

3.13.4. CODRU MOMA MOUNTAINS

(Reprint from Karst Hydrogeology of Romania, 2010)

Codru-Moma Mountains extend over an area of about 1200 km², being located in the western part of Apuseni Mountains, and they bear the shape of a NW-SE striking nappe system, bounded laterally by two Neogene basins: that of Crişu Negru (Beiuş) to the NE, and that of Crişu Alb (Zarand) to the SW. They consist of two zones which are quite distinct in terms of topography, Codru Mountains to the north, and Moma Mountains to the south, separated by Moneasa valley and by its tributary Boroaia in the western half, and by Iugii valley and Briheni brook further to the east.

Carbonate terrains of Codru-Moma Mountains occupy an area of 169 km², distributed as follows (Fig. 4.1):

- Dumbrăviţa de Codru-Moneasa-Dezna area (66 km²);
- Clăptescu area (13 km²);
- Vaşcău plateau (90 km²).

4.1. Current status of the hydrogeological investigations

The first geographic and hydrographic information about Codru-Moma Mountains was published by A. A. SCHMIDL in its book “Das Bihar Gebirge an der Grenze von Ungarn und Siebenburgen”, issued at Vienna in the year 1863. The author provided a detailed description of the Vaşcău plateau topography, also mentioning the ebb and flow spring at Călugări and the thermal water discharges at Moneasa.

The first hydrogeological observations concerning Codru-Moma Mountains are due to E. KERY, who published in the year 1866 the description of the thermal water discharges at Moneasa, together with the corresponding chemical analyses, performed the same year by K. NENDWITZ.

The Vaşcău Plateau is probably the first place in Romania where water tracing was carried out. In 1901, the geologist S. MIHUŢIA added powdered coal to the water of the Ţarina stream and demon-

strated a connection between the Cămpeneasca cave (photo 1) and the Boiu spring (S. MIHUŢIA, 1904).

Starting from the year 1970, I. ORĂŞEANU has conducted detailed hydrogeological investigations in all Codru-Moma Mountains karst areas and, either on his own or in cooperation with E. GAŞPAR and other investigators, he has performed a series of tracer tests which outlined, for all those areas, the general framework of the underground karst flow. E. ANGHIEL (1974), GH. PONTA and N. TERTELEAC (1977-1978) joined to the hydrological reserches.

A paper addressing the groundwater geochemistry in the Dumbrăviţa de Codru plateau has been published in 1979 by JANETA MERŢ MATYASI.

In the years 1985 and 1987, I. ORĂŞEANU has published two papers addressing the hydrogeology of Vaşcău plateau and of Moneasa area,



Photo 1. Cămpeneasca cave. Aquarelle in the book of A. A. Schmidl, „Das Bihar Gebirge an der Grenze von Ungarn und Siebenburgen”, published in Vienna in 1863.

while in the year 2000, together with J. MATHER, he has published another paper concerning the origin of the thermal water discharges at Moneasa and Vaşcău.

In the year 1986, the Institute of Geology and Geophysics has issued the hydrogeological map, sheet Vaşcău, at the scale 1:50,000, prepared by PONTA GH., BLEAHU M., PANIN ŞT. and ORĂŞEANU I., where the karst terrains hydrogeology was extracted from unpublished reports of I. & NICOLLE ORĂŞEANU (1973-1978).

The Vaşcău Plateau physiography has been investigated by I. O. BERINDEI et al. (1978), M. BLEAHU (1978), and P. COCEAN and T. RUSU (1984), while M. BLEAHU et al. (1976), GROH et al. (1976, 1978), G. HALASI (1979, 1984), K. GOPFRICH (1986), S. MATYASI and L. MATYASI (1987) addressed the results of the speleological investigations carried out in Codru-Moma Mountains karst areas. A synthesis concerning the underground cavities in Moneasa area has been published by G. HALASI in 1978.

4.2. Geological and structural framework of Codru Moma Mountains

The Codru domain, where formations subsequently incorporated in the Codru nappes have been deposited, includes at its bottom a crystalline basement overlain by a sedimentary cover that consists of a thick stack of Permian-Werfenian molasse deposits, followed by a prevalently carbonate stack, whose most recent age reached the Early Jurassic. After a sea retreat episode, which had lasted during the Medium Jurassic, the Codru domain has been again covered by sea during the Tithonic-Neocomian time interval.

Between Crişu Negru stream to the north and Moneasa spa to the south, carbonate deposits form a continuous strip, incorporated in the generally homoclinal, eastward dipping geological structure of the central part of Codru Mountains. This main strip, consisting of Triassic limestones and dolomites and displaying average outcrop widths of 2-3 km, is followed to the east by a second one, which is discontinuous, displays average outcrop widths of only 50-100 m, and consists of Early Jurassic limestone. The two carbonate strips are separated from one another by thick deposits consisting prevalently

of Norian and Rhetian shales and sandstones, which are virtually impervious and thus isolate the groundwater accumulations located in each of the two carbonate strips. Groundwater accumulations in the main carbonate strip are underlain by Werfenian quartz sandstones, while those in the secondary strip are overlain by flysch type deposits of Tithonic-Neocomian age. The lower half of the eastern slope of the ridge and the streambed of Ursului brook are covered by quartz sandstone scree and boulders accumulations, which frequently cover the Early Triassic deposits (Figure 5.1).

In Codru-Moma Mountains, outcrops consist of sedimentary deposits which belong to the Finiş, Moma, Vaşcău and Coleşti nappes. In devising the hydrogeological maps (Fig. 4.1 and 4.5), there has been used the geological background provided by the following sheets of the Geological Map of Romania, scale 1:50.000: Dumbrăviţa de Codru (BLEAHU et al., 1984), Petru Groza (BLEAHU et al., 1981) and Vaşcău (BLEAHU et al., 1979).

4.3. The Codru Mountains

4.3.1. The Codru Mountains physiography

The topography of Codru Mountains closely mirrors their geological structure and constitution. It includes three main mountain ridges, which strike roughly north-south and incorporate hard rocks of Permian age. Those ridges bound two depressions, which are shaped in less competent rock formations and are occupied by the upper reaches of the longest streams in those mountains, Finiş and Tărcăiţa.

The western ridge, also known as The Big Ridge of Codru Mountains, extends between the peaks Bălăteasa and Izoi. It is about 12 km long and reaches a maximum elevation of 1111.9 m in Pleşu peak. This ridge overlooks Zarand basin to the east, forming a continuous wall which rises by almost 1000 m above the depression.

Toward the east, the Big Ridge also appears as a prominent feature, an effect of the elevation drops in excess of 400 m recorded down to the upper reaches of Finiş stream, or down to Brătcoia and Izoi-Tinoasa karst depressions. The latter are typical karst depressions of lithological contact, shaped under the circumstances created by the under-

ground sinking of the surface streams that originate on the Big Ridge eastern mountainsides. The depressions are flat internal drainage areas, covered to a large extent with grass, occupying areas of 3.8 and 4.1 km² respectively, strongly alluviated with quartz sandstone boulders, and strewn with temporary water ponds.

To the north, the Big Ridge disperses into a series of secondary ridges that smoothly descend toward Beiuș basin. Here is located Dumbrăvița de Codru karst plateau, well known for its areas strewn with lots of large size sinkholes. It is completely devoid of surface streams and it forms a internal drainage area extending over 5.5 km².

Eastward from Dievii peak there occurs another karst area of Codru mountains, known as Clăptescu area, after the name of the corresponding peak (818.4 m elevation), which appears as the prominent feature of the local topography, due both to its height, and to its median position. Between the peaks Dievii (1044.0 m) and Clăptescu, a series of small depressions generated by karst stream piracy extend along a north-south direction, being shaped by runoff collected on the eastern mountainside of Dievii peak.

Water in the southern part of Codru Mountains is collected by Moneasa brook, a tributary of Dezna stream, which at its turn is a tributary of Crișu Alb river. The valley of Moneasa brook is tectonically controlled, closely following the strike of the overthrust plane of the Moma Nappe over the Finiș Nappe. In the karst area the stream supply occurs asymmetrically, its tributaries, that are excavated mainly in carbonate formations (Scărița, Megheș, Băilor, Pietros), coming only from the right side. Băilor brook is mainly supplied by water discharged through Grota Ursului outlet cave.

The underground cavities in Moneasa area consist of several caves and potholes, among which we mention: the cave “Peștera cu Apă de la Moară” (2012 m), “Grota Ursului” cave (250 m), and the pothole in Teia valley (1337.5 m long, and -90 m deep).

4.3.2. The hydrogeology of Codru Mountains karst areas

Groundwater accumulations in the carbonate deposits of Codru-Moma Mountains discharge through springs of relatively significant flow rates.

Table 4.1 provides the hydrodynamic parameters of the main karst outlets, Table 4.2 provides the results of recession and spectral and correlative analysis, while Table 4.3. provides the tracer tests performed in Codru Mountains.

4.3.2.1. Izvorul Morii de la Borz karst system

Izvorul Morii de la Borz karst system incorporates mainly Dumbrăvița de Codru karst area. Out of the entire karst system water supply, 95% is provided by rainfall on the limestones and dolomites outcrops, while catchment areas developed on impervious formations contribute with only 5%. Runoff collected on non-karst terrain diffusely sinks in the streambed when reaching carbonate terrains.

Izvorul Morii (“The Mill Spring”) is located on territory of Borz village (site 1 in Figure 4.1), at the end of a blind valley which displays the character of a torrent, at an absolute elevation of 211 m, which is 61 m above the base level represented by Crișu Negru stream. The spring has 101 l/s average flow rate and a relatively small value of the base flow index (11.7). The extreme flow rate values recorded during the X. 1986-IX. 1987 period were 30 l/s and 350 l/s respectively, while the average temperature was 9°C. The small value of the recession coefficient (0.0065) suggests the existence of major water accumulations, stored mainly in the cracks and the bedding joints of the Anisian dolomites and of the Anisian-Carnian limestones.

The only known occurrences of groundwater in Dumbrăvița de Codru karst plateau are related to a few domestic dug wells that tap epikarst water accumulations, of temporary and local character (Fântâna Josana, Fântâna Talpii, (sites 2 and 3 in Fig. 4.1).

The spring in Luncii Valley (site 7 in Fig. 4.1) is the second largest outlet in terms of flow rate on the territory of Dumbrăvița de Codru village. It is the outflow of the underground stream that flows in the nearby cave in Luncii valley. The spring has an average flow rate of 12 l/s, with minimum value of 4-5 l/s, it is tapped and it provides discharge to groundwater accumulations beneath Bujorului peak and possibly to diffuse infiltration occurring in the upper reaches of Ormanului brook.

4.3.2.2. Finiș - Feredeiu karst system

Tracer tests performed in the years 1977 and 1986 in Brătcoia depression by I. ORĂȘEANU

and E. GAȘPAR (Table 4.3) have outlined the existence of a major diffidence area, which concerns water that sinks in Dosu Varului swallet, located in the northern part of the indicated depression

(site 17 in Fig. 4.1). Specifically, the tracers that had been used - namely Iodine-131 and In-EDTA - have been detected in the Finiș spring outlets (site 15 in Fig. 4.1) and in Feredeu spring (site 13 in

No.	Source	Q	Q	Q	n_v	B_f	Cv	Tracer tests	
		mean	min	max				V, m/h	L, km
Codru Mountains									
1	Valea Morii, Borz	0.101	0.030	0.350	11.7	0.31		45.4-53.7	2.95-4.3
2	Finiș	0.289	0.025	2.300	92.0	0.15		10.8-25.0	0.8-4.05
3	Feredeu (5)	0.044	0.035	0.069	1.55	0.88	0.05	27.6-103.0	2.9-6.0
4	Grota Ursului (1)	0.058	0.017	0.657	38.6	0.40	0.64	120-368	1.84-5.8
5	Băilor stream (1, 2)	0.141	0.054	0.900	16.7	0.43			
6	Băilor stream (1, 3)	0.040	0.006	0.640	106.7	0.17			
7	Băilor stream (2, 4)	0.198	0.050	5.520	110.4	0.37			
Vaşcău Plateau									
1	Boiu	0.587	0.070	5.400	77.14	0.14	0.88	5-500	1.7-8.6
2	Șopoteaș	0.120	0.011	0.275	119.4	0.26	0.62	29.4	418
3	Crisciorel fishery	0.126	0.007	0.350	50.0	0.08			
4	Pepineaua	0.048	0.02	0.335	16.7	0.44	0.55	20	0.625
5	Colești	0.034	0.002	0.420	210.0	0.06	0.97		
6	Rășchirata	0.040	0.015	0.110	22.0	0.13	0.76		
7	Valea Seacă	0.077	0.023	0.250	10.9	0.32	0.51	96.3-130	0.65-1.05

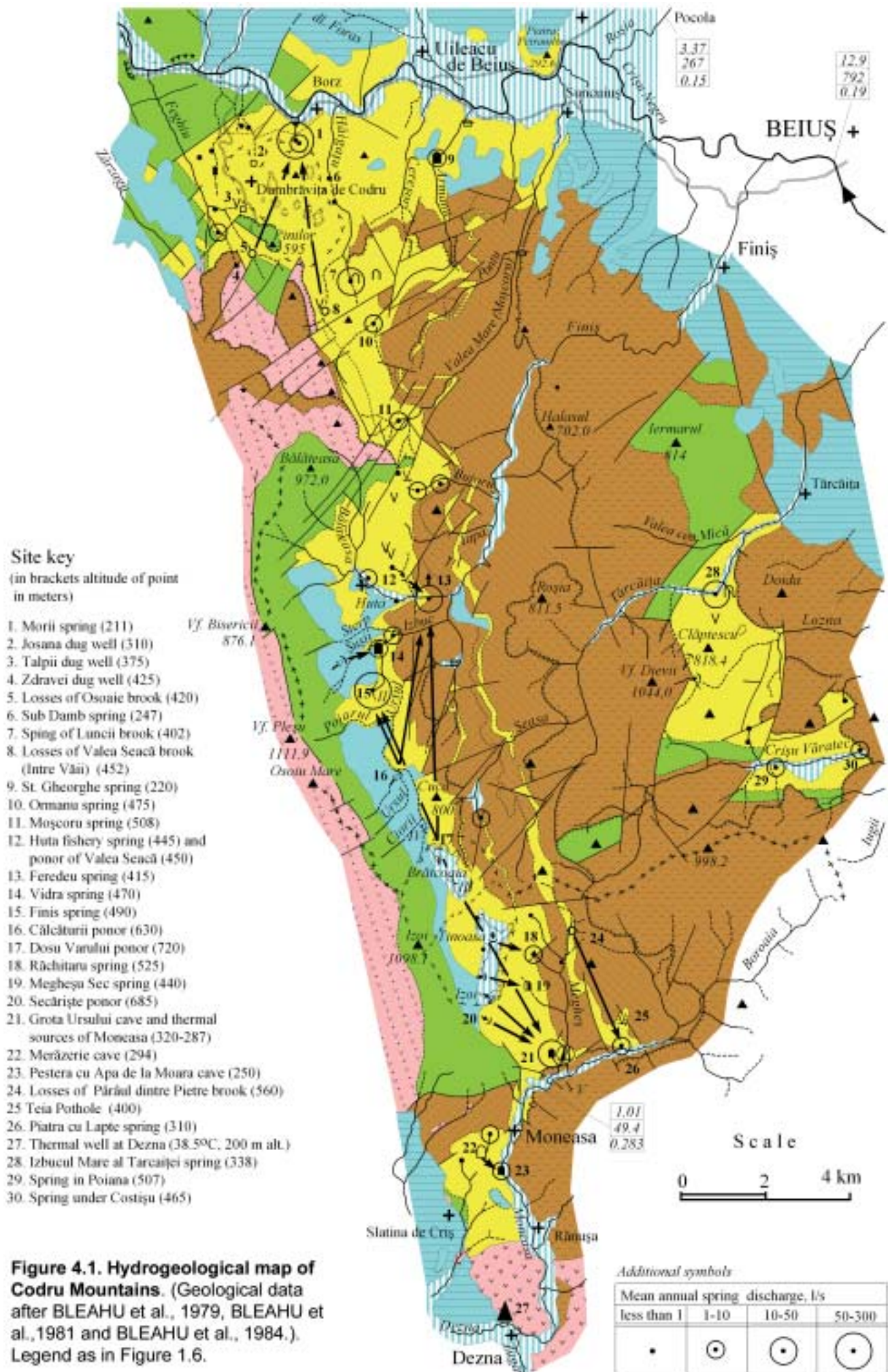
n_v , (Q_{max}/Q_{min}); B_f , base flow index (the ratio between Q_{min} of the drought month of the year and Q mean annual). Cv, the discharge time series variation coefficient (the ratio between average deviation and the annual average of an hydrologic annual series of mean daily discharges values; (1), X. 1997-IX. 1998 time interval; (2), Băilor stream in Ciuperca gauge section; (3), Băilor stream in Pavilion 1 gauge section; (4), 1976-1997 time period.; (5), V. 2004-XII. 2007 time period.

Table 4.1. Hydrodynamic parameters of karstic springs (X.1986-IX.1987, time interval).

No	Karst system	Period	Recession curve analysis			i	k	Corelation and spectral analysis		
			α (day^{-1})	V dyn	V year			ME (day)	TF	RT (day)
				(106 m ³)						
1	Grota Ursului	X.1997-IX.1998	0.0090	0.41	0.50	0.610	0.082	18	0.192	6.9
2	Boiu	X.1986-IX.1987	0.0120	1.66	18.51	0.43	0.089	16	0.100	19
3	Șopoteaș	"	0.0050	0.40	6.74	0.52	0.060	55	0.084	36
4	Rășchirata	X.1997-IX.1998	0.0045	1.01	1.60	0.380	0.230	51	0.080	61
5	Valea Seacă	"	0.0034	1.51	1.58	0.240	0.350	60	0.100	62

$\alpha(day^{-1})$ - base flow (recession) coefficient; Vdyn, dynamic volume; Vyear, annual volume; i and k, Mangin's index classification; ME, memory effect; TF, truncation frequency; RT, regulation time.

Table 4.2. Results of recession and spectral and correlative analysis.



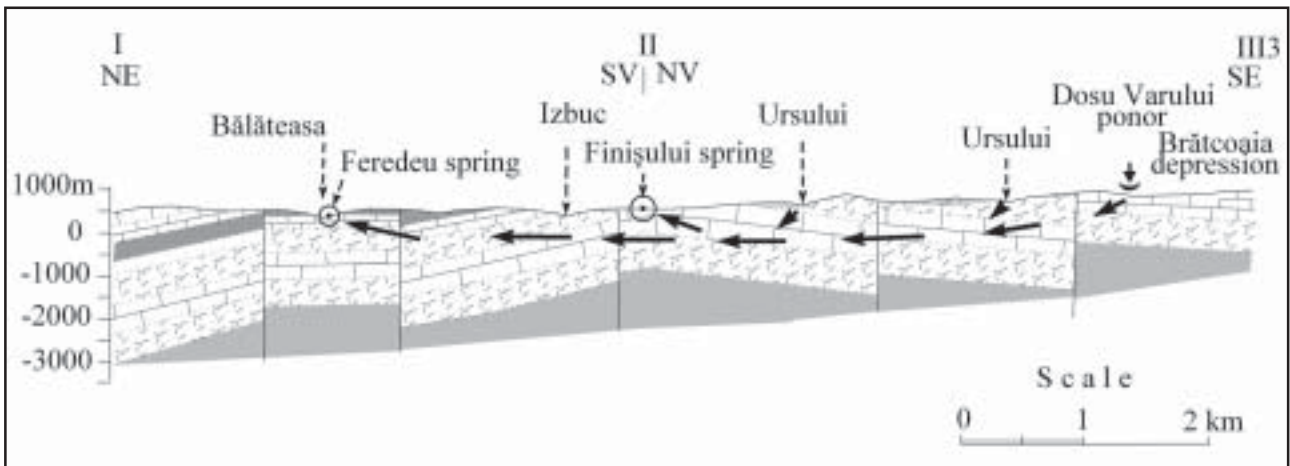


Figure 4.2. Hydrogeological cross section of Codru Mountains.

Legend as in Figure 1.6. Line of section shown in Figure 4.1.

Fig. 4.1), located to the north, as well as in Grota Ursului resurgence (site 21 in Fig. 4.1) and in certain thermal water outlets at Moneasa (the thermal spring no.1 and the thermal water wells S2 (4663) and S4 (4664)), located to the south, thus indicating that the groundwater divide between the catchment areas of Crişu Negru and Crişu Alb rivers is located in Brătcoia area. The indicated tracer tests have additionally outlined that the springs Finiş and Feredeş on the one hand, and the resurgence Grota Ursului and the thermal water outlets at Moneasa on the other hand, all belong to unitary karst systems (Fig. 4.2 and 4.3).

During the hydrological year X.1986 - IX.1987, the monthly average flow rate of Finiş spring fluctuated between 0.025 and 2.3 m³/s. The corresponding base flow index value, $n_v=92$, ranges among the highest recorded for the Codru-Moma Mountains karst outlets. The wide fluctuation in terms of discharge corroborates with the large value of the recession coefficient ($\alpha=0.01$),

suggesting that groundwater storage and movement occurs mainly in largely developed karst cavities, and to a lesser extent in fissures and fine joints. Spring water has an average temperature of 8.5°C and it becomes very muddy during heavy rainfall and snowmelt periods.

Feredeş spring is located on the right side of Bălăteasa brook, some 700 m upstream from its junction with Ursului brook (site known as “La Cruce”, Fig. 4.4). The spring water emerges from the upper dolomite, close to the contact with Rhaetian marls. In the outlet area vegetation is abnormally abundant and a significant amount of gas is released from the spring water. The latter has a temperature of 11.2-13.0°C and it is always very clear. The spring annual average flow rate was 43.4 l/s in V. 2004-XII.2007 period, with very small fluctuations ranging between 35.1 and 69 l/s, a fact which was also in accordance with the very low value of the discharge time series variation coefficient, $C_v=0.05$. The source being one of the first steady.

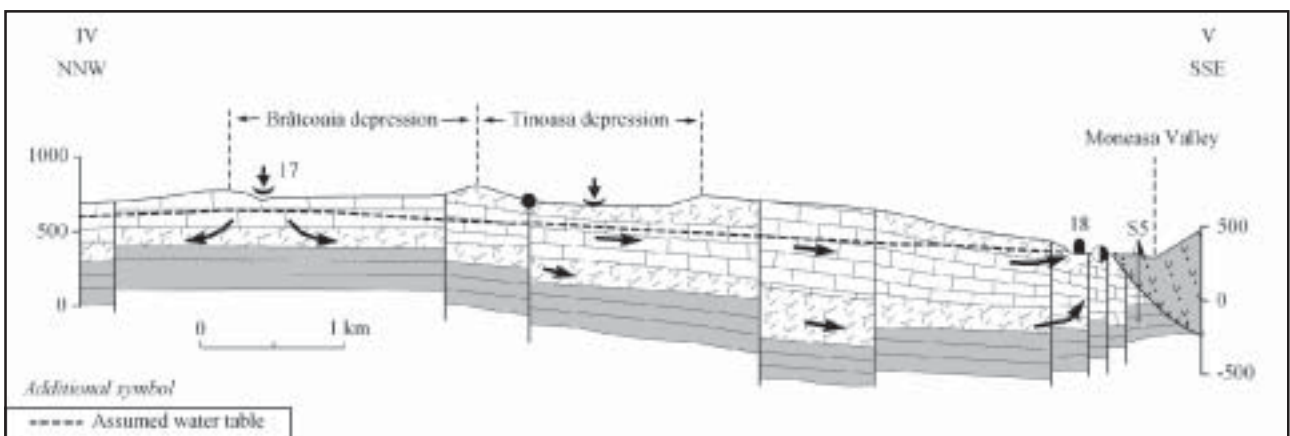


Figure 4.3. Hydrogeological cross section of Codru Mountains.

Legend as in Figure 1.6. Line of section shown in Figure 4.1.

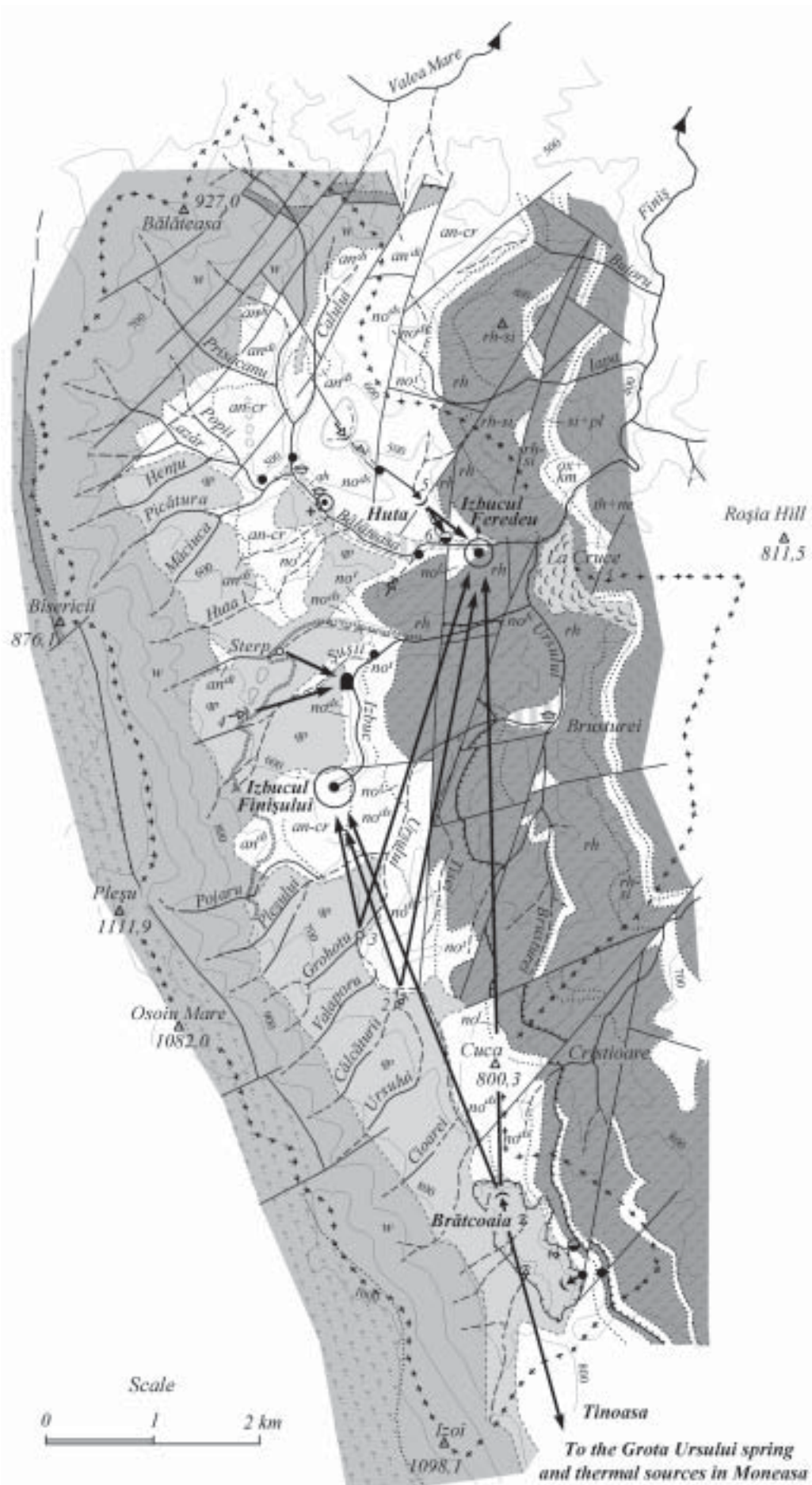


Figure 4.4. Hydrogeological map of the upper Finiş stream watershed.
 Geological data after BLEAHU et al., 1981 and 1984. (Legend as in figure 1.6).

Labelling no.	Drainage no.	Insurgence	H, m	Resurgence	H, m	L, m	ΔH , m	Used tracer	T, hours	V, m/h	Date of labelling	Author(s) of labelling
1	1	Izoi ponor	680	Grota Ursului spring	320	2110	360	HTO	6	355	1970	I. Orășeanu et al.
	2	"	"	"a" hypothermal spring, Moneasa	295	2180	385	"	6	363	"	"
2	3	Ponor of Secăriște	685	Grota Ursului spring	320	1840	365	HTO	5	368	1970	I. Orășeanu et al.
3	4	Teia pothole	400	Piatra cu Lapte spring (fig. 4.1, no. 19)	310	650	90	I	25	41	1972	Tănăsescu et al.
4	5	Tinoasa ponor	657	Răchitarul spring	525	1075	132	F	43	22	1973	I. Orășeanu
5	6	Losses of Haiuga Veche brook	669	Megheșul Sec spring	440	1200	229	I	1	1200	1974	I. Orășeanu et al.
6	7	Tăul Bivolilor ponor (fig. 4.1, no. 21)	294	Pestera cu Apă de la Moară cave (no. 20)	250	630	44	F	8	80	1974	I. Orășeanu
7	8	Dosul Varului ponor (fig. 4.1, no. 17)	720	Feredeul spring (fig. 4.1, no. 13)	415	6000	305	I	58	103	1977	I. Orășeanu et al.
	9	"	"	Grota Ursului spring	320	5800	400	"	48	120	"	"
8	10	Călcătării ponor (fig. 4.4, no. 2)	630	Finișului spring	490	2100	140	F	87	25	1977	I. Orășeanu
	11	"	"	Feredeul spring	415	4250	215	"	150	28	"	"
9	12	Dosul Varului ponor (fig. 4.1, no. 17)	720	Grota Ursului spring	320	2100	230	In	168	12.5	1986	I. Orășeanu E. Gașpar
	13	"	"	Feredeul spring	415	6000	305	"	96	62.5	"	"
	14	"	"	No. 1, thermal spring, Moneasa	294	5900	426	"	600	9.8	"	"
	15	"	"	No. 4, thermal well, Moneasa	297	6250	424	"	480	13	"	"
	16	"	"	No. 2, thermal well, Moneasa	303	6150	427	"	460	13.4	"	"
10	17	Losses of Pârâul dintre Pietre (fig. 4.1, no. 24)	560	Piatra cu Lapte spring (fig. 4.1, no. 19)	310	2680	350	R	70	38.3	1987	I. Orășeanu
11	18	Losses of Scărița brook	540	Piatra cu Lapte spring	310	1700	230	F	48	35.4	1987	I. Orășeanu
12	19	Losses of Blidărița brook	630	Piatra cu Lapte spring	310	3100	320	In	72	43	1987	I. Orășeanu E. Gașpar
13	20	Losses of Osoaie brook	420	Morii spring at Borz	211	2950	209	R	65	45.4	2004	I. Orășeanu
14	21	Losses of Valea Seacă brook (fig. 4.1, no. 8)	452	Morii spring at Borz (fig. 4.1, no. 1)	211	4300	241	F	80	53.7	2004	I. Orășeanu
15	22	Losses of Ursului brook (fig. 4.4, no. 3)	592	Finișului spring	490	1460	102	F	59.5	24.5	2004	I. Orășeanu
	23	"	"	Feredeul spring	415	3740	177	F	144	26	"	"
16	25	Ponor of Valea Seacă brook (fig. 4.4, no. 5)	450	Feredeul spring	415	770	35	F	30	25.7	2005	I. Orășeanu
	25	"	"	Gura Văii Seci spring (fig. 4.4, no. 6)	425	700	25	"	20	35	"	"
17	26	Ponor in Șușii brook basin	580	Vidra spring (fig. 4.4, no. 4)	470	1000	110	F	35	28.6	2006	I. Orășeanu

H - elevation, in meters a.s.l., L - horizontal distance between losses and springs, 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, M. Midoiu, T. Tănase, D. I. Slavoacă and Nicolle Orășeanu - 1 and 2; E. Gașpar, E. Anghel, C. Stanca, T. Tănase and Nicolle Orășeanu - 5; E. Gașpar, M. Midoiu, T. Tănase and Nicolle Orășeanu - 7, Gh. Ponta and N. Terteleac - 7 and 8.

Table 4.3. Results of tracer tests performed in Codru Mountains.

No.	Source	n	T (°C)	CH ₄	CO ₂	O ₂	N ₂	Ar
1	Feredeu	1	13.0	0.036	7.39	0.24	92.31	0.010
2	Thermal spring no. 1, Moneasa	1	24.0	0.300	0.30	20.80	77.60	0.890
3	Thermal spring no. 2, Moneasa	1	24.0	0.700	1.00	19.10	71.20	0.820
4	Rengle	6	17.0	0.016	2.32	13.79	83.21	0.611
5	Sfârșele	1	17.2	0.594	1.455	12.50	84.07	0.554
6	Racova	7	14.5	0.014	2.51	13.26	83.80	0.586
7	Țucrești	7	14.5	0.033	2.32	14.05	82.92	0.620
8	Fântâna Rece (Bârza)	1	11.8	0.004	0.72	12.60	86.00	0.558
9	Căptălanul	2	8.6	0.022	2.21	15.94	81.06	0.705
10	Crisciorel fishery	2	12.1	0.087	1.66	11.04	86.62	0.490
Atmosphere (Rankama,1970)				0	0.03	20.95	78.09	0.930

Note: Other compounds for which the gases were analysed: C₂H₆, C₃H₈, C₄H₁₀, and He, are leaking;
n = number of analysis.

Table 4.4. Chemical composition of gas outflow from springs (%vol.).

Feredeu spring water has a magnesium bicarbonate chemical character, its average mineralization is 516.1 mg/l, (35.6 mg/l Mg⁺⁺), it is not radioactive, and gas released from the spring consists mainly of nitrogen (Table 4.4).

4.3.2.3. Grota Ursului karst system

Considered in global terms, the karst area which extends between Brătcoia, Tinoasa, Izoi and Moneasa, together with its catchment area that extends further to the west up to Izoi ridge, makes up a single karst system, part of which displays a thermal character in its southernmost end, and whose underground water flow is directed from north to the south, discharging mainly through Grota Ursului spring and the thermal outlets (Figure 4. 3). The water amount which cannot be carried within this flow, as a consequence of the limited transfer capacity of the karst channels and fractures, flows toward the east, through the overflow springs in the Megheș brook catchment area (Figure 4.1).

The hydrogeological relationships existing between the water sunken through the swallets in Brătcoia and Izoi-Tinoasa karst depressions, and the cold and thermal outlets situated along Băilor and Megheș brooks, have been delineated by means of tracer tests (Table 4.3).

Băilor brook has its origin in Grota Ursului cave and it further receives, downstream from this

outlet, a significant inflow of thermal water. The cumulated mixed flow rate is monitored in a systematic way in the gauging section (g. s.) installed by the National Institute for Hydrology and Water Management (NIHWM) on Băilor brook, in the area where the brook reaches the alluvial plain of Moneasa brook (Ciuperca g. s.). The gauging section operates since 1976, the average flow rate for the time interval 1976-1997 being 198 l/s, with extreme values ranging between 50 and 5,520 l/s.

In order to know the flow rate of the underground stream in Grota Ursului, a gauging station has been installed during the hydrological year X.1997-IX.1998 inside the cave, in the place where a mine passage reaches into the underground stream. Over the indicated time interval, the recorded average annual flow rate has been 58 l/s, while the average water temperature has been 8.8°C.

The karst system discharging through Grota Ursului displays rather elevated values of the recession coefficient α (0.009-0.017), a circumstance which suggests that the underground flow occurs mainly along wide cavities and that groundwater storage is not very significant. The rainfall-discharge transfer occurs rapidly, with a rather high coefficient of the cross correlation diagram ($r_k = 0.342$).

Out of the total amount of water discharged through Grota Ursului cave (Grota Ursului g.s.), the percentage discharged by the fast flow amounts

to 10.2-18.5 %. In the case of Băilor brook at Ciuperca g.s, the percentage of water discharged by the fast flow decreases to 2.1-10.3 %, as a result of the contribution of the thermal water inflow, which discharges essentially as base flow.

According to the karst systems classification proposed by Mangin (1974, 1975), which takes into account parameters k and i , Grotta Ursului karst system ranges in types II-III, that are inferred to be subject to more intense karst processes in their upstream section, to include a largely developed flooded karst in their downstream section, and to be supplied to some extent by runoff collected on non-karst terrains (binary systems).

In the south western extremity of Codru Mountains, within the territory of Dezna village, on the right side of Moneasa brook, some 200 m upstream from its junction with Zugău brook, Foradex Company has drilled in the year 1978 a groundwater well, that over its entire depth (897 m) has crossed prevalently carbonate deposits (E.Vălenaş, V. Fasola, 1978, Hydrogeological raport). The well discharges 3.5 l/s of calcium-magnesium bicarbonate water, with a temperature of 38,5°C. The water is used for treating locomotion disorders in the nearby sanatorium.

4.3.2.4. Izvorul Mare al Tărcăiței karst system

In the carbonate deposits of Clăptescu area, which is located between the streams Tărcăița and Crişu Văratec, there are located significant water accumulations that are supplied mainly by rainfall collected within the areas where those deposits outcrop, and subordinately from surface streams originating in the permanent springs at the bottom of the Dievii peak eastern mountainside. These surface streams sink in the underground, either through swallets where human access is not possible, or through the very thin alluvia in the streambed of Cârțala brook, which only during very abundant rainfall periods carries water over its entire length (down to the junction with Lozna brook).

These groundwater accumulations discharge mainly to the north, via Izvorul Mare al Tărcăiței spring that is situated on the right side of Tărcăița brook, in its floodplain, under the Clăptescu peak northern slope which consists mainly of Anisian dolomites (site 23 in Figure 4.1). The spring average flow rate is 40 l/s and its temperature fluctuates between 10 and 10.6°C. During heavy rain-

fall periods, the spring water does not become muddy. The water has a calcium-magnesium bicarbonate chemical character, and an average mineralization of 687.7 mg/l.

4.4. The Vaşcău Plateau

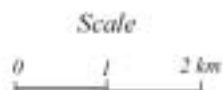
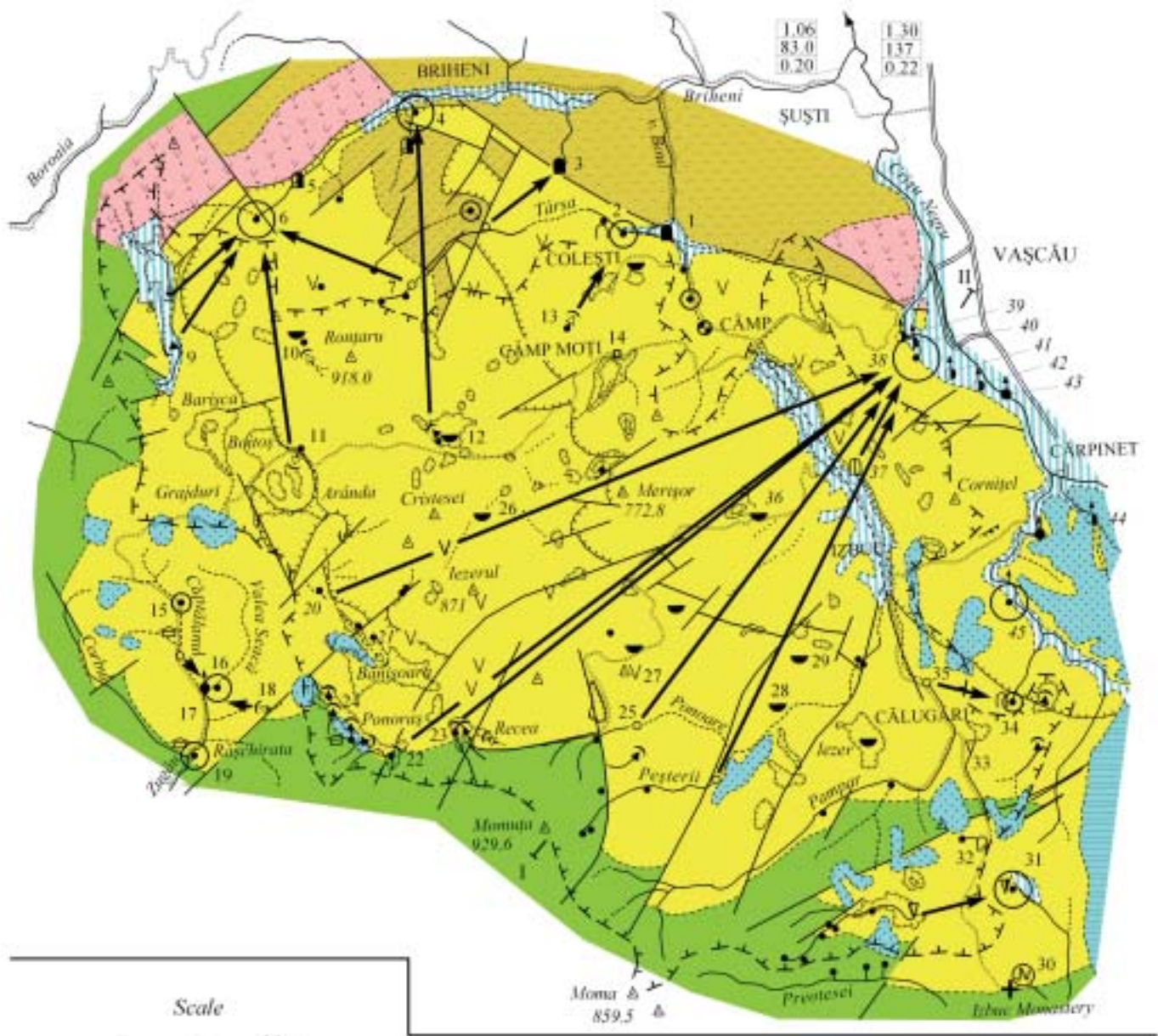
In the southern part of Codru-Moma Mountains carbonate deposits build up a single entity that extends over an area of about 90 km², outcropping at 600 m average elevation and being designated, in terms of physiography, as Vaşcău Plateau. Hard, non-carbonate deposits surround this entity to the north, south and west, thus bounding a carbonate rocks amphitheatre which faces east, toward the Beius depression, where carbonate deposits sink in a stepwise manner under the Neozoic filling of the depression.

The Vaşcău Plateau topography is dominated by a few peaks which follow to one another, starting from the north-west and running toward the central-southern area (Ronțaru-918 m, Iezerul-870m), thus building a high altitude zone from which the relief rapidly falls westward into a series of large karst depressions (Arânda, Ponoare-Pociovești, Bănișoara, Ponoraș), while to the east it gently lowers into a vast plain strewn with sinkholes and dry valleys, whose major feature is the karst stream piracy depression Țarina-Câmpeneasca. Close to the Beiuș depression, in the proximity of Vaşcău town, the topography sharply drops by 200 m over a horizontal distance of about 500 m, along a system of NW-SE striking fractures that subsequent, Neozoic deposits obliterate (Figure no. 4.5).

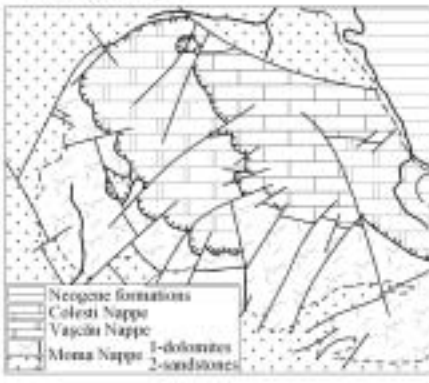
The original streams network became dislocated as a result of the frequent karst stream piracy phenomena, so that most streams collected on the non-karst slopes that adjoin the plateau sink right away into the multitude of swallets which occur along the karst area boundary. The only exception is Țarina brook, which after collecting the water on the south-western rim of the plateau, keeps flowing for 5 km along a valley that is excavated in limestones, to finally sink into Câmpeneasca swallet cave.

A compact area of internal drainage occurs in Vaşcău Plateau, extending over 73.3 km², one of the largest areas of this kind in Romania.

Carbonate deposits in Vaşcău Plateau occur in a stack that progressively thickens from west to



Structural map



Additional symbols

Mean annual spring flow, l/s				
less than 1	1-10	11-50	51-250	251-550
•	◉	◉	◉	◉

Site key (in brackets, altitude in meters, asl)

1. Coșal de la Chietroc (390)
2. Colești spring (400) and Deliman cave (450)
3. Popii cave (400)
4. Șopoteasa spring (355)
5. Maura Dracului cave (415)
6. Tisa spring (450)
7. Losses of Hăiuga lui Șandor brook (675)
8. Peșterii ponor (Dănești brook ponor, 601)
9. Cobului ponor (636)
10. Spring in Poiana lui Gupi (770)
11. Fântâna din Drum spring (770)
12. Spring (645) and ponor (630) in Tăul Ponorului
13. Fântâna lui Dobocș spring (565)
14. Fântâna lui Oache dug well (555)
15. Izbucaș spring (640)
16. Căptâlanu spring (562)
17. Spring in Valea Seacă brook (565)
18. Ponor of Schița brook (610)
19. Râșchirata spring (500)
20. Sîrâș spring (667)
21. Fântânile Bănișorii springs (650)
22. Priză ponor (640)
23. Fântâna Lotrilor (631) and Recea (634) ponors
24. Ponorăș ponor (629)
25. Losses of Ponoare brook (560)
26. Fața Vălaicilor spring (685) and lake (690)
27. Ilii pothole (735)
28. Tăul Dâmbo Șoimului lake (537)
29. Tăul Drăghivanu lake (485)
30. Călugări ebb and flow spring (385)
31. Pepusena spring (400) and pothole (410)
32. Blidar cave (470)
33. Zoampa ponor (440)
34. Toplița spring (375) and Căsoia cave (400)
35. Losses at Coșal de la Căldare (430)
36. Tăul lui Ghib lake (509)
37. Cămpeneasca cave (406)
38. Boiu spring (300)
39. Sîrâșele hypothermal spring (295)
40. Rengle hypothermal spring (298)
41. Racova hypothermal spring (305)
42. Tucrești hypothermal (310) and cold (42c-309) springs
43. Blagului spring (305)
44. Fântâna Recea spring (330)
45. Spring of Crisicioel fishery (340)

Figure 4.5. Hydrogeological map of the Vașcău Plateau.
 Geological data after BLEAHU et al., 1979. (Legend as in figure 1.6.).

the east, to reach a maximum estimated thickness of 2500 m in the proximity of Vaşcău town (M. Bleahu et al., 1979). These deposits, that in structural terms are ascribed to the Moma, Vaşcău and Colesti nappes, include at their bottom Permian-Werfenian quartz sandstones, conglomerates and shales, which belong to the Moma Nappe. The thrust planes between those units gently dip eastward, in accordance with the plateau homoclinal structure. The entire stack is intensely dissected by vertical faults, which bring in tectonic contact compartments that consist of rocks of different

lithologies, as shown in Figure 4.5 and in the section in Figure 4.6.

Among the carbonate series of the plateau, a special mention deserve the Anisian black dolomites of the Moma Nappe, estimated to be about 1200 m thick. The secondary porosity of those rocks, which is a result of the dolomitization processes, together with the fracturing due to the tectonic actions, largely favored karst processes, leading to the occurrence of karst depressions of an impressive size, unparalleled in plateau areas where other types of carbonate deposits outcrop. Those

Labelling no.	Drainage no.	Insurgence	H m	Resurgence	H m	L m	ΔH m	Used tracer	T hours	V m/h	Date of labelling	Author (s) of labelling
1	1	Câmpeneasca cave	406	Boiu spring	300	1700	106	PC	3-4	500.0	1901	S. Mişuţia
2	2	Losses of Fântâna Lotrilor brook	613	Boiu spring	300	7600	331	I	216	26.0	1978	I. Orăşeanu et al.
3	3	Losses of Ponoare brook	579	Boiu spring	300	5900	279	Br	225	26.2	1978	I. Orăşeanu et al.
4	4	Losses of Hăiuga lui Şandor brook	675	Tisei spring	450	2150	225	I	150	14.3	1978	I. Orăşeanu et al.
5	5	Câmpeneasca cave	406	Boiu spring	300	1700	106	R	10	170.0	1978	I. Orăşeanu et al.
6	6	Ponor of Ponorul brook	499	Pepineaua spring	400	1250	99	R	20	62.5	1978	I. Orăşeanu et al.
7	7	Ponor of Arânda depression	720	Tisei spring	450	3200	270	In	192	16.6	1984	I. Orăşeanu, E. Gaşpar
8	8	Ponor of Dăneşti brook	601	Tisei spring	450	1500	151	S	15	100.0	1985	I. Orăşeanu
9	9	Losses of Cohuri brook	635	Tisei spring	450	2000	186	R	15	133.3	1985	I. Orăşeanu
10	10	Tăul Ponorului ponor	633	Sopoteasa spring	355	4280	272	In	144	29.7	1986	I. Orăşeanu et al.
11	11	Losses of Târşa brook	520	Spring of Peştera Popii cave	400	1200	117	I	60	20.0	1986	I. Orăşeanu et al.
12	12	Coşul de la Căldare losses	440	Căsoaia spring	375	1040	65	F	17	61.1	1986	I. Orăşeanu
13	13	Sfârşuş ponor	667	Boiu spring	300	8025	367	In	1632	5.0	1987	I. Orăşeanu et al.
	14	"	"	Sfârşuşele warm spring	295	8050	372	"	1704	4.7	"	"
14	15	Losses of Priga brook	640	Boiu spring	300	8090	340	I	96	82.9	1987	I. Orăşeanu et al.
	16	"	"	Sfârşuşele warm spring	295	8300	345	"	168	50.6	"	"
15	17	Doboş ponor	565	Coleşti spring	400	1200	165	Dy			1988	I. Orăşeanu, E. Gaşpar
	18	"	"	Coşul de la Chietroc spring	390	1500	175	"			"	"
16	19	Ponor of Scăriţa brook	610	Spring of Valea Seacă	565	650	45	F			1994	I. Orăşeanu, E. Căpraru
17	20	Peştereliu ponor		Boiu spring		5940	255	I	12	495	1985	G.Ponta, E.Gaşpar

H - elevation, in meters a.s.l., L - horizontal distance between losses and springs, ΔH - vertical drop; T - time of first arrival of tracer; V - apparent velocity.

Tracers: PC = charcoal powder; F = Fluoresceine, R = Rhodamine B, I = I-131, Br = Br-82, In = In-EDTA, Dy = Dy-EDTA, S = Stralex; KI (activable).

Note 1: The following labellings were performed by the author in cooperation with: E. Gaşpar and T. Tănase: 2, 3 and 4; C. Crăciun, E. Gaşpar, I. Pop and T. Tănase: 10, 11, 13 and 14; Gh. Ponta, N. Terteleac and G. Halasi: 2, 3, 4, 5 and 6.

Table 4.5. Results of tracer tests performed in the Vaşcău Plateau.

depressions trace the outcrop of the thrust plane of Vașcău Nappe over Moma Nappe. Colești Nappe prevalently includes Rhaetian-Carnian limestones, while Vașcău Nappe includes Anisian dolomitic limestones and dolomites, and to a smaller extent, Ladinian and Late Triassic limestones.

4.4.1. The carbonate deposits hydrogeology

The tracers average transit time was 85.0 m/hour, with extreme values ranging between 5 and 500 m/hour. The longest distance covered by a tracer test, 8.6 km, was recorded between the swallet in Prigă (site 22 in Figure 4.5) and Boiu spring (Table 4.5).

4.4.1.1. Boiu karst system

Boiu spring (no. 38 in Figure 4.5) is located in the western part of Vașcău town, at the bottom of Osoiu-Cornețel hill. The spring water emerges from two outlets that do not allow human access, one of them with a permanent character, located to the north, and the other one, with a temporary character, located to the south.

Performed tracer tests have indicated that Boiu spring extends its radius of influence over the entire south-western area of Vașcău Plateau, starting from the cave Câmpeneasca and up to Ponoraș and Sfăraș spring, in the proximity of Zugău val-

ley. The swallets which supply the karst system are located 1.7-8.6 km away from Boiu resurgence. For tracers injected in the western extremity of Boiu karst system, transit velocities ranged in the 14.3-26.2 m/hour interval, which was much less than the velocity recorded for the flow path between Câmpeneasca cave and Boiu spring (500 m/hour).

During the hydrological year X.1986-IX.1987, the average discharge of Boiu spring was 0.588 m³/s, with extreme values ranging between 0.069 and 6.0 m³/s, while the discharge variation coefficient value was very high ($n_v = 77$).

The recession coefficient determined for the spring drought period is relatively high ($\alpha = 0.0120-0.0087$) and it suggests that groundwater flow and storage occur in cavities and cracks of noticeable size, thus resulting a relatively fast drainage of the aquifer. This inference is also supported by the very low value of the base flow index ($B_f = 0.142$). Out of the entire water amount discharged by Boiu spring during the indicated hydrological year, only 59.3 % originates in the base flow.

The spring water is not potable, since Țarina brook flows across the villages Călugări and Izbuç. Further on, along the underground flow path of this stream from Câmpeneasca swallet cave to Boiu spring, transit is short and it occurs rapidly, a cir-

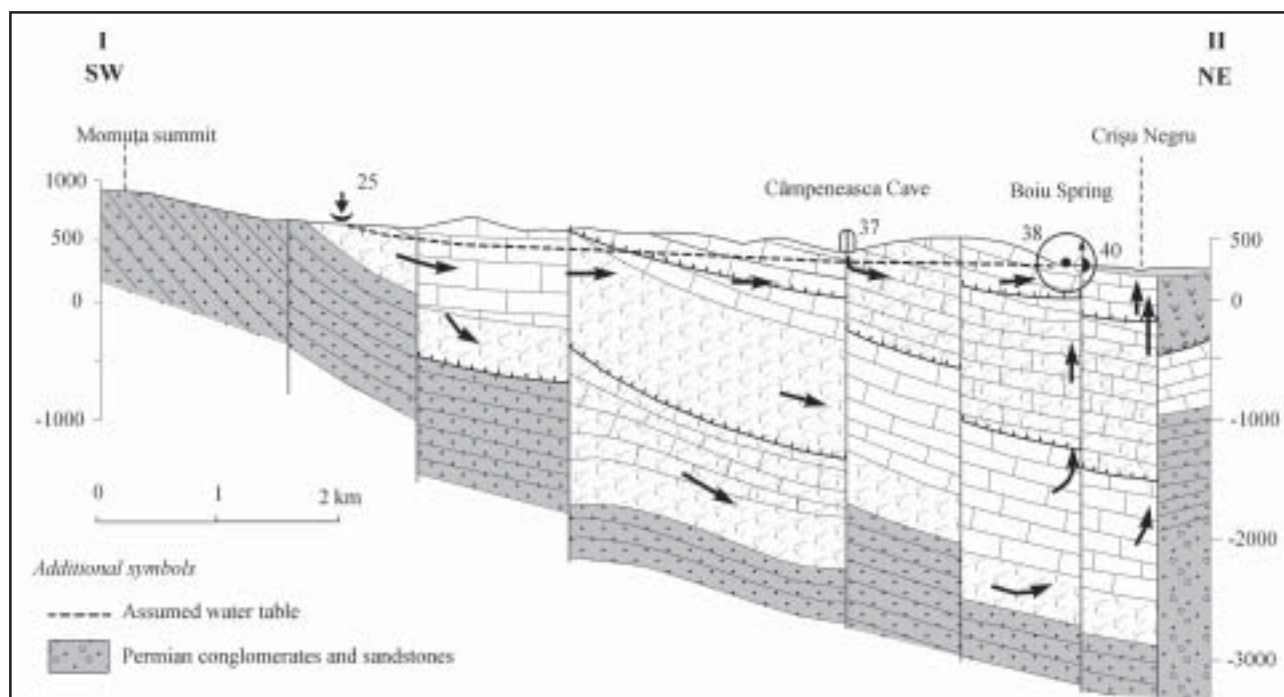


Figure 4.6. Hydrogeological cross section of the Vașcău Plateau.
(Legend as in Figure 1. 6. Line of section shown in Figure 4.5).

cumstance which does not favor water self-purification. The spring water is still used for supplying an important trout hatchery, situated downstream from the junction between Boiu spring stream and Crișu Negru river.

4.4.1.2. Șopoteasa karst system

Water in the central-northern part of Vașcău plateau discharges in Șopoteasa spring (Figure 4.5, site 4), located on the territory of Briheni village. Spring water is up flowing along the tectonic contact between the Vașcău Nappe limestones and the deposits of the Permian formation of the Moma Nappe. It emerges from a limestone blocks accumulation, a circumstance which prevents speleological exploration. The tracer test performed on 04.07.1986, when In-EDTA had been injected in the swallet at Tăul Ponorului (Figure 4.5, site 12), being subsequently detected in Șopoteasa spring water, has proven the continuity of the carbonate deposits of the plateau beneath the essentially impervious Toarcian deposits, which outcrop southward from the spring.

Șopoteasa spring has a rather large average flow rate, 0.214 m³/s, and a small recession coefficient ($\alpha=0.005$), a circumstance which suggests large residual dynamic resources.

4.4.1.3. Tisa karst system.

Tisa spring (Figure 4.5, site 6) provides the discharge of the groundwater in the north-western part of Vașcău karst plateau, being supplied both by surface streams that run across Ponoare and Pocioveliște depressions, and by diffuse infiltration in Arânda and Sfărașul Ligii-Țărau areas. The spring emerges at the bottom of a steep, almost 100 m tall cliff, the average discharge being rather high (0.139 m³/s), and the corresponding recession coefficient as well ($\alpha=0.0855$), a circumstance which suggests that underground flow occurs prevalently through well-developed karst cavities. During rainy periods, the spring flow rate increases in a spectacular way.

4.4.1.4. Rășchirata karst system

Rășchirata spring (Figure 4.5, site 19) is located within the upper reaches of Dezna stream catchment area, on the left side of Căptălanul brook, a tributary of Dezna, at the junction with Corbului brook, in the very close neighborhood of

an old furnace for melting the iron ore and of a forestry hut. The spring up flows through the scree, at the bottom of a cliff where Anisian dolomite outcrops as meter-thick layers with an abundance of karst dissolution pockets.

Over the hydrological year X.1997-IX.1998, the average flow rate of Rășchirata spring was 50.8 l/s, with fluctuations ranging between 18.6 and 144.5 l/s, the flow rates variation index (Q_{\max}/Q_{\min}) being 7.8, while the base flow index was 0.37. Over the indicated time interval, the spring water did not become muddy, its temperature fluctuated between 8.2°C and 8.9°C, while pH values ranged between 6.76 and 7.44.

The flow rates recession diagram constructed for the period 02.02-19.10.1998 displays a very small slope, with the corresponding recession coefficient having also a very small value, $\alpha=0.0045$. The dynamic storage volume is very large and it includes only a small percentage of water, 2.1%, directly derived from the fast flow.

The significant amount of storage is also substantiated by the karst system elevated memory effect, EM=46 days. The regulation time is very long, TR=55 days, thus suggesting a significant duration of the unit transfer function.

4.4.1.5. The Valea Seacă karst system

The spring is located on the left side of Valea Seacă ("the Dry Valley"), 25 m away from the valley junction with Căptălanul brook (Figure 4.5, site 17). The spring water discharges via two closely spaced cracks of the Anisian dolomites. In 1987, the spring has been tapped in order to supply water to the pilot station built in the same year by IPEG Deva at Grajduri for the iron ore wash. By the present time the water intake isn't operating anymore.

Over the time interval X.1986-IX.1987, the average flow rate of the spring in Valea Seacă was 77 l/s, with fluctuations ranging between 23 and 250 l/s. (Table 5.1). During the above indicated hydrological year, the water temperature fluctuated between 8,5°C and 8,8°C, while its pH ranged between 6.82 and 7.39. Following very strong rainfall or fast snowmelt, the spring water becomes, for a short period of time, very muddy.

In the area of occurrence of the spring in Valea Seacă, on the terrains covered by the Anisian dolomite, there are two places where the karst aq-

uifer receives surface water inflows: the swallet of Scărița brook (Figure 4.5, site 18) and the diffuse sink in the Căptălanul brook streambed, downstream from Căptălanul forestry hut.

Radioactivity analyses of the water samples collected from Rășchirata spring and from the spring in Valea Seacă have indicated that their water is not radioactive, the recorded alpha and beta concentrations being one order of magnitude below maximum concentrations stipulated by official regulations for drinking water.

4.4.2. The low-temperature thermal water at Vașcău

On the western side of Vașcău town (Figure 4.5), four thermal spring, associated with the outflow of gas, discharge from the karstic limestones of the Colești Nappe and the alluvial deposits of the Crișu Negru river: Sfărășele (no. 39), Rengle

(no. 40), Racova (nr. 41), and Țucrești (no. 42). The temperature of the thermal springs ranges from 14.5-17.2°C, and the cumulative mean discharge is 15 l/s. In addition to these thermal springs, gas is observed discharging from three cold-water spring: Blagu (no. 43), Fântâna Rece (no. 44) and spring of the Crisciorel fishery (no. 45).

The thermal waters close to Vașcău town are similar in terms of chemical composition to the cold karst groundwaters, while the associated gas only slightly differs from the atmosphere. Sometimes, the waters exhibit iodine and even bromide character, a consequence of prolonged contact with the deposits that fill Beiuș basin, the same chemical character being recorded also for other low-temperature thermal waters in that basin (Ceica, Răbăgani etc.). A slight increase in the percentage of nitrogen is still noticeable, probably as a result of the consumption of some oxygen by the oxidation reactions (Table 4.4).

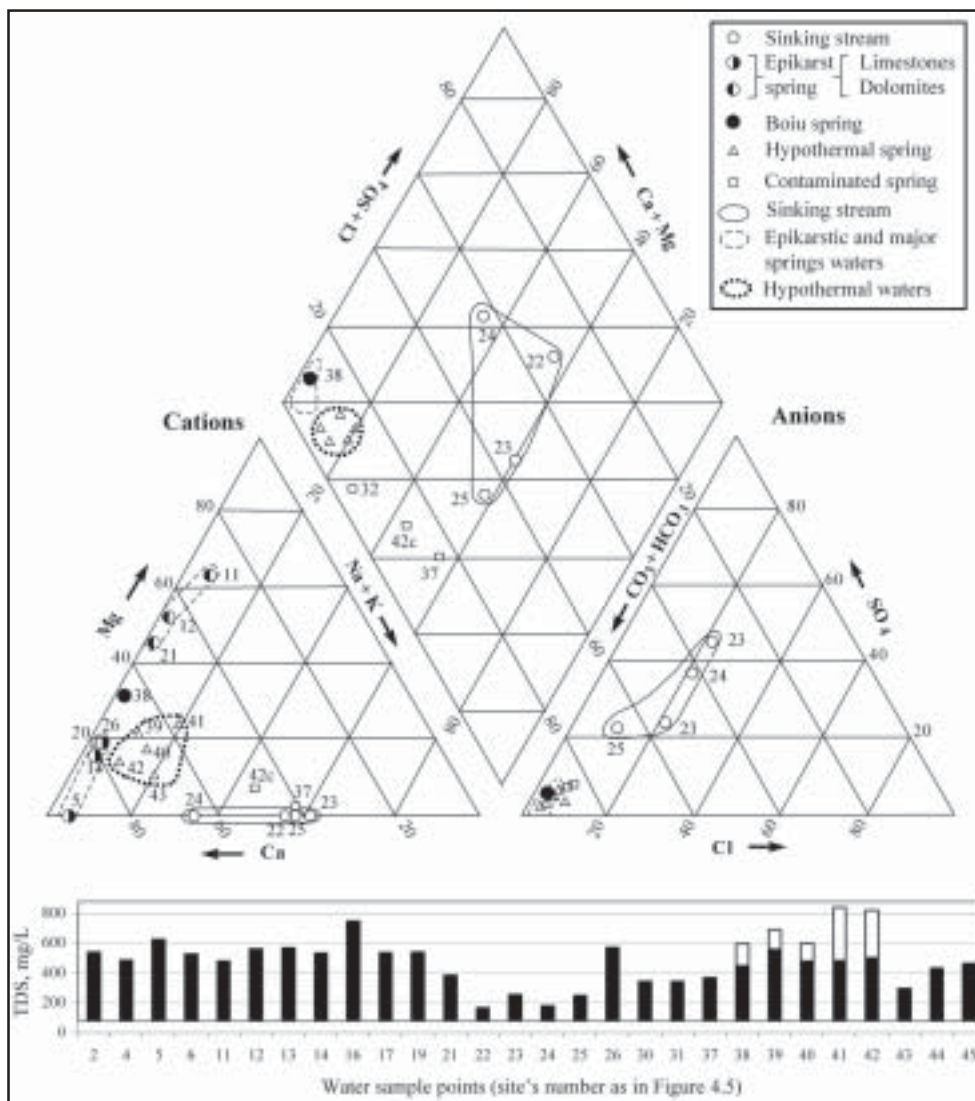


Figure 4.7. Piper diagram showing composition of waters (above) and waters TDS in the Vașcău Plateau (below)

The chemical compositions of the main groundwater types are plotted on the Piper diagram in Figure 4.7 (I. ORĂȘEANU, J. MATHER, 2000). The waters from the sinking stream in the southwestern part of the plateau are distinctive; these waters, derived from the werfenian quartzitic sandstones, have a mean TDS of only 135 mg/L, a low pH of 5.3, and no Mg. The epikarstic springs are typical karst groundwater, with a mean TDS of 421 mg/L. The main variation is in the Ca/Mg ratio, which is controlled by whether the spring arises from limestones or dolomites. A dug well at Oache (no. 14) yields water of a composition that is similar to the epikarstic springs.

The discharge springs on the margin of the plateau plot in the same field as the epikarstic springs and only the major Boiu spring (no. 38) is shown in Figure 4.7. Mean TDS is 435 mg/L. The thermal waters plot in a separate field and are intermediate in composition between the karstic waters and the sinking stream derived from the quartzites. However, the TDS (502 mg/L) of the thermal waters is higher than either of these waters. Three of the groundwaters are polluted. The water of the Țarina stream it enters the Cămpeneasca cave (37) and the Pepineaua spring (31) have elevated concentrations of Na and K, probably as a result of domestic sewage pollution from the villages of Izbuc and Ponoare, and the cold spring at Țucrești (42) is also polluted by a small stream.

Vășcău town, on the eastern side of the Vășcău Plateau, is close to the faults that divide the Codru Moma Mountain Block from the Beiuș Basin. These faults are a barrier to groundwater flow from the west, and most of the near-surface flow is intercepted by the Boiu spring. Deeper flow moves up to faults to mix with the colder water to form the thermal springs. The thermal component of the waters is probably at least partly derived from the Permo-Werfenian deposits at depth of 1000 m or more beneath the surface.

Area is close to the Pannonian Basin, where heat flow of more than 95 mW/m² are recorded (VELICIU, OPRAN, 1983). The thermal water is brought to the surface by hydraulic barriers that intercept flow and allow water to move up faults and fracture and mix with cooler groundwater in the upper karstic units. This mixing accounts for the variation in temperatures among individual springs.

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