Iancu Orăşeanu

3.13.2. PĂDUREA CRAIULUI MOUNTAINS

(Reprint from Karst Hydrogeology of Romania, 2010)

Introduction

Pădurea Craiului Mountains are situated in the north-western part of the Apuseni Mountains Group, featuring a fingering shape, that reaches down to the environs of Oradea town. They are bounded by the Neogene basin of the Vad (of the Crişu Repede river) to the North, by the Neogene basin of the Beiuş (of the Crişu Negru river) to the South and they border on the eruptive Vlădeasa massif in the East, with the Leşu lake-Hordâncuşa summit-Meziad stream headwater line acting as a demarcation between the two massifs.

The Pădurea Craiului Mountains form a geologically well-defined unit, which, morphologically speaking, boasts two distinct main units, conventionally separated by the Vârciorog-Dobreşti alignment: the Pădurea Craiului Mountains in the East and the hills of the Pădurea Craiului (the Vârciorog, Tăşad, Hidiş, Dobreşti and Vălani) in the West. The karst terrains extend mostly in the eastern half of the mountains, where they outcrop over a 330 km^2 area (out of the mountains total 670 km^2 area). The present paper considers only this very geomorphologic unit. In Pădurea Craiului Hills, limestone terrains extend over small areas.

2.1. A Brief History of Hydrogeological Research

Over 1956-1976, researchers of the Institute of Speology „Emil Racoviţă" in Cluj-Napoca, and TH. RUSU in particular, conducted a complex geomorphologic study of the karst in the Pădurea Craiului Mountains, making a substantial contribution to knowledge of the morphology of the exo- and endokarst; furthemore, they could pinpoint the areas of influence of numerous karst sources at the end of 41 labellings with fluorescein. In 1988, he published a monography which included the results accumulated in over 30 years.

The hydrogeologic investigation of the massif starts in 1979 by I. ORĂŞEANU, A. IURKIEWICZ and H. MITROFAN (Prospecţiuni Company), and it is mainly focussed on the requirements of bauxite accumulations exploitation and on the assessment of the overall aquifer potential.

In the period spanning 1981-1983, an extensive programme of hydrometeorological observations and measurements for the entire Pădurea Craiului Mountains area was worked out, as the fruit of the cooperation between the Prospecţiuni Company (I. ORĂŞEANU, A. IURKIEWICZ), Meteorological and Hydrological Institute (G. & PARASCHIVA HOŢOLEANU, VICTORIA PREOTEASA, TATIANA NICOLAE, LUMINIŢA TIBACU) and Institute of Speology ,,Emil Racoviţă" (I. POVARĂ, TH. RUSU, C. MARIN, M. ŞERBAN, I. VIEHMANN, G. DIACONU, C. LASCU) which supplied early quantitative data on the condition of the sources and the aquifer potential of the massif.

Subsequently, several papers were published, dealing with the karst of Suncuiuş-Mişid area (L. VĂLENAŞ, A. IURKIEWICZ, 1980,1981), the chemistry of the karst water (C. MARIN, 1981), tracing experiments (E. GAŞPAR et al., 1983, E. GAŞPAR, I. ORĂŞEANU, 1987), the karst capture processes (I. ORĂŞEANU, A. IURKIEWICZ, 1982, I. ORĂŞEANU, 1985), and the hydrogeological karst systems (I. ORĂŞEANU, A. IURKIEWICZ, 1987). In 1991, I. ORĂŞEANU publishes the hydrogeologic map of the Pădurea Craiului Mountains (scale 1 :50,000).

The results of karst investigations conducted in Pădurea Craiului Mountains are summarized in the monograph volume published by G. RACOVIŢĂ, OANA MOLDOVAN and B. ONAC in the year 2002.

The speological research, which resulted in the discovery of roughly 700 underground cavities – with the longest cave, the Vântului Cave and the deepest pothole, the Stanu Foncii, among them –

contributed substantial data about the hydrogeological past and present of the massif, about the karst networks that have been carved by waters (A. SZILAGY, 1976, L. VĂLENAŞ and R. DRÂMBA, 1978, L. VĂLENAŞ, 1980-1981, BABOŞ, 1981, a. o.).

2.2. Physiography

Relief

The great variety of rocks making up the geologic structure, as well as their mosaic-like disposition, which is a result of an advanced tectonic process the massif underwent, are morphologically expressed by a chaotic relief that lacks a general unique feature. The massive, stately relief including sandstones, conglomerates and eruptive rocks, alternate with the lower relief of karst capture depressions and the flat relief characterizing the karst plateaus strewn with sinkholes (Figure 2.1).

The altitude of the relief drops from the South-East to the North-West and a major crest can be defined only in the first half of the massif, inbetween the peaks of Hodrânguşa (1,027 m), Măgura Dosului (945 m) and Rujeţ (844 in). Farther on, its high relief scatters in vast karst plateaus broken by isolated ridges, a result of the rough geologic structure of the underlayer, or by deep valleys carved by water courses.

There are several secondary ridges springing off the main crest and their morphological elements boast a general North East-South West orientation, as imposed by the geologic structure. Noteworthy towards the North-East are the Leşului Hill, Boţii Hill and the Preluca Peak crest, bounded by the Acre depression and the Remeţi karstic area to the South-East and by the karst plateaus of Chicera-Arsuri and Ponoare to the North-West. They are followed by the karst depressions of Damiş, Ponoraş and Cărmazan, separated by summits including non-karstifiable rocks, and then the rough relief marks room for the large karst plateaus of Zece Hotare**,** Zgleamănu and Igreţ (Hârtoapele), that extend to the North-western limit of the massif.

South of the main crest the relief is stronger and broken by deep valleys. The salient feature of the relief in that area are the broken course of the Lazuri brock, the broad groove of the karst corridor of Albioara-Poiana Damiş, the scenic karst relief of the Vida valley and the sinkholes of the Răcaş-Sclavul Pleş, and Runcuri karst plateaus.

Before merging with the flat relief of the Beiuş basin towards the South, the Pădurea Craiului Mountains relief dips in the Senonian basin of the Roşia and then modestly rises on the Luncasprie-Căbeşti alignment.

The hydroghaphic network.

The surface waters in the Pădurea Craiului Mountains belongs to the hydrographic basin of the rivers Crişu Repede and Crişu Negru, whose watershed boasts a well-defined location in the South-eastern half of the massif. In the North-western part, however, in the area under karst plateaus, the location of the surface watershed is uncertain for lack of an organized surface runoff (Figure 2.1).

The hydrographic network of the Pădurea Craiului Mountains is highly disorganized as a result of the intense processes of karst capture that led to the burial of many surface flows. The only important, permanently active valleys crossing the karst area of the massif are the valleys of Iad and of the Brătcuţa in the Crişu Repede basin, of the Vida and the Roşia, with its tributaries – the Lazuri, the Sohodol, the Meziad and the Strâmtura, in the Crişu Negru Basin. The Vida valley is the only important valley in the respective massif that crosses karst terrains only. The Vida stream is 21.5 km long and has a reception basin extending on 28 km^2 and a hydrogeologic basin stretching on roughly 55.5 km^2, to the Luncasprie hydrometric station, a device located upstream of Vida lake.

The process of karst capture of surface flows by the main karst spring on the outskirts of the massif is in full progress (I. ORĂŞEANU, 1985). So, for instance, in the case of the hydrographic basin of the Crişu Repede, the waters of the Luncilor brook (the upper part of Mişid brook) are temporarily caught totally by the spring of Brătcani, while the waters of the Mniera brook, in the Cornet section, are partially caught by the spring of Moara Jurjii.

Similar processes, showing in the drainage of brooks in the capture areas, are under way in the valleys of the Poiana and the Pestiş, both tributaries of the Topa stream, in the hydrographic basin of the Crişu Negru. The waters infiltrated in these sectors are partially found in the spring of Aştileu, Iancu Orășeanu

HYDROGEOLOGICAL MAP OF THE PADUREA CRAIULUI MOUNTAINS

(Gelogical data after S. Bordea et al., 1986, D. Patrulius et al., 1983, D. Patrulius et al., 1973, E. Popa, 1981)

(Legend as in Figure 1. 6)

C. Key of the site

(In brackets altitude of site in m a.s.l.)

1. Astileu spring (250)
2. Potriva cave (347)
3. Spring of Groapa Moțului (295)
4. Gălășeni Cave (394)
5. Cioroiu spring (300)
6. Spring of Moara Jurjii (400)
7. Losses of Mniera stream at Cornet (495-505)
8. Vadu Crișului Cave (305)
9. Bătrânului cave (547)
10. Izbândiș spring (370)
11. Tomii ponor (640)
12. Ponors of Cărmăzan
13. Vântului cave (320) and spring of Poiana Frânturii (305)
14. Losses of Recea brook (600)
15. Ungurului cave (305)
16. Losses of Mișid stream (470)
17. Moanei (485) and Stanu Ciuții caves (575)
18. Filii spring
19. Ponors (615, 610) and cave (604) of Ponoraș
20. Secătura Brătcanilor (487)
21. Brătcanilor spring (345)
22. Dămișenilor spring (420)
23. Toaia ponor (675)and Pașcalău T. pothole (765)
24. Peșteruța ponor (687)
25. Munău cave (710)
26. Spring of Moara Dedii (350)
27. Groapa Râtii ponor (583)
28. Peștera cu Apă de la Bulz cave (370)
29. Sâncuta ponor (725)
30. Vidului spring
31. Tăul fără Fund spring (435)
32. Springs of Lunca Pizlii (470)
33. Davelii spring (480)
34. Firez spring (545)
35. Peștera cu Apă din valea Leșului cave (650)
36. Acre ponor (815)
37. Losses of Soimușul Drept stream (660)
38. Peștera de sub Stan cave (265)
39. Țiclului cave (373)
40. Losses of Pestiș stream (325)
41. Osoi cave (400) and losses of Poiana stream (390)
42. Gabor cave (445) and Vichi spring (440)
43. Cioroaiele Țârcului spring (490)
44. Jiloasa pothole (430)
45. Hypothermal Spring of Vida forest hutt (325)
46. Caves of Viduța stream (350, 370)
47. Ruștiu spring (475)
48. Springs of Gura Ursului (450)
49. Groieșului spring (490)
50. Apa de sub Stan spring (525)
51. Ponor of Prislop (666)
52. Toplița de Vida spring (245)
53. Ponors under Merișorul summit (458)
54. Toplița de Roșia spring (275)
55. Albioara ponor (430)
56. Ciur Ponor cave (480)
57. Jurcanilor cave (545)
58. Ponor of Botului brook (550) and Sohodol pothole (545)
59. Losses of Barc brook (615)
60. Ponors from Fântânele (679)
61. Runcșor ponor (570)
62. Toplicioara spring (430)
63. Roșia spring (290) and Bonchi cave (455)
64. Ponor of Iezere brook (550) and Stanu Foncii pothole (600)
65. Izbuneală spring (325)
66. Tăul Fierbintea hypothermal spring (220)
67. Meziad cave (435)

B. Geological map

1. Neogene
2. Senonian
3. Aptian (Ecleja Form.)
   a. Aptian (midlle lms.)
4. Neocomian-lower aptian
5. Midlle and upper Jurasic
6. Lower Jurasic
7. Midlle and upper Triasic
8. Lower Triasic
9. Permian
10. Rhyolites and dacites
11. Cristalline shists

A. Additional symbols

Mean annual spring flow, l/s

under 1	1-5	6-20	21-50	51-100	101-500
●	⊙	⊙	⊙	⊙	⊙
∩	∩	∩	∩	∩	∩

in the hydrographic basin of the Crişu Repede, which is the reason of a marked lack of concordance between the position of the watersheds of the surface and underground waters between the two basins. A similar – though of a lesser scope – situation is to be encountered also in the case of the upper basins of the brooks of Soimuşul Drept and Vida, where drainage sectors emerged in the wake of underground capture.

2.3. The Karst of Pădurea Craiului Mountains

Pădurea Craiului Mountains exhibit the highest density of surface and underground karst features in Romania. Corresponding the 1981 stage of investigation (C. Goran, 1982), 680 cavities had been recorded. In present, 32 caves exceeded 1 km length. Among them (Table 2.1), Romania's longest cave, Peştera Vântului (Fig. 2.1, no. 1) – 45,3 km long, Peştera Ciur-Ponor (Fig. 2.1, no. 2) – 17.1 km long, and Stanu Foncii pothole, -339 m deep (Fig. 2.1, no. 64).

With the analysis of the morphometric and hydrologic data referring to a number of 260 caves as a basis, Th. Rusu (1988) shows that by summing up the lengths of their galleries, we reach an average of the massif standing at 295.75 m of galleries per km^2; 62.3% of these caves are fossil cavities, 32.32% are temporarily active and 5.38 % boast permanent hydrologic conditions. As for the distribution of these caves according to the age of the formations shaping their entrances, the aforesaid author shows that 52.3% boasts Jurassic limestones, 28.46% Eocretaceous limestones and 18.46% Triassic limestones and dolomites.

The genesis of the Pădurea Craiului Mountains karst is linked to the emergence of the carbonate platform of Bihor in Upper Triassic, from the end of the Jurassic and, more particularly, of the current stage, which started in Paleogene. To assess the age of the karst formations generated in the first two stages of the karst formation process is a highly difficult task, possible only in the areas where the covering deposits were not subjected to erosion. Belonging to the first generation might be the relief boasting Anisian and Ladinian limestones

No.	Cave	H (m)	L (m)	D (m)	H. R.	References
1	Vântului (13)	320	45,300	190	f	Meandre , L. Vari 2005
2	Ciur Ponor (56)	480	17,078	200	p.i	Rusu 1988
3	Sâncuta (29)	728	8,000	296	f	Speomond 8-9
4	Bonchi (63)	455	6,686	163	t.i	Rusu 1988
5	P1 J2 Jofi *)	445	6,657	144		Speomond 8-9
6	Meziad (67)	435	6,292	89	t.i	Speomond 7
7	Ponoraş (19)	604	6,000	211	f	Speomond
8	Aştileu (1)	250	5,050	50	p.o	Nymphaea 1998
9	Dămişeni spring (22)	420	4,800	4	p.o	Styx 1
10	Gaura cu Vânt		4,110	160	f	Speomond 7

No.	Pothole	H(m)	D (m)	L (m)	H. R..	References
1	Stanul Foncii (64)	600	339	4,106	a	Rusu 1988
2	Pobraz	830	200	1,500	a	Speomond 7
3	Albioara *)	365	132	268	a	Speomond
4	Fanea Babii	540	131	173	f	Rusu,1988
5	Sohodol (58)	545	102	250	a	Matoş
6	Paşcalău Traian (23)	765	100	180	f	Rusu 1988

H = Elevation of cavity entrance; L = Length of cave passages; D = Difference in level between maximum and minimum cave passage altitude; *) - Intercepted by mining works; HR = Hydrologic regime of cave entrance: p.i. - perennial inflow; t.i - temporary inflow; p.o - perennial outflow. All caves are active. Hydrologic regime of pothole: a - intercept an underground stream; f - fossil.

Table 2.1. Main cavities in Pădurea Craiului Mountains.

(After C. GORAN, 1981, P. MATOȘ, 1982-1988 and A. POSMOȘANU & P. DAMM, 1995-2005. In brackets number of cavities in figure 2.1.)

and dolomites, sub-sequently covered by the detritic deposits of the Eojurassic transgression. It is well known in the Şuncuiuş area in particular owing to the exploration and exploitation operations performed on the refractory clays that are characteristic of that relief.

Linked to the second generation karst, which is better known, is the genesis of the bauxite accumulations. Their exploitation uncovered a depressionary rough paleorelief with numerous hollows, dissolution channels and lapies. It has been studied from Cornet to Răcaş and the Roşia spring and, in the case of the areas with covered bauxite deposits, the data supplied by research drilling provide for the elaboration of topographic map of the paleorelief formed in the period of emergence at the end of the Jurassic.

Undoubtedly, the genesis of the numerous karst formations covering the entire area under limestones and dolomites is mainly the result of the third stage of the karst-formation process, a stage that still continues after having reached a climax during the Pleistocene, when hydrometeorologieal conditions were highly suitable for karst formation.

The origin of the Pădurea Craiului Mountains karst is related to the paleogeographic evolution of the Apuseni Mountains Group as a whole, a tight correlation being outlined between the levels where karst cavities occur and the erosion levels established during the surface streams network evolution (A. IURKIEWICZ, H. MITROFAN, 1984).

2.4. Geologic Framework

Pădurea Craiului Mountains develop mostly on deposits belonging to the Bihor Autochtonous. In their southern and south-eastern parts, deposits ascribed to the Codru Overthrusts system (Vălani, Ferice and Arieşeni nappes), and igneous rocks of Vlădeasa banatitic massif, also occur on restricted areas (Figure 2.1, B).

The sedimentary formations of the Bihor Autochtonous feature an extended homocline, with the crystalline basement outcropping in its eastern and south-eastern parts, and with increasingly recent formations deposited above, toward the north-west, up to the Late Cretaceous deposits occuring in the area of the 1 Mai spa, near Oradea town. Toward the north-east and the south-west, the geologic structure of Pădurea Craiului Mountains sinks beneath the Neogene deposits of the Vad and Beiuş basins.

The sedimentary cover of the Autochtonous has a German type tectonic structure, slightly folded and dissected by many vertical or steep faults, which delimit several compartments, that deepen stepwise to the west (D. PATRULIUS, in V. IANOVICI et al., 1976). Three major carbonate series occur within the Bihor Autochtonous (Figure 2.1):

- the Triassic carbonate series, up to 1500 m thick, consisting of Anisian limestones and dolomites, and of Ladinian limestones, underlain by a Permo-Werfenian detritic series;
- the Jurassic-Early Aptian carbonate series, consisting of limestones ascribed to the Middle and the Late Jurassic (150-200 m thick) and to Neocomian-Barremian (50-350 m thick), separated from the Triassic carbonate series by an Early Jurassic detritic series, up to 70 m thick;
- the Early Aptian carbonate series, consisting mainly of 50- 350 m thick Early Aptian limestone stacks, separated by the previous series by a 100-700 m thick monotonous succession of grey marls (the Ecleja layers), and overlain by an Aptian-Albian, mostly detritic complex.

The carbonate deposits of the Bihor Autochtonous outcrop over 304 km^2, 29 km^2 of which are included in Remeţi graben.

Following the Mediterranean diastrophism, which generated the Codru Overthrusts, essentially detritic Cretaceous formations continued to settle in Pădurea Craiului Mountains area during the Senonian. They outcrop in Roşia basin, in Remeţi graben and in a few more places where their complete erosion was avoided.

2.5. Climate and Runoff

For the time interval X.1981-IX1983, the national observation network has been expanded in order to obtain hydro-meteorological data required for the interpretation of the hydrogeological setting of Pădurea Craiului Mountains: there have been added two rainfall gauging stations, one meteorological microstation (Zecehotare), 10 flow gauging stations located on the streams and 11 next to the springs (Figure 2.2). Table 2 shows the characteristic of stream discharges for different period.

The annual rainfall in Pădurea Craiului Mountains increases from west to the east, ranging between 800 and 1200 mm average multiannual values. During the hydrologic year October 1982 - September 1983, recorded rainfall values were 635 mm at Oradea, 712.6 mm at Vârciorog, and 1390.5 mm at Remeţi.

Temperature variation is opposite to that of the rainfall, i.e. an increase occurs from east to the west. The average multiannual values range between 4 and 8°C, with average temperatures in January ranging between -3 and -6°C, and those in July between 14 and 18°C (M. GRIGORE, in G. POSEA et al., 1982).

Evapotranspiration values increase fron east to the west. During the hydrologic year X.1982-IX.1983, its values ranged between 540.4 mm at Zece Hotare and 695.8 mm at Oradea.

Hydrometric measurements were also made in five hydrographic basin situated at various altitudes on non-karst terrains with a view to assessing the variation of the specific annual mean runoff, q, function of altitude. The results obtained (Table 2.2 and Figure 2.3) bespeak a fine correlation between the two parameters and indicate a value of 3.3 l/sec/km^2 of the vertical gradient of the specific annual mean runoff in case of a level difference of 100 m.

With the help of the diagram in Figure 2.3 and knowing the mean altitude of the hydrographic basins whose runoff is influened by the karst, the available specific annual mean runoff of the respective basin (q_a) can be assessed. By comparing the values of the measured (q) and available (q_a) specific annual mean runoff, the presence of losses or contributions from/in the respective hydrographic basin is highlighted, as well as their values (witness basins method).

The surface hydrographic network karst capture processes resulted in an extended of internal drainage areas, covering 224 km^2 (Fig.2. 4). The available water amount, left on that area after the evapotranspiration fraction had been removed, totally seeps and subsequently resurges prioritar

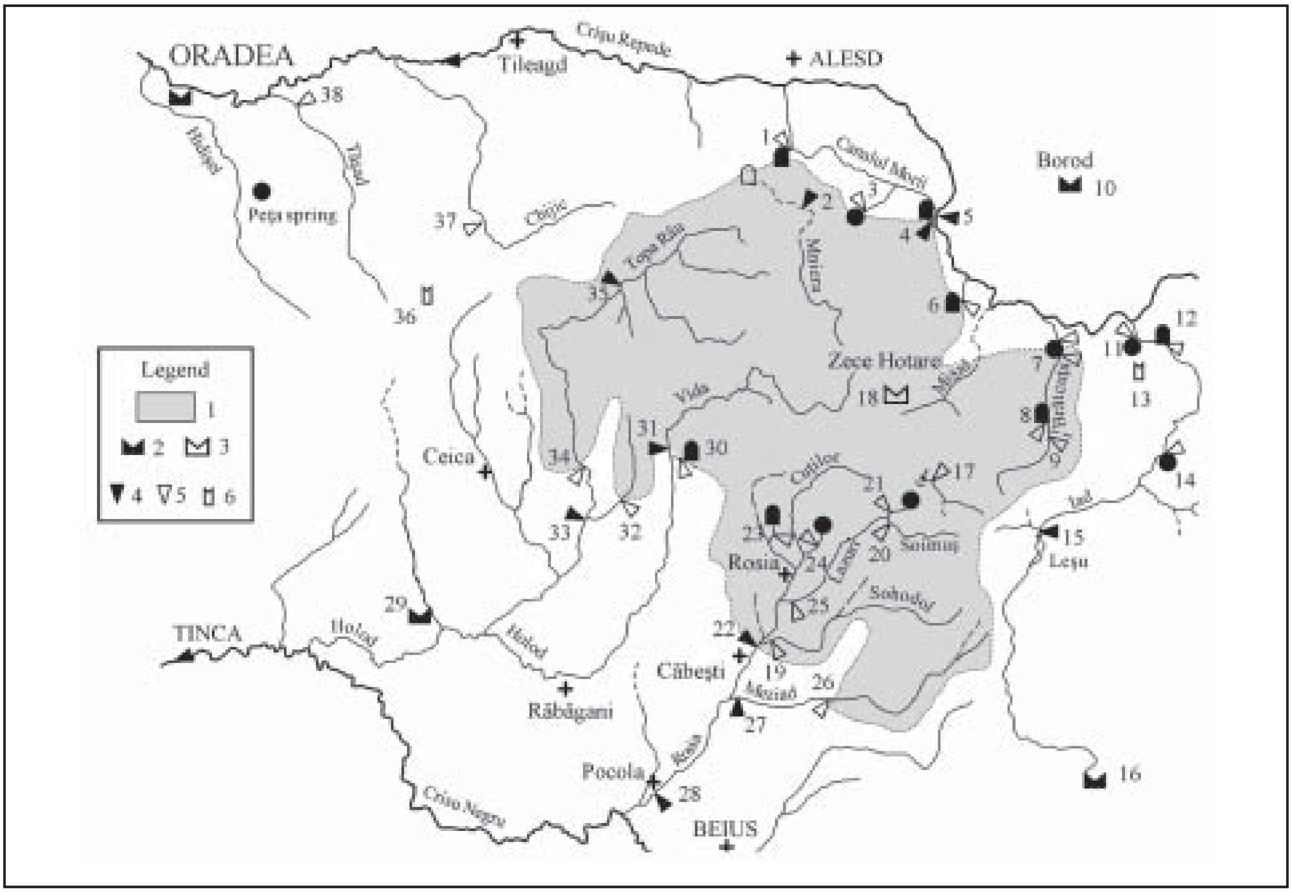

Figure 2.2. Hydrometeorologic network in Pădurea Craiului Mountains in X.1981-IX.1983 period.
Legend: 1 - Surface of water budget performed; 2 - meteorologic station in national network; 3 - temporary meteorologic station; 4 - hydrometric station in national network; 5 - temporary hidrometric station; 6 - temporary raingaugemeter.

No	Stream	Gauge station	h	H	F	p	Qmean	Qmax	Qmin	q	qa
			m	m	km²		m³/s			l/s/km²	
1	Crişu Repede	Vadu Crişului	280	821	1325	3	20.4			15.4	
	Crişu Repede	Vadu Crişului	280	821	1325	4	15.6	89.6	3	11.8	
2	Crişu Repede	Oradea	119	629	2126	3	24.2			11.4	
3	Iad	Aval baraj Remeţi	425	979	101	4	2.66	13.6	0.067	26.3	
4	Iad	Leşu	979	979	101	3	2.83			23.9	
5	Iad	Remeţi	914	914	163	3	3.89			24.4	
6	Iad	Bulz	849	849	223	3	4.99			22.7	
7	Brătcuţa	upstream Rusu brook	435	771	15	4	0.311	6.36	0.058	20.8	
8	Brătcuţa	downstream Brătcani spring	335			4	0.725	5.32	0.26		
9	Mniera	Călăţea	372	561	31.5	3	0.28			8.9	
	Mniera	Călăţea	372			4	0.17	4.06	0.003		
10	Chijic	Călăţea	195	289	36.5	4	0.162			4.4	
11	Tăşad	Oşorhei		190	52.3	4	0.096			1.8	
12	Crişu Negru	Beiuş	177	551	792	2	13.1			116.6	
13	Roşia	Pocola	167	(427)	(267)	2	3.4			(12.7)	
	Roşia	Pocola	167	(427)	(267)	4	2.71	59.2	0.431	(10.1)	
14	Roşia	Căbeşti	212	(584)	(155)	4	1.57	38.8	0.303	(10.1)	
15	Lazuri	Între Râuri	305	599	47	4	0.657			14	14.5
16	Şoimuşuri	upstream Toplicioara brook	372	685	16.5	4	0.236			14.3	16.8
17	Runcşor	Moara Darului	600	750	6.8	4	0.138			20.2	
18	Vida	upstream Luncasprie	215	508	55.5	4	0.624	16.1	0.085	11.2	12
19	Valea lui Vasile	Dobreşti	165	331	14.25	4	0.075			5.3	
20	Topa	Vârciorog	275	474	72.5	1	0.494			6.8	
	Topa	Vârciorog	275	474	72.5	4	0.322	15.5	0.004	4.4	11

h - altitude of gauging station; H - mean altitude of hydrographic basin (b.h); F - surface of b.h.; p - period of measurement: (1: 1950-1966; 2: 1950-1967; 3: 1950-1974; 4: X.1982-IX.1983); q - measured mean annual specific runoff (Q mean / F); qa - available mean annual specific runoff (computed by witness basins method)

Table 2.2. Specific runoff data.

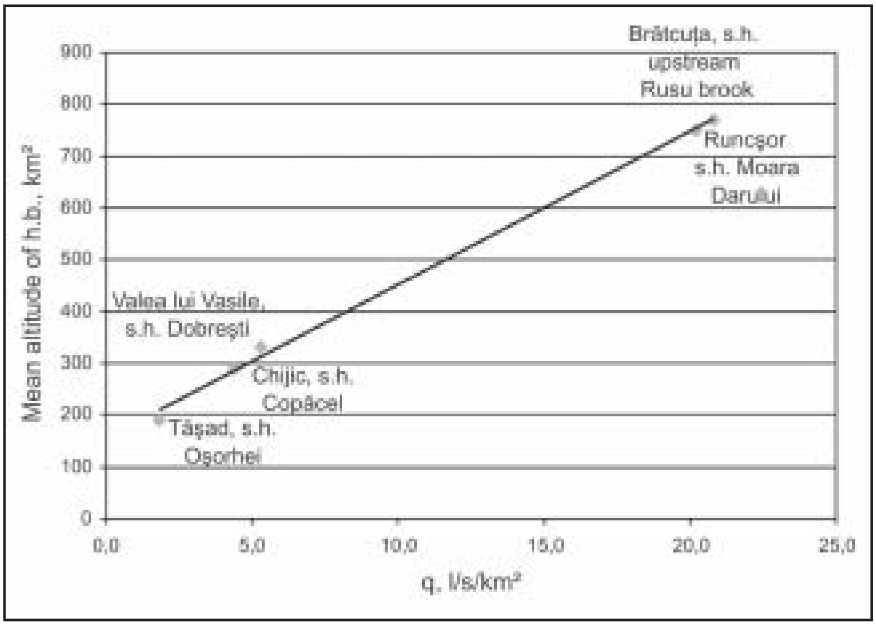

Figure 2.3. The relation between the mean annual specific discharge (q) and the mean altitude of hydrographic basin in X. 1982 - IX. 1983 period.

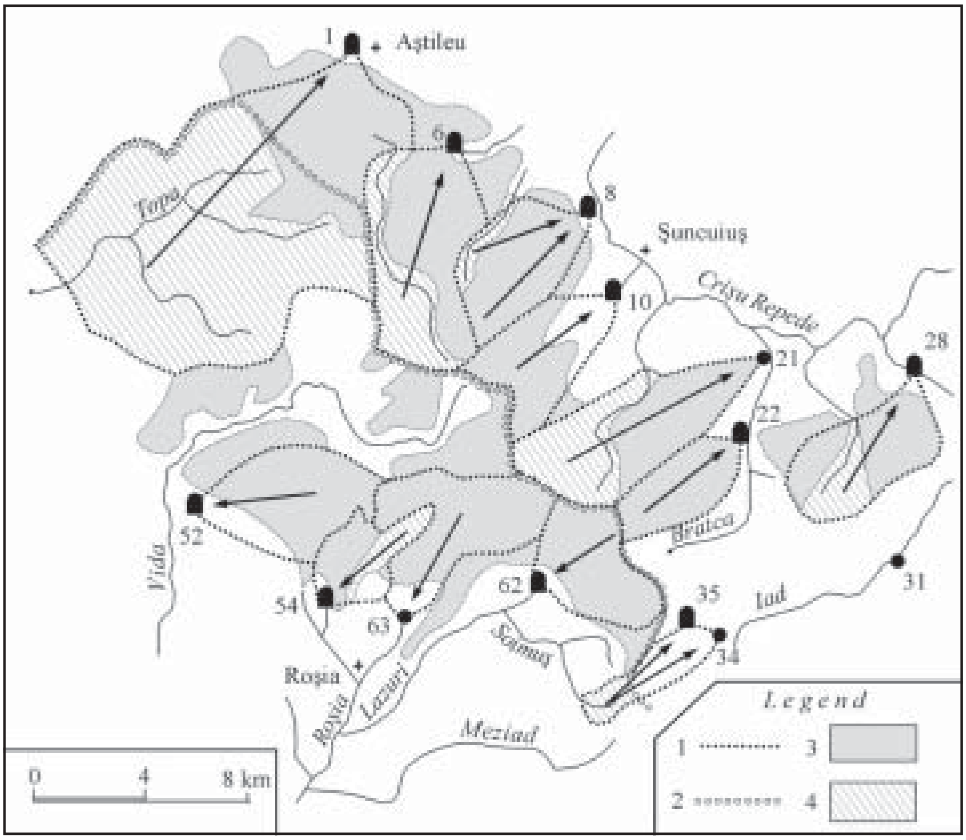

Figure 2.4. Distribution of main internal drainage areas, diffluence surfaces and karst systems in the Pădurea Craiului Mountains.
Legend:
1 - Aproximate limit of main karst systems;
2 - Watershed beetwen Crișu Repede and Crișu Negru rivers;
3 - Internal drainage area;
4 - Diffluence surface.

Numer of sources as in Figure 2.1.

through the springs at the periphery of the mountains massif, in the outer drainage area of Pădurea Craiului Mountains.

There is no runoff in the case of the large karst plateaus, but inside of the internal drainage areas permanent surface courses can develop, which are carved into the relief and whose subaerial link with the basic (outer) hydrographic network was severed by underground karst capture processes. A typical example in this respect is the Mniera brook.

Together with internal drainage areas, another widely developped feature, that significantly controls runoff distribution, are the diffluence surfaces, resulting from basin karst diffluence processes, by which the available water amount of a hydrographic basin, as a consequence of partial captures, is divided into a infiltrated fraction directed by underground flows outside this basin, and another fraction that permanently or temporarily follows its original surface flow, downstream the partial capture area (I. ORĂŞEANU, A. IURKIEWICZ, 1982, I. ORĂŞEANU, 1985).

The diffluence surfaces occur on 107 km^2, and their existence makes water budget computations difficult (Figure 2.4). The most extended diffluence surface in Pădurea Craiului Mountains is that of Topa stream, of 66 km^2, situated upstreams of the confluence with the Măgura brook. The effective rain on this surface resulted in an available water amount divided between runoff - 4.4 l/s/km^2, and infiltration-11.0 l/s/km^2(478 1/sec in the hydrologic year X.1982-IX.1983). A small fraction of the total water amount infiltrated over this whole area is recovered in the spring at Aştileu, as indicated by the tracing experiments performed by means of In-EDTA. Most of the infiltrated water enters a deep flow directed westward, toward the thermal aquifer in 1 Mai - Felix area (I. ORĂŞEANU, 1991).

The Mniera valley represents a permanent surface course, with a hydrographic basin situated at the highest altitude in the karst area of the massif. It is 15.5 km long and boast a reception basin of 17.5 km^2, which develops in the internal drainage area of the massif. The major hydrologic effect in Mniera runoff history was the karstic capture in the Şaua Gurguiatu-Potriva cave zone, the interruption of the flow of the Mniera brook waters towards the Beiuş basin and their underground direction towards the Vad basin.

Tracer experiments provide a massive infiltration in Cornet area directed to the Moara Jurjii spring, the diffluence surface developed upstream of Călăţea has a area of about 13 km^2. Runoff at the Călătea hydrometric station stopped in the droughty periods of a prolonged autumn.

Other diffluence surfaces are Mişid brook - Brătcanilor spring (12.5 km^2), Boiu brook - Peştera cu Apă de la Bulz cave (5 km^2), Cuţilor brook - Topliţa de Roşia spring (4 km^2), etc. (I. ORĂŞEANU, 1991).

2.6. Karst Terrains Hydrogeology

Karst water accumulations in Pădurea Craiului Mountains are relatively scattered and have various sizes, according to the karst terrains extent. Overall, they form a huge aquifer complex, that includes the three carbonate series previously mentioned (Triassic, Jurassic-Cretaceous, and Cretaceous), separated by two impervious intercalations (Early Jurassic quartzite sandstones and Ecleja marls). In the whole area of extent of the aquifer complex, its impervious substratum consists of mostly detritic Permo-Werfenian deposits. They outcrop in the eastern part of Pădurea Craiului Mountains and progressively deepen westward, together with the whole structure. The deepening is however not uniform, as many vertical, mainly reverse faults occur, with relatively small displacements, insufficient for bringing back to the surface the impervious substratum.

The water accumulations in the carbonate deposits discharge through springs of a wide variety, both in what concerns their recharge and their yield and flow regime. Most of the springs in the massif, which are called ,"izbucuri" on the local plane, discharge binary type karst systems supplied by both precipitations and runoff from non karstic terrains (Aştileu, Brătcani, Moara Jurjii, etc.). Springs exclusively supplied by the diffuse infiltrations of precipitations are rare and their flow rate are low (the spring in Poiana Damiş, Fântâna lui Onuţ, Pişniţa spring, etc.). The springs are either permanent or temporary and their discharges directly depend on precipitations.

In broad lines, the springs on the northern flank of the Pădurea Craiului Mountains are gravitational type (Aştileu, Vadu Crişului, Brătcani, etc.) and those at the foot of the southern slope are lithologic-contact type springs. The latter are to be found in the contact zone between karstic terrains and the Senonian deposits of the Roşia depression (Topliţa de Roşia, Roşia, Izbuneală) or the Permian deposits of the Arieşeni Nappe (Topliţa de Vida).

Karstic springs and even caves are also to be found on the terrains covered by the Senonian deposits of the Roşia depresion, in calcareous streaks. They develops on a limited area and do not modify the generally impermeable character of those deposits, a character lent by the broad development of marls and clays.

In order to investigate the hydrologic regime of the main karst sources in Pădurea Craiului Mountains, the hydrometric behaviour of 13 main springs was monitored during the hydrologic year October 1982 - September 1983, the results of field data processing being indicated in Table 2.3. It is worth mentioning that the indicated hydrologic year was a droughty one, the last in a succession of three, when increasingly smaller flowrates had been recorded at the springs as a consequence of low rainfall. On the average, the flowrates recorded during that hydrologic year were only half the flowrates recorded during an average hydrologic year (I. ORĂŞEANU, A. IURKIEWICZ, 1987).

By processing the flow rate time series recorded at 11 karst springs, valuable information has been obtained in terms of the structure of the karst systems which discharged through those outlets.

Cv, the discharge time series variation coefficient, is the ratio between average deviation and the annual average of an hydrologic annual series of mean daily discharges values. It ranges between 0 and 1, the large values indicating outlets with large variations of their flow rate, associated to karst systems subject to a strong karst development, with a well organized underground flow. The small values are characteristic to springs displaying small fluctuations of their flow rate, associated to karst systems subject to a poor development of the karst, with a poorly organized underground flow, mainly through small fissures. Low values may also be recorded in the case of outlets that discharge confined systems subject to a constant supply head on their boundary (for instance from surface streams). The values of the Cv index are also dependent on the lythologic constitution of the non karst catchment area (binary systems), on the presence of underground large lakes, on the hydraulic conductivity of the karst cavities filling and on the rainfall regime, the latter assertion being sustained by the good correlation that exists between the Cv coefficient and the rainfall variance.

The recession coefficient α describes the flooded zone process of draining. For the considered cases, one can easily notice two corresponding patterns of aquifer water release. Certain systems, such as Brătcanilor and Izbândiş, display large values of the α coefficient (0.034-0.01), which indicate that the stored water reserves are quickly evacuated. For the other considered systems the reserves drainage occurs less rapidly, a circumstance which is highlighted by their smaller α values (Table 2.4).

Yet a small value of the recession coefficient is not necessarily an indicator of important stored water amounts: on certain occasions, such values are associated with systems that are supplied by surface streams collecting their water from non-carbonate terrains (binary systems). This is the case of Topliţa de Roşia karst spring, the outlet of the more than 10 km long Ciur Ponor through cave.

The recession coefficients (Table 2.4, A. JURKIEWICZ, I. ORĂŞEANU,1997) have a maximum value for the Vadu Crişului cave outlet, indicating water storage and circulation to occur mainly in karst cavities. This observation is also supported by the results of speleological exploration, which indicated that the length of Vadu Crişului cave is 1000 m, and that of Bătrânului cave, the major swallet of this karst system, is 1633 m.

A synopsis of the recession curves analysis is provided by the i/k diagrams, A. MANGIN, 1975 that include non-dimensional parameters which describe the infiltration zone (the i parameter), and qualitatively assess the size of the flooded zone (the k parameter). The analysis and interpretation of those diagrams has outlined that karst systems in Pădurea Craiului Mountains were subject to intense karst processes, and that some of them (Aştileu and Topliţa de Roşia karst springs) included extensive networks of flooded passages (Fig. 2.5).

In the X.1982-IX.1983 hydrologic year, the mean annual discharge of the main karst springs in Pădurea Craiului Mountains (Aştileu, Moara Jurjii, Peştera de la Vadu Crişului cave, Izbândiş, Brătcani, Peştera cu Apă de la Bulz cave, Tăul fără Fund, Toplicioara, Roşia, Topliţa de Roşia and Topliţa de Vida), were 2.83 m^3/s, the minimum mean discharge of these sources being 0.66 m^3/s. The mean annual discharge of others sources are estimated to 1 m^3/s.

The mean annual discharges of springs have large oscilations from one year to another, depending of rainfall regime. Thus, the mean annual discharge of Aştileu spring was 575 l/s in X.1982-IX.1983 period and 356 l/s in X.1983-IX.1984

No.	Source	Q mean	Q min	Q max	n_v	B_f	Cv	Tracer data	
		l/s						V/hour	L (km)
1	Aştileu (1)	356	74	3410	46.0	0.303	0.618	5.6-266	2.62-11.5
2	Moara Jurjii (6)	163	18	1070	59.0	0.387	0.647	181.3	4.35
3	Peştera de la Vadu Crişului (8)	127	22	1270	58.0	0.213	0.690	47.8	4.25
4	Izbândiş (10)	346	49	3980	81.0	0.171	0.821	7-82.3	3.4-5.65
5	Brătcanilor (21)	305	68	2412	36.0	0.404	0.556	42.2-211	1.7-5.7
6	Damişenilor (22)	83	28	519	19.0	0.361	0.532	39.5-230.9	2.77-5.06
7	Ibanului (26)	55	12	410	34.0	0.254	0.643	11.1	1.85
8	Peştera cu Apă de la Bulz (28)	136	20	1600	80	0.176		77.9-150.6	2.56-6.0
9	Topleţ (31)	150	112	255	2.3	0.780		2.7	0.6
10	Topliţa de Vida (52)	161	22	3150	143.0	0.174		3-141.7	3.37-6.8
11	Topliţa de Roşia (54)	74	11	965	88.0	0.176	0.840	25.8-72.8	1-3
12	Roşia (63)	522	78	14300	183.0	0.201	0.902	7-34.6	2.1-5.7
13	Toplicioara (62)	299	66	3200	48.0	0.234	0.864	3.6-86.4	0.95-3.07

n_v - index of discharge variability (Q max/Q min); B_f - base flow index (ratio between monthly mean discharge of the driest month and mean annual discharge); 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)

Table 2.3. Specific parameters of main springs in X.1982-IX.1983 period.

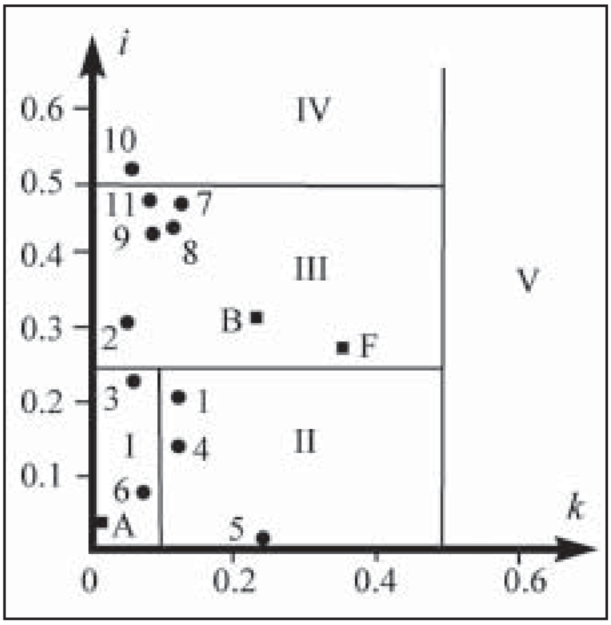

Figure 2.5. Position of major karst system according to Mangin's classification (1975): 1 - Aștileu, 2 - Brătcani, 3 - Izbândiș, 4 - Toplița de Vida, 5 - Toplița de Roșia, 6 - Roșia (Pădurea Craiului Mountains), 7 - Păuleasa, 8 - Tăuz (Bihor Mountains), 9 - Boiu, 10 - Șopoteasa, 11 - Grota Ursului (Codru Moma Mountains)

period. The minimum discharge recorded at the same spring in dry sesons was 170 l/s in 1981, 140 l/s in 1982 and only 74 l/s in 1983.

The temporary hydrologic stations network set up during the hydrologic year X.1982-IX.1983 has provided information about the average daily flow rates recorded both on the surface streams and at the main karst outlets. The overall area concerned both by the network of temporary stations, and by the INMH regular network of flow rate gauging stations extended over 525 km^2. For this area the corresponding output of discharged water being 5.382 m^3/s (323 mm), out of which the surface runoff amounted to 4.392 m^3/s, while the discharge of the main springs located at the border of the considered area amounted to 0.988 m^3/s.

The considered area average rainfall amount, estimated by means of the Thiessen polygons method, has been 774.4 mm, while evapotranspiration computed by means of the ETR-elevation diagram amounted to 595 mm. By using those data, there has resulted a value of -173.6 mm for the term which included infiltration ± stored reserves variation, being impossible to further ascribe, by using the adopted classical method, a distinct value to each of those two indicated terms. The author has proposed an ad hoc method – the so-called „witness catchment areas method" – in order to assess, for the considered domain, the amount of the infiltration, the resulting value for that specific term being 55.5 mm, a circumstance which further indicated a negative variation, -88.1 mm, for the stored reserves.

The performed water budget indicates that during the hydrogeological year X.1982-IX.1983, the system outflow has exceeded the inflow, hence the groundwater reserves were highly stressed. Out of the total discharge which left the karst areas of the massif through the gauging sites located at its border, 27 % (1.47 m^3/s) were derived from the aquifer reserve accumulated during the previous years. We specifically point to the fact that the considered hydrological year has been a quite dry one, a circumstance also mirrored by the annual average flow rate of Vida stream (with a catchment area extending almost exclusively on carbonate terrains), that amounted to only 68.8 % of its multiannual average.

	Source	**Recession analysis**					**model**	**Corelative and spectral analysis**		
		α	**V dyn**	**Vyear**	**i**	**k**		**EM**	**FT**	**TR**
		day^{-1}	**10^6 m^3**					**days**		**days**
1	Aştileu	0.007	1.35	11.16	0.21	0.12	$B \Rightarrow F$	46	0.120	32
2	Brătcani	0.037	0.50	9.61	0.31	0.05	$A \Rightarrow B$	20	0.168	24
3	Izbândiş	0.010	0.70	10.94	0.23	0.06	$A \Rightarrow B$	15	0.124	18
4	Topliţa de Roşia	0.004	0.29	2.3	0.14	0.12	A	29	0.168	25
5	Topliţa de Vida	0.0017	1.22	5.1	0.013	0.04	A	12	0.184	9
6	Roşia	0.008	1.23	16.27	0.08	0.07	A	13	0.210	10

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

Table 2.4. Parameters of recession and spectral and correlative analysis for main springs in Pădurea Craiului Mountains.

Tracer tests

By now, 74 tracer tests have been performed in Pădurea Craiului Mountains (Table 2.5), 41 of them being performed by T. RUSU (1988), by means of fluorescein, while 31 were performed by the present author, in co-operation with E. GASPAR, A. IURKIEWICZ, E. POP and P. BRIJAN, using rhodamine, fluorescein, NaCl, I-131 and In-EDTA. The average groundwater flow velocity indicated by those tracer tests is 46 m/h. The largest distance between sinking points and outlets, recorded as a result of the tracer tests performed in Pădurea Craului Mountains, is 11,55 km. It was reached along the connection Pestişului stream losses - Aştileu spring.

The relatively high value of that velocity and the interpretation of the curves showing the passage of tracers through monitoring sections indicate a mixed circulation – through channels and fissures. The mainly conductive role of the karstic channels and the mainly capacitive role of the fissures are obvious.

Hydrogeological karst systems

The hydrogeological karst systems include karstic terrains, hosting groundwater flow of karstic type, as well as non karstic terrains, the flow of which, both surficial and subterranean, takes part integrally or only with a fraction of itself (diffluence areas) to the supply of the same spring or interconnected group of springs, during a given period.

The Figure no. 2.4 indicates the approximate boundaries of the hydrogeological karst systems

Labelling no.	**Insurgence**	**H (m)**	**Resurgence**	**H, m**	**L, m**	**ΔH, m**	**Tracer**	**T, hours**	**V, m/h**	**Date of labelling**	**Author(s)**
1	Potriva cave	347	Aştileu spring	250	2620	107	F	10	262.2	04.04.1966	T. Rusu
2	Losses of Poienii stream	390	Aştileu spring	250	8350	140	In	768	11.3	15.10.1983	I. Orăşeanu et al.
3	Ponor of Pestişului stream	325	Aştileu spring	250	11550	75	In	2040	5.6	04.06.1983	I. Orăşeanu et al.
4	Ţiclului cave	373	Peştera de sub Stan cave	265	900	108	F	45	20.2	22.07.1972	T. Rusu
5	Losses of Peşteranilor stream	520	Aurica mine	475	300	45	I, NaCl	7	43.3	03.10.1980	I. Orăşeanu et al.
6	Groapa Popii ponor	555	Cioroaiele Ţârcului spring	490	1270	65	I, NaCl	122	10.4	03.10.1980	I. Orăşeanu et al.
	"	"	Brusturi mine	460	180	95	I, NaCl	105	1.9	03.10.1980	"
7	Gălăşeni cave	390	Spring of Groapa Moţului	295	1750	95	F	13	134.8	19.06.1969	T. Rusu
8	Losses of Mniera stream	500	Moara Jurjii spring	400	4350	100	R	24	181.3	09.12.1982	I. Orăşeanu
9	Bătrânului cave	574	Vadu Crişului cave	305	4250	269	F	89	47.8	16.05.1962	T. Rusu
10	Ponor of Tomii brook	639	Izbândiş spring	370	5400	269	In	768	7.0	25.05.4983	I. Orăşeanu et al.
11	Groapa Blidireşti ponor	729	Izbândiş spring	370	3400	359	F	63	54.3	23.10.1964	T. Rusu
12	Ponor of Brezului brook	645	Izbândiş spring	370	5650	275	F	80	70.1	18.06.1970	T. Rusu
13	Ponor of Olfului brook	635	Izbândiş spring	370	5320	265	F	73	73.0	17.08.1971	T. Rusu
14	Ponor of Birăului brook	600	Izbândiş spring	370	5100	230	F	62	82.3	02.07.1974	T. Rusu
15	Ponor of Recea brook	600	Spring of Poiana Frânturii	305	3185	295	I	260	12.3	02.10.1980	I. Orăşeanu et al.
16	Losses of Luncilor brook	470	Brătcanilor spring	345	4800	125	R, In	114	42.2	19.09.1982	I. Orăşeanu et al.
17	Ponor of Mocra brook	583	Moanei cave	485	500	98	F	45	11.3	08.06.1975	T. Rusu
18	Ponor of Ponoraş	604	Brătcanilor spring	345	4800	250	F	35	137.3	10.10.1969	T. Rusu
19	Ponor of Huţii brook	620	Brătcanilor spring	345	5700	325	F	27	211.2	19.06.1969	T. Rusu
20	Ponor of Secătura Brătcanilor	485	Brătcanilor spring	345	1700	140	F	27	63.0	07.07.1970	T. Rusu
21	Toaia ponor	675	Dămişenilor spring	420	3550	255	F	90	39.5	12.07.1968	T. Rusu
22	Peşteruţa ponor	687	Dămişenilor spring	420	5060	267	R	96	52.8	21.05.1983	I. Orăşeanu et al.
23	Munău cave	705	Dămişenilor spring	420	2770	285	F	12	230.9	06.07.1970	T. Rusu
24	Ponor of Groapa Râtii	583	Moara Dedii spring	350	1850	233	F	168	11.1	07.1971	D. Grigorescu
25	Sâcuta ponor	725	Peştera cu Apă de la Bulz c.	370	6000	355	R	77	78.0	12.07.1981	I. Orăşeanu, A. Iurkiewicz
26	Ponor of Ponorului brook	625	Peştera cu Apă de la Bulz c.	370	2950	242	F	38	77.9	11.10.1966	T. Rusu
27	Ponor of Brădeştilor brook	640	Peştera cu Apă de la Bulz c.	370	3100	270	F	29	106.9	15.05.1966	T. Rusu
28	Ponor of Şes	680	Peştera cu Apă de la Bulz c.	370	2750	310	F	20	138.4	13.05.1966	T. Rusu
29	Ponor of Stiopului brook	690	Peştera cu Apă de la Bulz c.	370	2560	320	F	17	150.6	11.05.1966	T. Rusu
30	Losses of Iadului stream	450	Tăul fără Fund spring	435	600	15	F	220	2.7	1964	E. Jekelius
31	Losses of Caprei brook	662	La Izvoară spring	540	700	122	F	114	6.2	15.06.1962	T. Rusu

32	Losses of Dişorului brook	562	Turii cave	470	500	92	F	23	21.8	18.07.1972	T. Rusu
33	Losses of Pârâul cu Soci brook	625	Springs of Lunca Pizlii	470	700	155	F	68	10.3	16.08.1980	T. Rusu
34	Losses of Izvorului brook	600	Davelii spring	480	900	120	F	78	11.6	08.07.1972	T. Rusu
35	Losses of Valea Rea brook	662	Peştera de la Faţa Apei c.	480	700	182	F	94	7.5	15.06.1972	T. Rusu
36	Losses of Daica brook	665	Peştera cu Apă (Daica) c.	580	300	45	F	12	25.0	09.07.1972	T. Rusu
37	Losses of Strivinoasa brook	562	Dumiter's spring	490	500	72	F	50	10.0	15.06.1972	T. Rusu
38	Losses of Sălătrucului brook	550	Ciuhandru spring	516	500	34	F	25	22.0	30.10.1980	T. Rusu
39	Ponor of Acre	815	Peştera cu Apă cave (Leşu)	650	1550	165	F	102	15.2	14.06.1972	T. Rusu
	“	“	Firez spring	545	2250	300	F	185	17.0	14.06.1972	"
40	Fântânele ponor	679	Toplicioara spring	430	3070	249	F	220	3.6	26051983	I. Orăşeanu et al.
41	Ponor of Runcşorului brook	570	Toplicioara spring	430	950	140	F	11	86.4	10.07.1966	T. Rusu
42	Ponor of Hârtopul Bonchii	455	Gruieţului cave	320	1200	135	F	22	54.6	19.09.1970	T. Rusu
43	Losses of Barc brook	615	Roşiei spring	290	5700	325	In	624	9.1	25.05.1983	I. Orăşeanu et al.
44	Ponor of Botului brook	550	Roşiei spring	290	5050	260	F	146	34.6	05.07.1966	T. Rusu
45	Ponor of Iezere brook	550	Roşiei spring	290	3400	260	F	350	9.7	13.06.1967	T. Rusu
46	Jurcanilor cave	545	Roşiei spring	290	5110	255	R	168	30.4	26.05.1983	I. Orăşeanu
47	Ponor of Fiului brook	510	Roşiei spring	290	2100	220	F	300	7.0	21.09.1970	T. Rusu
48	Losses of Cuţilor brook	360	Topliţa de Roşia spring	275	1000	85	F	17	59.0	20.09.1970	T. Rusu
49	Ponor of Tinoasa brook	539	Topliţa de Roşia spring	275	3000	264	F	78	38.5	04.05.1968	T. Rusu
50	Ponor of Groapa Ciurului	480	Topliţa de Roşia spring	275	2400	205	F	93	25.8	05.07.1968	T. Rusu
51	Losses in Ciur Izbuc cave	535	Topliţa de Roşia spring	275	2800	260	F	70	40.0	04.05.1968	T. Rusu
52	Doboş cave	467	Topliţa de Roşia spring	275	1600	192	R	22	72.8	04.08.1981	I. Orăşeanu, A. Iutkiewicz
53	Ponor of Albioara brook	430	Topliţa de Roşia spring	275	2500	155	F	89	28.1	20.07.1978	T. Rusu
54	Marchiş ponor	510	Topliţa de Vida spring	245	3400	265	F	168	20.6	24.05.1982	I. Orăşeanu et al.
55	Fântâna Rece ponor	456	Topliţa de Vida spring	245	3370	211	I	552	6.1	24.05.1982	I. Orăşeanu et al.
56	Merişor ponor	458	Topliţa de Vida spring	245	4320	213	NaCl	276	15.6	21.05.1982	I. Orăşeanu et al.
57	Bichi ponor	458	Topliţa de Vida spring	245	4800	213	In	1224	3.9	06.08.1982	I. Orăşeanu et al.
58	Baia Niţului ponor	458	Topliţa de Vida spring	245	4580	213	In	1536	3.0	21.12.1983	I. Orăşeanu et al.
59	Ponor of Poiana Prie	455	Topliţa de Vida spring	245	6800	210	In	48	141.7	21.05.1986	I. Orăşeanu et al.
60	Ponors of Prislop	666	Groieşului spring	490	2300	176	F	120	19.2	26.08.1971	T. Rusu
61	Fundătura Roşiorului ponor	640	Springs of Gura Ursului	450	1380	190		168	8.2	22.09.1983	I. Orăşeanu et al.
62	Hârtoapele Hododii ponor	620	Ponors of Gura Ursului	450	1200	130	R	192	6.2	22.09.1983	I. Orăşeanu et al.
63	Ponor of Gropilor (Coş) brook	520	Spring of Meziad cave	405	600	115	F	42	14.3	06.02.1964	T. Rusu
64	Losses of Peşterii brook	470	Spring of Meziad cave	405	400	65	F	25	16.0	29.02.1974	T. Rusu
65	Cave of Băroaia Bătrană	529	Spring near Groieşu spring	470	1300	59	R	50	26.0	24.09.1983	I. Orăşeanu
66	Iacoboaia ponor	680	Izbândiş spring	370	5800	330	F	72	80.0	12.04.1986	C. Lascu, C. Diaconu
67	Ponor of Groapa Brăjeşti	615	Spring of Ruştiului brook	475		130	F	210	4.3	12.04.1986	I. Povară, C. Lascu
68	Ponor of Tinoasa de Vida	574	Peştera cu Apă din Vida c.	458	820	116	F	39	21.0	12.04.1986	I. Povară, C. Lascu
69	Perje ponor	485	Roşiei spring	290	4020	195	F			13.04.1986	I. Povară, C. Lascu
70	Fântâna cu Soci ponor	400	Cave of Strâmtura brook	325	450	75	F	40	11.2	20.07.1987	I. Orăşeanu et al.
71	Cioroi ponor	390	Spring of Cailii brook	320	360	70	In	10	36.0	20.07.1987	I. Orăşeanu et al.
	"	"	Cave of Strămtura brook	325	730	65	In	20	36.5	20.07.1987	"
72	Ponor of Groapa Morăreştilor	715	Izbuneală spring	325	1950	390	R	220	8.8	08.07.1987	I. Orăşeanu, P. Brijan
73	Ponor of Groapa Dealului	635	Izbuneală spring	325	840	310	F	50	16.8	08.07.1987	I. Orăşeanu, P. Brijan
74	Losses of Şoimuşul Drept brook	660	Peştera cu Apă cave (Leşu)	640	2100	20	In	144	14.5	16.07.1987	I. Orăşeanu, E. Gaşpar
	"	"	Firez spring	545	2700	115	In	168	16.1	16.07.1987	"

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 = Iodine-131, In = In-EDTA
Note 1: The following labellings were performed by the author in cooperation with E. Gașpar, Nicolle Orășeanu, I. Pop and T. Tănase: 5, 6, 10, 22, 40, 43, 61, 62, 70, 71; A. Jurkiewicz, E. Gașpar, Nicolle Orășeanu, and I. Pop: 16, 56, 57, 58, 59; E. Gașpar and Nicolle Orășeanu: 2, 3, 16, 61; E. Gașpar and I. Pop: 62.

Table 2.5. Results of tracing tests in Pădurea Craiului Mountains.

associated to the main springs from the mountains areas, drafted according to the tracing experiments and to the analysis of the water-budget.

The overal hydrogeological picture of the Pădurea Craiului Mountains, without Remeţi graben, is characterized by the presence of a unitary karstic aquifer in which there is a deep circulation from the East to the West overlay by numerous underground ,,surficial" (epidermic) ones which discharge at the periphery of the massif, by sources with overflow meaning, the water excess resulting from the rainfall on its surface and which can't be involved in deep circulation.

The karst waters with deep circulation, while moving westwards are thermalized as a consequence of the hyperthermal regime of the area adjacent to the Pannonian Basin and are partially discharged by the sources in the Felix - 1 Mai zone, which is part of the vast karstic aquifer.

2.7. Karst Water Chemistry

In 1981, C. MARIN brought out a detailed study on the chemical composition of the carbonate waters in the Pădurea Craiului Mountains. L. VALENAS and A. JURKIEWICZ (1980-981) outline, in a work dedicated to the Mişid area, a number of chemical analyses of the waters in that zone.

In 1979-1983 time interval, as many as 123 samples were taken and analysed in S. C. Prospecţiuni laboratories in Bucharest with a view to chemically characterizing the surface and underground waters in the Pădurea Craiului Mountains. Those analyses show that the water in this massif is Ca-HCO_3 and Ca, Mg-HCO_3 type water, with the exception of the area of the lower course of the Mişid brook, where Ca-SO_4 type water is also to be found.

Table 2.6 shows the mean, minimal and maximal concentration of the major ionic species in the carbonate waters of the karst sources – both those emerging from limestones and those springing from dolomites. The table also shows the same data for the water of Mişid area with calcium sulfate water. The sources emerging from dolomites are hydrochemically individualized, owing to their magnesium content, which is richer than that of the sources springing from limestones.

The acid, calcium-sulfate water (with a pH values of up to 3) in the lower basin of the Mişid brook (Izvorul cu Lapte spring, water of underground courses of Ungurului, Izvor and Vântului caves, the surficial course of Hodoabe and Tare brooks) are a result of the oxidation of the pyrites in the Lower Jurassic deposits, which locally cover the Triassic limestones and dolomites where from these waters spring off, by infiltration water.

Several springs from Pădurea Craiului Mountains, display gas outflows containig $O_2$and N_2. The water of these springs is Ca-HCO_3 or Ca, Mg-HCO_3 type, similar to the water of the other springs of the karstic aquifer complex.

The chemical composition of the outflown gases (Table 2.7) is close, if not identical, to that of the atmosphere. As compared to the atmospheric gas, the concentration in oxygen is diminished, due to the biochemical and oxidation proc-

Sursa		**n**	**T D S**	**Cl^-**	**SO_4^{--}**	**HCO_3^-**	**Na^+**	**$K^=$**	**Ca^{++}**	**Mg^{++}**
Spring from limestones	mean	65	403.8	5.66	15.3	215.3	13.1	1.03	81.93	2.61
	min		158.7	35.0	1.0	85.4	0.2	0.4	28.8	0.7
	max		625.4	28.3	34.4	400.6	58.1	2.5	125.8	36.5
Spring from dolomites	mean	42	369.2	7.2	8.08	237.5	13.6	1.2	61.07	14.3
	min		254.0	7.0	1.9	134.2	0.4	0.4	29.6	0.5
	max		732.1	21.3	30.	518.8	71.9	3.0	106.6	49.1
Spring from Mişid area	mean	10	591.6	8.7	245.6	47.5	29.6	2.4	52.7	20.9
	min		207.6	2.7	86.4	0.3	3.9	1.2	40.1	9.2
	max		856.6	21.3	415.9	109.8	57.4	3.8	50.1	39.4
Surface stream water	mean	6	255.1	8.2	13.0	147.4	18.2	1.5	35.7	3.5
	min		100.7	7.0	6.4	36.6	1.5	0.7	12.0	0.1
	max		5551	14.1	25.0	341.6	48.5	2.4	86.5	20.9

n - number of samples analysed.

Table 2.6. Chemical composition variation range of the waters in Pădurea Craiului Mountains.

No.	Source	T (°C)	Q (l/s)	CH_4	CO_2	O_2	N_2	Ar
1	Topliţa de Vida warm spring (52)	20	4.0	6×10^{-4}	0.00	12.15	87.22	0.538
2	Tăul Fierbintea spring (66)	18.0	4.0	0.0	0.11	19.58	79.31	0.915
3	Izvorul cu Travertin spring (Rusu brook)	10.3	5.0	7×10^{-4}	0.0	20.3	75.5	0.900
4	"La Sălcii" spring (downstream no. 22)	11.2	8.0	0.004	0.0	20.7	77.0	0.916
5	Vida forestry hutt spring (45)	12.9	1.0	0.0	0.87	12.4	86.0	0.550

Other compounds for wich the gases were analysed, C_2H_2, C_3H_8, C_4H_{10}, He, H_2, are lacking.
In brackets number of spring in Figure 2.1.

Table 2.7. Chemical composition of the gas outflowing from springs.

esses. Corresponding to the consumed oxygen fraction, the nitrogen concentration increases accordingly.

The water of the subthermal spring Toplita de Vida originates in the hydrogeological karst system Topliţa de Vida, as a consequance of a deep flow it undergoes an increase in temperature. The emergence occurs on the tectonic contact plane between the permian sandstones of the Arieşeni Nappe and the cretaceous limestones of the Bihor Unit.

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