilion}} + 74$; $R^2 = 0.884$).

The cross corelogram of rainfalls Izoi - flow rate Băilor brook (h.s. Ciuperca) has got a swift reaction of the karstic system for rain impulse (Fig. 4). The corelogram has two clearly-articulated sections. The first section points a swift relation of rain-debit, relatively important ($r_k = 0{,}342$). The value $r_k = 0{,}2$ is reached in 5 days. The corelogram reaches 0 when $f_c = 0{,}005$ and corresponds to a 39 day time slot. The constant descending flow of the crossed corelogram up to zero shows that various components contributing to the system are well integrated in one response.

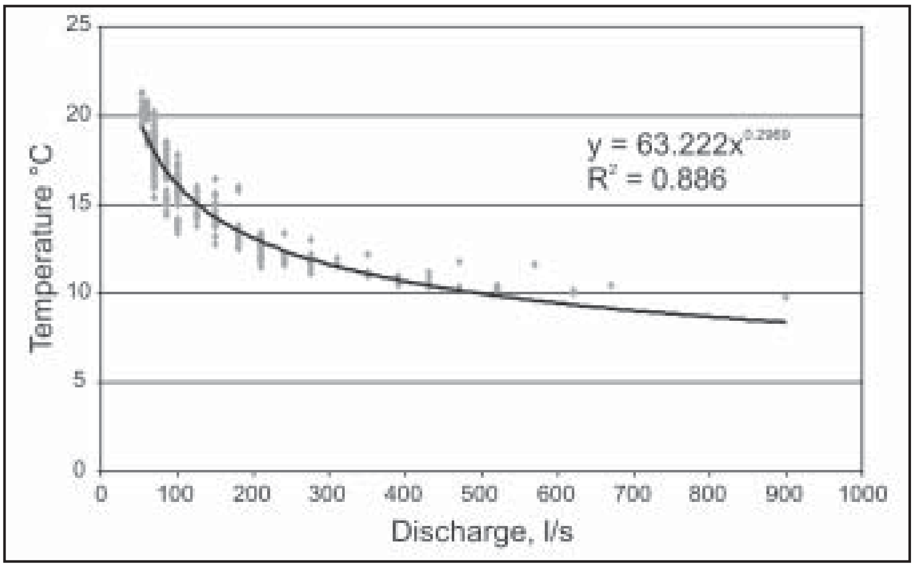

Figure 5. Relation mean daily discharge / mean daily temperature of Băilor stream. Ciuperca gauging section.

The raise of temperature for Băilor stream between h.s. Pavilion and h.s. Ciuperca varied between 0.8 şi 6.1°C, the raise going down once the debit of the stream raised (Fig. 5).

Geothermally, the whole area of Băilor stream is an abnormal area compared to the maximum placed close to springs 4 and 5 (APOSTOL et al., 1975, Figure 3).

5. Thermal waters sources

Thermal waters at Moneasa, both coming from natural sources as well as from wells, are karstic waters coming from carbonate deposites of Finiş homocline, close to the contact plane of impermeable deposits of Moma Nappe (Fig. 2 and 6).

Thermal waters in Moneasa are part of mesothermal (20-37°C) and hipothermal waters (10-20°C), the values of supplies debits and their temperatures being presented in Table 3, as an average of daily collected data by the author in between X.1975-IX.1976 and X.1997-IX.1998 and the expeditions taking place between 1970-1998.

The main natural supply thermal sources are placed on Băilor brook (Fig. 3 and Table 3) downstream the Grota Ursului resurgent cave, their temperatures rising once getting close to the deposits of Moma Nappe (Fig. 7).

Thermal springs are collected and used until 1990 for internal treatment (spring no.1), developed for potable water supply (no.1, 2 and 3) and for spa treatments (no. 3, 4 and 5 and well 1). Currently, the catchments of thermal supplies are under serious degradation.

6. Experimental pumping test

In 1997 experimental pumping test took place with a constant water debit at well S5 (4666), (Q=11.5 l/s, drawdown s = 46.6m), for 120 hours while monitoring the variation of the water level at wells S1, S2 (4663) and S4 (4664) while pumping and drawing back. Also, while exploiting well S1 by the spa (Q = 2.45 l/s, for a dynamic level of 0.14 m over the ground) the variation of the water level was monitored for well S4. Observation wells S1, S2 and S4 were equiped with piezometers.

The transmissivity and the storage coefficient of the the karstic reservoir has a wide variation on direction, and this anisotropy depends both the stratification in beds of limestones and dolomites, as well as direction of the systems of fractures and crackers affecting them.

Thus, higher values of the transmisivity and storage coefficient were collected for the directions between wells S1-S5 and S4-S5, directions corresponding the area of limestones and dolomites compression because of the overthrust of Moma Nappe, the direction of stratification for carbonate deposits as well as the main direction of fissu-

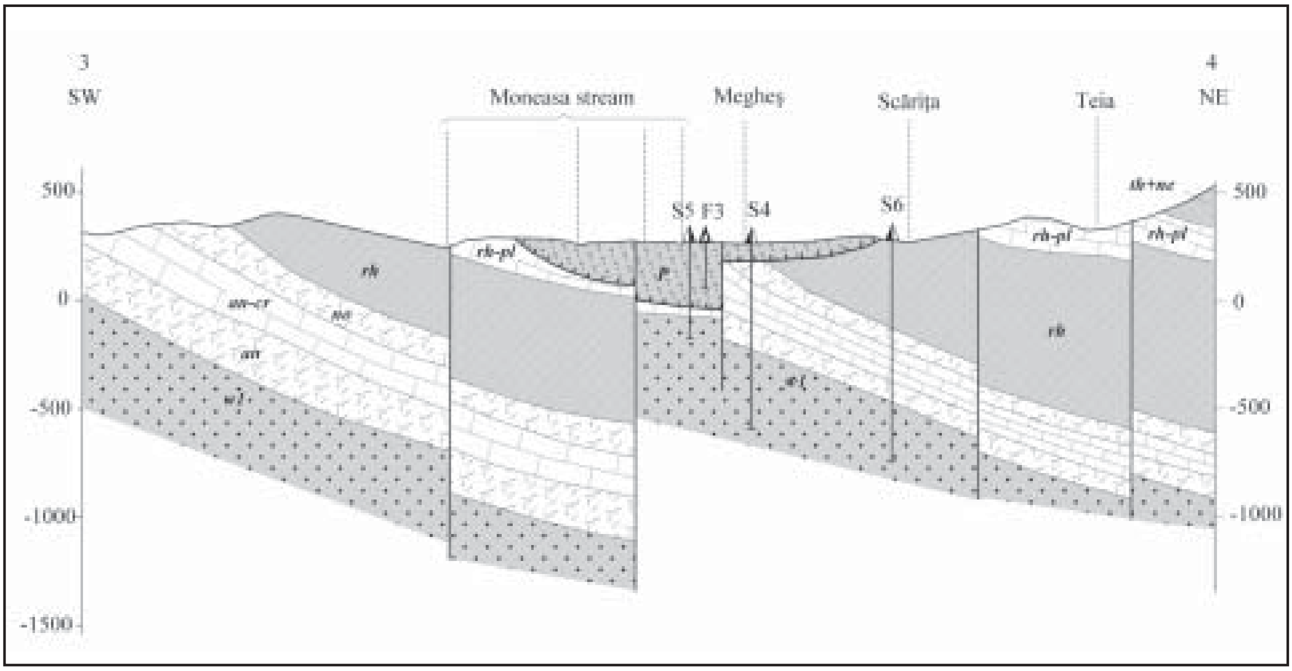

Figure 6. Hydrogeological cross section 3-4. Legend as in Figure 1. Line of section shown in Figure 1.

No	Springs and wells	Drilling year	Ground level (m)	Deep (m)	Piesometric level (m)	Discharge (l/s)	Dinamic level (m)	T (°C)
1	Spring no.1		293.96			3.29		24.0
2	Spring no.2		293.90			3.32		24.0
3	Spring no.4		292.69			4.30		31.0
4	Spring no.5		292.59					31.2
5	Well S1	1895	292.59	316.0	305.6	2.90	292.8	24.2
6	Well S2 (4663)	1972	302.59	604.0	305.2	0.40	302.8	28.4
7	Well F3	1974		197.0	Dry. Cimented			
8	Well S4 (4664)	1975	296.97	836.4	305.4	3.00	296.0	32.8
9	Well S5 (4666)	1975	284.95	424.6	307.3	7.00	285.6	16.5
10	Well S6 (Şmelţ)	1987		1003.6	Technical abandon			
11	Well S7	1996	300.00	50.0	298.0		295.8	3.5

Table 3. Characteristic data of thermal water sources.

ration for those deposits (Fig. 8). Lower values were collected for S4-S1 direction because of its perpendicular position on the stratification of the carbonated deposits and their lower degree of tectonization given the further away positioning from the compression area represented by the overthrust plane of Moma Nappe.

The interference between those wells with constant debits of waters of various temperatures (S5-15.9°C, S1-24°C, S2-28.5°C and S4-32,5°C), together with the results of tracer tests, pointing relations between cold karstic waters and thermal ones indicating the presence of a unique karstic aquifer with an extremely non-homogenous distribution of temperatures caused by local water supplies with higher temperatures on a insufficiently developed karstic network.

7. The hydrogeological budget of Moneasa

The karst of Moneasa has a major quantitative influence on the runoff distribution, a phenomenon well illustrated by processing hydrometric data collected in the watershed of Moneasa

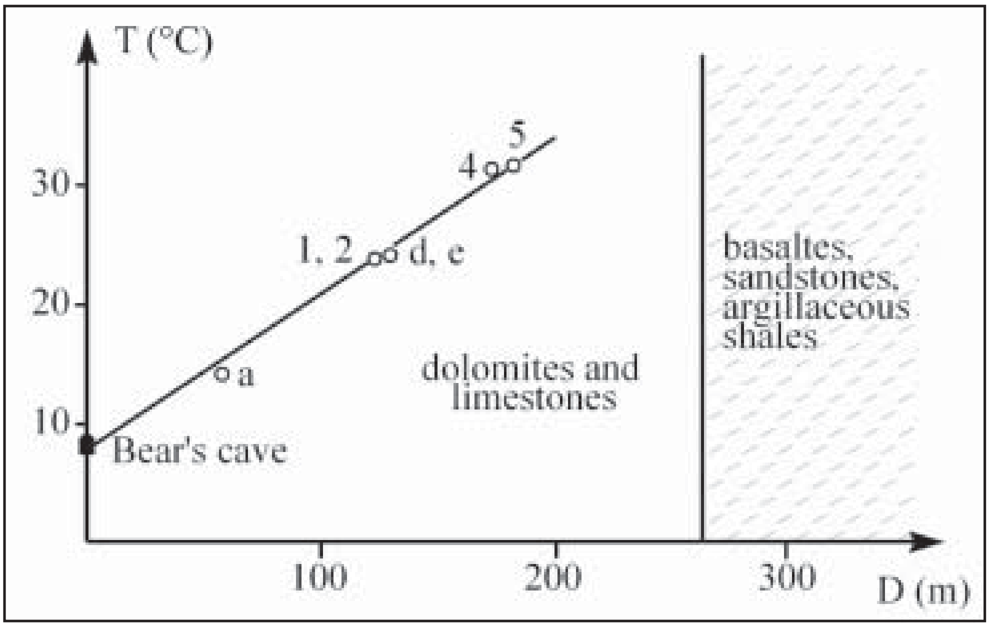

Figure 7. Relation between water sources temperature and distance from Bear's cave entrance.

stream, a representative hydrologic basin of NIHWM, with a high density of recording and monitoring hydro-metereological parameters.

In order to study the extension of the supply area of the karstic system which is discharged to the South in the area of Moneasa spa, both through the Bear's cave cold spring, and the thermal springs and wells, a global data collection was done for water supplies, surface and underground ones.

The hydrogeological collection of data was done for Megheş, Băilor and Pietros brooks and the internal drainage area of Tinoasa-Izoi depression whose connection with the resurgence in Megheş and Băilor brooks was demonstrated by tracer labellings. Brătcoaia internal drainage area was not introduced in this survey since it is only partially drained by supplies from Moneasa valley, its contribution to those supplies being indirect.

The complete survey was done for the whole perimeter as well as for each watershed, in order to set flow and drainage relations between those (I. ORĂŞEANU, 1987). To do that, we used as basic data the hydro-meteorological measurements done in Moneasa by F. PALFY, MARIA ANA GROZA, S. CRIŞAN, N. ONCEAN, NUŢA ONCEAN, T. CONDEA, G. ZACOI (1976) for the year X.1975-IX.1976.

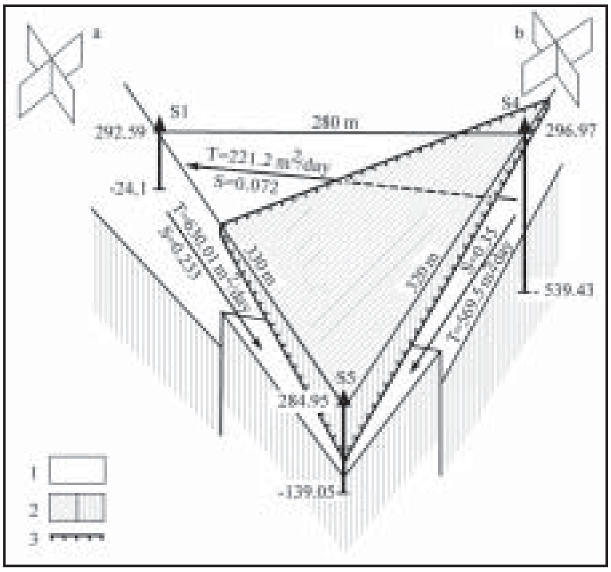

Figure 8. Block-diagram with pumping tests results.

1 - Karstifiable rocks;

2 - Nonkarstifiable rocks: a - permian basalts and shales; b - werfenian sandstones;

3 - Overthrust plane. a and b-main direction of rock fisssuring at Bear's cave spring and in left-hand slope of Megheș brook, near Tămăduirii spring.

The survey showed that, within the error limit of 5% accepted for hydrometric measurements, there is an adequate correspondence between entries and exits calculated for the whole surface taken into consideration. Separately, for each watershed, the budget pointed aut a serious lack of correlation between their surface and the surface of hydrogeologic reservoirs drained by superficial flows: Megheş brook, 6.9 km^2 vs 3.6 km^2; Băilor brook, 1.38 km^2 vs 11.6 km^2; Pietros brook, 1.65 km^2 vs 1.30 km^2.

The relation of synthesis between specific multiannual average debits, q (l/s km^2) and mean H altitudes (m) based on data from hydrometric stations, is presented in Fig. no. 9 (P. MIŢĂ, I. ORĂŞEANU, C. CORBUŞ, 1998). The incorrect inclusion of the enhoreic Izoi-Tinoasa area in the watershed of Megheş brook leads to seriously decreased values of that q compared to the q data from stations uninfluenced by the karst. We mention that Izoi-Tinoasa area is mainly drained by the Bear's resurgent cave.

Tracer experiments undertaken more complicate this view, in that the surface taken into consideration includes both contributions from Brătcoaia depression, as well as losses from the diffluence surface Megheş-Piatra cu Lapte (I. ORĂŞEANU, 1985). Those values are probably relatively close and could not be marked in whole calculation. On the other side, such a situation is relevant to point out difficulties in the hydrogeological research of karstic areas and proves the need to approach such a research based on various methods.

8. Chemism of cold and thermal waters

The chemism of cold karstic and thermal waters in Moneasa-Tinoasa area is calcic-magnezium bicarbonate with a low mineralization, in between 200 and 400 mg/l. Gradually, the chemical composition of the water of thermal springs undergoes fluctuations, most significant variations being noted for ionic elements Na^+ , K^+ , Cl^- and $SO4^{--}$. The mineralization of thermal sources on Băilor stream is reduced from upstream to downstream, while going further away from Bear's cave (Fig.10).

The waters of thermal spring 1 and the wells S1, S2 and S4 are slightly oversaturated for calcite and dolomite (the IS index of saturation is positive). Tests taken at various moments show that the waters have fluctuation of their indices of saturation around the balance point, sometimes slowly unsaturated, sometimes slightly oversaturated.

Thermal springs 1 and 3 have low gas emissions with a composition identical to atmospheric gas.

Complete tests taken by A. SZABO (1967) on the radioactivity of thermal waters at Moneasa point values between 0.69 - 1.0 nCi, figures much lower than the limit of 20 nCi when waters are considered radioactive.

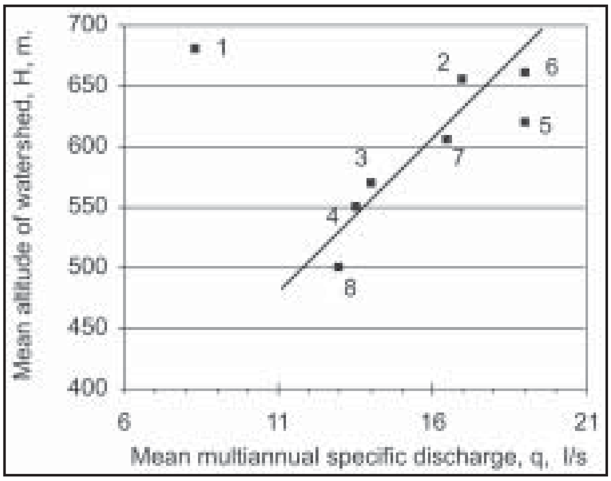

Figure 9. Relation q-H for streams in Moneasa area. (After P. MIȚĂ a.o., 1998.)
1 - Megheș, h.s. Sonda;
2 - Moneasa, h.s. Boroaia;
3 - Valea Lungă, h.s. Păstrăvărie;
4 - Dezna, h.s. Dezna;
5 - Ruja, h.s. Ruja;
6 - Moneasa, h.s. Moneasa;
7 - Momeasa, h.s. Rânușa;
8 - Fânuri, h.s. Rânușa.

In the Piper diagram in Fig.11, the chemical composition of the waters of superficial flows, the cold and the thermal springs in Moneasa is represented (I. ORĂŞEANU, J. MATHER, 2000). The analysis of the diagram shows that:

- The waters of sinking stream in Tinoasa-Izoi internal drainage area, originated in Izoi ridge, are Ca (Mg)- HCO_3(Cl) type, as a result of levigation of Werfenian quartz sandstones of the ridge;
- On the Bear'cave-S5 well alignment, the ratio of Mg in the cations goes up, the chemical character of the waters in this direction being changed from Ca(Mg)-HCO_3 type to Mg(Ca)-HCO_3 type, as a result of major contributions of deep waters flowing in dolomites.

The recharge of karstic reservoir discharged through cold and thermal sources in Moneasa is based on the following types of waters:

- karst waters results by mixing of the rainfalls (EC=20-40μS) drops on carbonate impluvium and the waters of epikarstic aquifers (EC = 400-450 μS), modified by chemical reactions with the matrix of the karstic reservoir. Karstic waters have wide variations of mineralizations following the rainfalls regime and the transit time interval through carbonate matrix;
- the water of sinking stream originated on Culmea Izoi slope (EC = 30-60 μS) and the water of the aquifer in Werfenian sandstones,

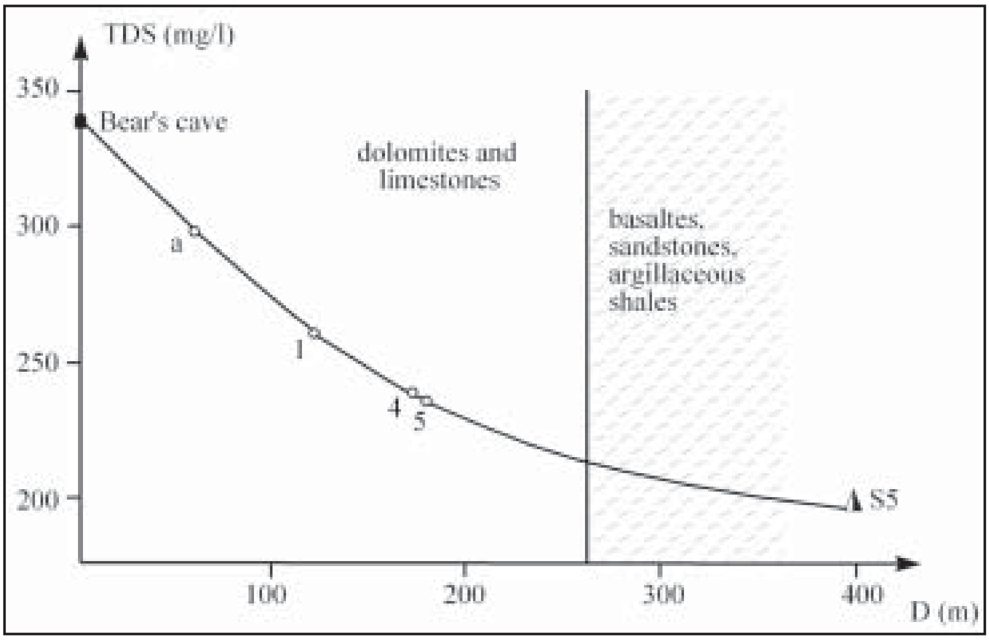

Figure 10. Source's TDS evolution along Băilor stream.

waters with a similar EC. Those two components will be further known as "Culmea Izoi water type".

Such two type of waters are mixed in various proportions in all supplies in the Moneasa perimeter. Warmer waters have in composition a higher amount of "Culmea Izoi water type".

To set the variation of mineralization of cold and thermal waters in Moneasa station, as well as the dynamics and the way mineralization took place, the electrical conductivity was pentadally measured between X.1997-IX.1998 year. Figure 12 presents the frequential distribution, average value and average deviation of EC. Classes are wide of 5 µS. Graphics presented in Fig. 12 show that:

- waters with a major EC variation are discharged in Grota Ursului, as a result of the high degree of organization of karstic network of the aquifer. This organization facilitates the resurgence of waters with different chemical composition and historics, without them being significantly mixed with other water of the aquifer;
- the water debited by well S5 presents two maximums on the frequency of EC classes. This suggests the influence of water withdrawal by well or an adequate organization of karst network and participation to the underground flow of Izoi ridge types waters, as well as karstic ones, with various seasonal contributions;
- waters discharged by thermal sources (springs no. 1 and no. 5, wells S2 and S4) have a low EC variation; the homogenization of waters shows a mild organized karstic aquifer with a preferential flow of water in cracks. The low EC average values indicate a major contribution of Izoi ridge water type in their chemical composition.

In Fig.13, a synthesis of debit, temperature and EC measurements of Băilor stream and water supplies in Moneasa is shown, along with precipitations and the air temperature. The following were concluded:

- in cold seasons, there is an adequate connection between precipitations and the debit of Băilor stream. In warm seasons, only major rain falls, over 15 mm, will lead to raised debits, lower rains being retained by vegetation and soil, to restore the supply of water used by evaporation;
- the debit and the temperature of Băilor stream have reversed directions of variation, following the change of relationship between the cold and thermal component contributing to the debit;

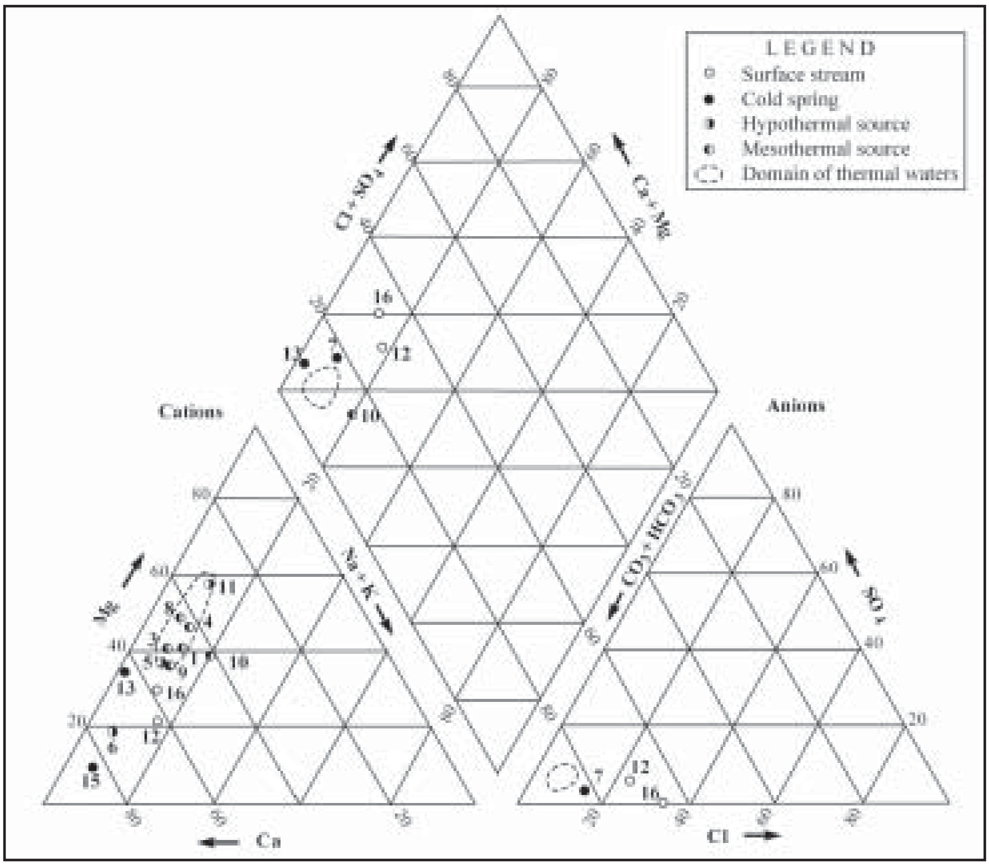

Figure 11. Piper diagram with chemical composition of surface and underground waters in Moneasa-Tinoasa area.
Sources:
1 - spring no. 1;
3 - spring no. 4;
4 - spring no. 5;
5 - spring "a";
6 - stadium spring;
7 - Bear's cave;
8 - well S1;
9 - well S2;
10 - well S4;
11 - well S5;
12 - Izoi brook;
13 - spring inTinoasa;
15 - Răchitaru spring;
16 - Hăiuga Veche brook

- in intervals of low waters, the electrical conductivity of water in Grota Ursului goes down, following the raised contribution of Izoi ridge type waters, with a low mineralization, to the whole debit;
- the melting of snow is marked by a significant EC raise for all supplies, raise marked by an interval of 15 days when the debits go up. Melted snow in Brătcoaia and Izoi depressions lead to an increase of the head of underground waters in the Northern side of the karstic aquifer, the head impulse impulse producing initially an expulsion of deep karstic waters, more mineralized because of their longer residence time in the underground;
- for all sources, there are two CE maxima caused by the interruption of melting by a colder time, a case well pointed by the variation of the temperature of the air on the same diagram. The decrease of electrical conductivity successive to those raises is caused by the dillution of karstic waters by infiltrated waters from snow melting, with a low mineralization.

Physical, chemical and isotopic tests (^{18}O, ^{2}H, ^{13}C, ^{14}C) taken in the Hydrology and isotopic chemistry Lab of the University Paris Sud, on water samples taken from Moneasa on 4-5 July 1993 pointed a distinction between two types of waters (TIMOFTE et al., 1995):

- a swift circulation of “cold” meteoric waters crossing the karst ($\delta^{18}O$ = -9% , $\delta^{2}H$ = -68%), waters with a chemical facies calcium bicarbonate;
- a deep circulation of “warm waters” ascending on faults ($\delta^{18}O$ = -11% , $\delta^{2}H$ = -77%), with a silicate chemical facies. The mix of these two types of water is done when warm waters goes up on Moneasa fault.

The ^{13}C compositon makes possible the distinction of two types of mineralization of waters:

- a mineralization in an open CO_2 biogenic system (($\delta^{13}C$ = -14%) for karstic waters;
- A mineralization in an almost closed system ($\delta^{13}C$ = -9%) for deep waters.

^{14}C measured activities clearly point the proportion of combination in a recent karstic water with an older water, of ^{14}C activity under 10%.

Waters with a reduced ^{14}C activity have the lowes ^{18}O index. They could come from deep aquifer, being fed in cold eras of superior Pliocen.

Thermal sources are simply part of the karstic aquifer located in the Southern section of Finiş Nappe, and is generated by a set of particular conditions of supply, circulation and discharge of the whole complex. The region is characterized by a high index of thermal flow (80 mWm^{-2}), being closed to the Panonic Reservoir, an area of a hiperthermal regime, with values of termic index up to 95 mWm^{-2} (S. VELICIU şi C. OPRAN, 1983).

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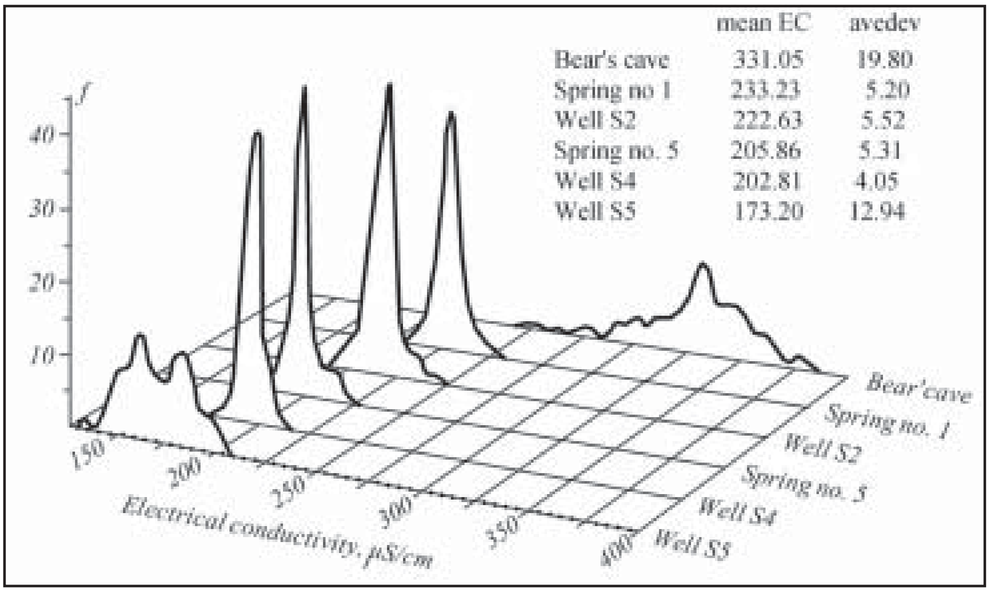

Figure 12. Frequential distribution of electrical conductivity of cold and thermal waters in Moneasa spa area

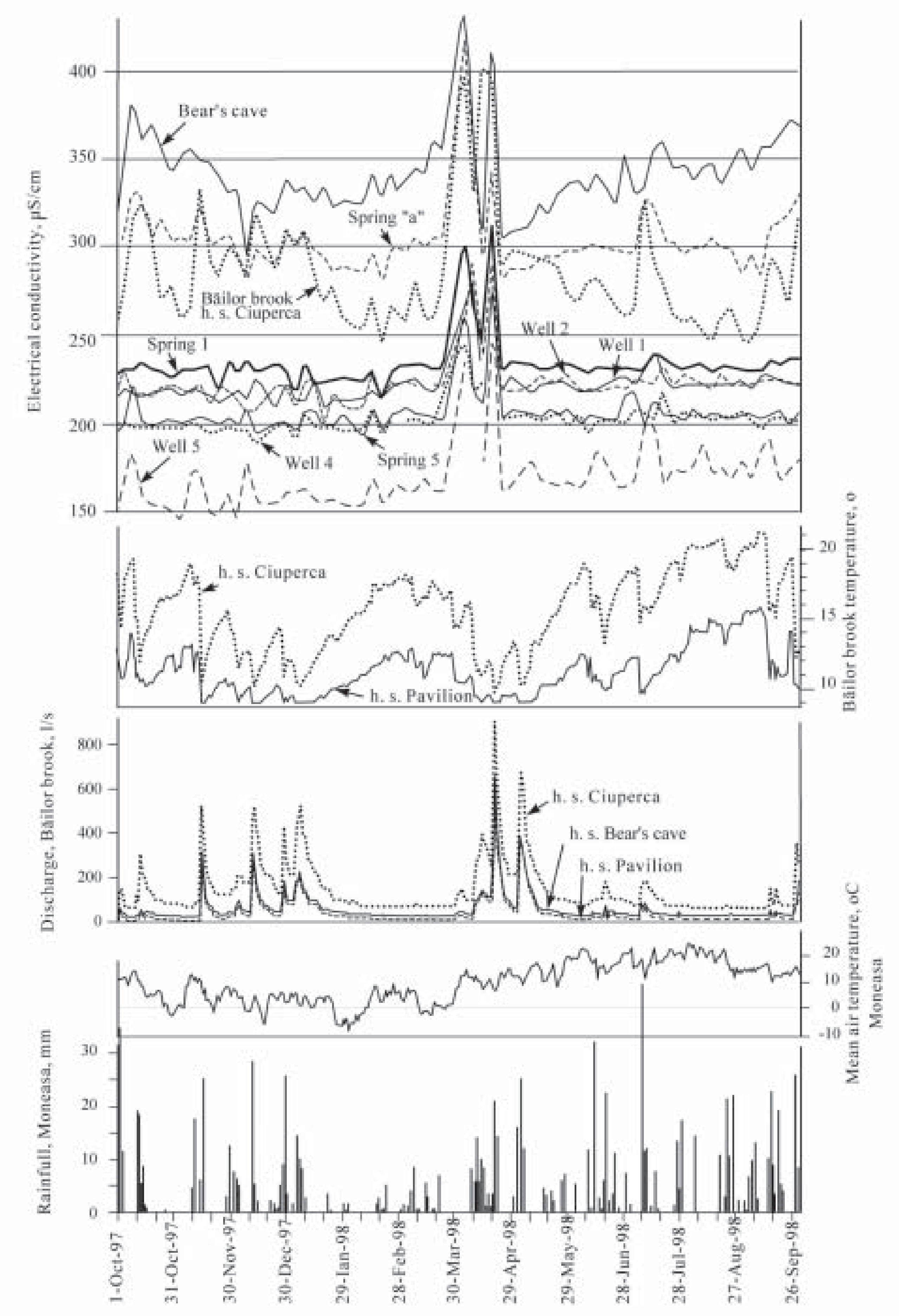

Figure 13. Multiparameters diagram of waters in Moneasa area.

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