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HYDROGEOLOGICAL MAP OF THE PĂDUREA CRAIULUI MOUNTAINS (ROMANIA)[1]

BY

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The hydrogeological map shown herein covers an area of 670 sq.kms. in the Pădurea Craiului, a massif that makes the North-western termination of the Apuseni Mountains. Owing to a varied geologic structure, with Mesozoic limestones and dolomites outcropping on 330 sq.kms., the relief boasts a great variety of features, noteworthy among which are the karst plateaus and valleys, as well as the caves and the potholes.

The numerous karst catchment processes, of which some are in full progress at present, disorganized the surface hydrographic network, leading to the formation of an endoreic zone of roughly 224 sq.kms. and of a diffluence area extending on 94 sq.kms. The hydrologic links between these areas and the zones bordering the massif is secured by surface and underground flows.

The great lithologic diversity and the different tectonization indices of the deposits in the lithologic structure of the Pădurea Craiului Mountains led to the individualization of five groups that boast distinct modes of underground water supply, circulation, storage and discharge. In the hydrogeological map, the five types are separated cartographically and characterized hydrogeologically; the map also gives their detailed lithologic description.

International conventional signs show various modes whereby the water penetrates the carbonate massif (diffusely, ponors and caves, a.o.), as well as different types of karst exurgences, all while pinpointing the permanent or temporary hydrologic character of the flow and the speleologists' access — or lack of it — to the underground realm through these points.

The precipitations that fell in October 1982 — September 1983 hydrologic year on the non-karst area of the massif generated a specific annual mean runoff ranging from 3 to 20 l/s sq.kms., with its vertical gradient standing at 3.3 l/s sq.kms. The value of that index is strongly influenced by the presence of the areal carbonate rocks wherein the karst-catchment processes substantially diminish the discharge.

The 78 tracer labellings performed by various authors pinpointed the general directions of flow of underground waters and the comparison between those data and the results of the hydrometeorological observations and measurements provided for a hydrogeologic characterization of the major hydrogeological karst systems. The discharge, variability indices and the recession curve discharge coefficients for 13 of the major karst sources of the massif, as well as the distribution in time of underground flow of that area were shown.

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The overal hydrogeological picture of the Pădurea Craiului Mountains, without Remeţi graben, is characterized by the presence of an unitary karstic aquifer in which there is a deep circulation from the East to the West overaly by numerous underground "surficial" (shallow) 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.

1. INTRODUCTION

The Pădurea Craiului Mountains lies in the North-western part of the Apuseni Mountains. They appear in the form of a digitation, extending far towards the West, almost reaching Oradea. They are bounded by the Neogene basin of the Vad (of the Crişul Repede river) to the North, by the Neogene basin of the Beiuş (of the Crişul Negru river) to the South and they border on the eruptive Vlădeasa massif in the East, with the Iad Valley acting as a demarcation line 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 Vîrciorog-Dobreşti alignment: the Pădurea Craiului Mountains in the East and the hills of the Pădurea Craiului (the Vîrciorog, Tăşad, Hidiş, Dobreşti and Vălani) in the West. The hydrogeological map at issue covers an area extending on 670 sq.kms and refers only to the terrains ascribed to the former unit. Therefore, it is that unit that will be further referred to as the Pădurea Craiului Mountains.

The salient morphological and hydrogeological elements of that area are represented by a broad development of Mesozoic carbonate rocks that crop out along 330 sq.kms.

The present map is a result of the author's hydrogeological research started back in 1979, temporarily accompagned by A. Jurkiewicz (over 1981–1982). It is partially represented on the hydrogeological map of Pădurea Craiului Mountains, scale 1 : 25.000, a map that includes neither the Senonian basin of the Roşia nor the Vălani–Căbeşti–Meziad area [2].

The geological base of the present map were the maps drawn up by S. Bordea et al. (1986), D. Patrulius et al. (1977), D. Patrulius et al. (1983), Elena Popa (1981), D. Patrulius and S. Bordea (1981), C. Mihăilescu et al. (1982), and Felicia Teodorescu and G. Teodorescu (1981).

2. A BRIEF HISTORY OF HYDROGEOLOGICAL RESEARCH

One may say that, more than in any other area, the cooperation between geology, geomorphology, speleology and hydrogeology in a karst region is so close than the limite between the respective sciences superpose, making it almost impossible to state where one begings and the other ends. This is the very case of the Pădurea Craiului Mountains in connection

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[2] I. Orăşeanu, Nicolle Orăşeanu (1983) — *Studii hidrogeologice complexe pentru ape potabile şi stabilirea condiţiilor hidrogeologice ale zăcămintelor de bauxită din Munţii Pădurea Craiului, jud. Bihor.* Arh. IPGG Bucureşti.

with which the first references to hydrogeologic elements (springs, ponors, underground drainages, a.o.) were made by researches of the underground, geomorphologists and geologists (Jeannel and Racovitza, 1929, Maxim, 1954, Preda, 1968, etc.).

Over 1956–1976, researchers of the Institute of Speology „Emil Racoviță" 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; furthermore, they could pinpoint the areas of influence of numerous karst sources at the end of 41 labellings with fluorescein.

The hydrogeological research proper into the massif, performed by the Enterprise for Geological and Geophisical Prospecting, started in 1979 being related, in the main, to research into the hydrogeological conditions of the bauxite deposits and the assessment of the aquifer potential of that area. In the respective interval, the author together with E. Gașpar, I. Pop, P. Stănescu, A. Jurkiewicz, T. Tudor, Nicolle Orășeanu and P. Brijan effected another 31 tracer labellings, of which some highlighted major karst catchment processes of surface flows.

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 Enterprise for Geological and Geophysical Prospecting (I. Orășeanu, A. Jurkiewicz), Meteorological and Hydrological institute (G. Hoțoleanu, Paraschiva Hoțoleanu, Victoria Preoteasa, Tatiana Nicolae, Luminița Tibacu) and Institute of Speology „Emil Racoviță" (I. Povară, Th. Rusu, C. Marin, M. Șerban, I. Viehmann, G. Diaconu, C. Lascu) which supplied early quantitative data on the condition of the sources and the aquifer potential of the massif.

The speological research, which resulted in the discovery of roughly 700 underground cavities – with the longest cave – the Vîntului 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 (Szilagy A., 1976, Vălenaș and Drîmba, 1978, Vălenaș, 1980–1981, Baboș, 1981, a.o.).

3. GENERAL FEATURES

3.1. RELIEF.

Althought of an average altitude – only 505 m (Figure 1) – the Pădurea Craiului Mountains are well-defined in point of relief, owing to the low altitudes characteristic of the depressions surrounding them in the North and the South.

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 masive, stately relief including sandstones, conglomerates and eruptive rocks, alternates with the lower relief of karst capture depressions and the flat relief characterizing the karst plateaus strewn with sinkholes.

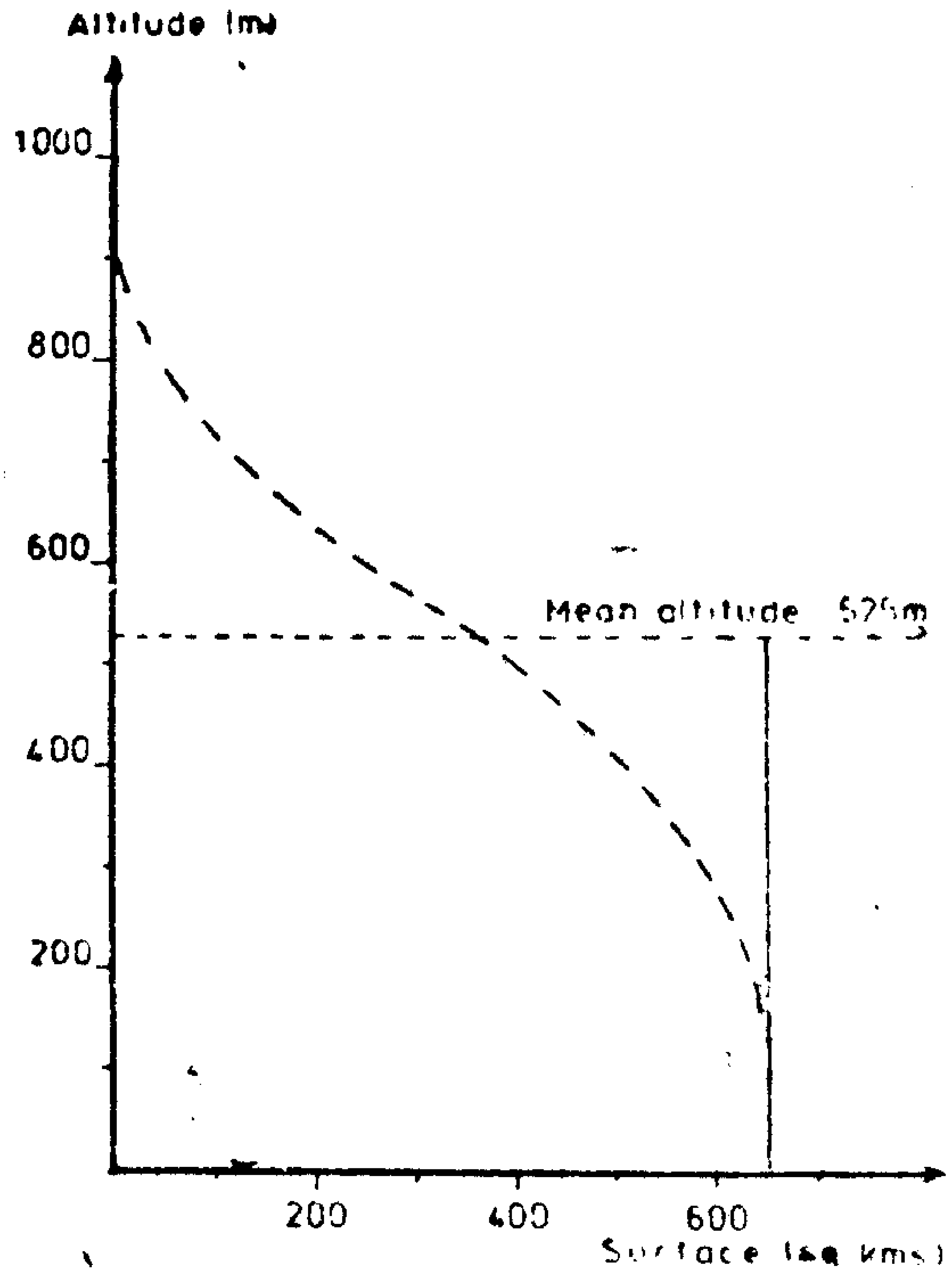

Fig. 1 — Hypsometric curve of the Pădurea Craiului Mountains.

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 Hodrînguşa (1,027 m), Măgura Dosului (945 m) and Rujet (844 m). 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 Cărmăzan, 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 (Hîrtoapele), 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 brook, 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.

3.2. THE HYDROGRAPHIC NETWORK.

The surface waters in the Pădurea Craiului Mountains belongs to the hydrographic basin of the rivers Crişul Repede and Crişul 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.

The hydrographic network of the Pădurea Craiului Mountains is highly desorganised 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 Crişul Repede basin, of the Vida and the Roşia, with its tributaries — the Lazuri, the Sohodol, the Meziad and the Strîmtura, in the Crişul Negru Basin. The Vida valley is the only important valley in the respective massif that crosses karst terrains only.

The process of karst capture of surface flows by the main karst spring on the outskirts of the massif is in full progress (Orăşeanu, 1985). So, for instance, in the case of the hydrographic basin of the Crişul Repede, the waters of the Luncilor 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 Peştiş, both tributaries of the Topa brook, in the hydrographic basin of the Crişul Negru. The waters infiltrated in these sectors are partially found in the spring of Aştileu, in the hydrographic basin of the Crişul 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.

3.3. VEGETATION

Roughly 50% of the Pădurea Craiului Mountains are covered by deciduous forests, which extend chiefly in the South-eastern part of the massif. The other half is covered by hayfields and agricultural cultures.

3.4. HUMAN ACTIVITIES

Inhabitants of the Pădurea Craiului Mountains are chiefly concerned with farming and animal breeding, as the vast pastures on the karst plateaus offer altogether exceptional conditions in this respect. A substantial part of the population is engaged in activities aimed at exploiting the bauxite deposits, which are scattered throughout the massif, refractory clay deposits, situated south of the locality of Suncuiuş, as well as the limestone and clay needed by the cement combine in Aleşd.

A third major concern of the inhabitants of the area is wood exploitation.

4. THE KARST OF THE PĂDUREA CRAIULUI MOUNTAINS.

The Pădurea Craiului Mountains boast the largest density of exo- and endo-karst formations in Romania. The 1981 inventory listed 680 caves, of which 17 has more than one kilometre in length (Goran, 1981). At present, their number is far larger; tables 1 and 2 give the morphometric data of the major cavities that were charted.

Table 1

The main caves of Pădurea Craiului Mountains [1]

No.	Cave [2]	H (m)	Location	L (m)	D (m)	HR
1	Peştera Vîntului	320	Northern border	36.000	190	f.
2	Ciur Ponor (182)	480	Runcuri plateau	17.078	200	p.i
3	Bonchii (204)	455	Roşia basin	6.686	163	t.i.
4	P_1J_2 Jofi	445	Roşia Basin	6.657	144	
5	Dămişeni spring	420	Brătcuţa basin	4.800	4	p.o.
6	Meziad	435	Roşia basin	4.750	89	f
7	Sincuţa	728	Chicera Arsuri plateau	4.200	296	f
8	Ponoraş (29)	604	Ponoraş depression	3.851	211	t.i.
9	Osoi (93)	400	Topa basin	3.700	50	p.o.
10	Potriva	357	Mniera basin	3.018	56	t.i.
11	Gabor (94)	445	Topa basin	2.707	25	p.o.
12	Aurica [3]	470	Topa basin	2.679	33	
13	Aştileu	250	Northern border	2.614		p.o.
14	Gălăşeni (7)	394	Northern border	2.357	33	t.i.
15	Viduţa II (118)	370	Vida basin	2.032	41	p.i.
16	Bătrinului	574	Zece Hotare plat.	1.633	78	t.i.
17	PV_2, Vălău mine [3]	375	Roşia basin	1.224	120	
18	Peştera cu Apă de la Bulz	370	Iad basin	1.177	64	p.o.
19	Moanei	485	Mişid basin	1.170	104	p.o.
20	Ciur Izbuc (183)	515	Runcuri pllteau	1.030	20	f
21	Peştera de la Vadu Crişului	305	Northern border	1.000	25	p.o.

[1] After Goran (1981) and Matoş (1982—1988);
[2] In brackets number of cave on hydrogeological map;
[3] Cave intercepted by mine gallery.
H = Altitude of cave entrance; L = Length of cave passages; D = Difference in level; HR = Hydrologic regime of cave entrance: f — fossil, p.i. — permanent inflow, t.i. — temporary inflow, p.o. — permanent outflow.
Note: All mentioned caves have stream water.

Table 2

THE MAIN POTHOLES OF PĂDUREA CRAIULUI MOUNTAINS [1)]

No	Pothole [2)]	(H (m)	Location	D (m)	L (m)	HR
1	Stanul Foncii (198)	600	Cutilor basin	339	4106	a
2	Pobraz (74)	830	Iad basin	185	353	a
3	Fanea Babii (209)	540	Lazuri basin	131	173	f
4	Big pothole from Gugu mine	625	Mniera basin	120	170	a
5	Sohodol II (189)	545	Roşia basin	102	250	a
6	Paşcalău Mihai (39)	765	Damiş area	100	180	f
7	Berna (30)	585	Damiş area	98	697	a
8	Condrovici	550	Zece Hotare area	85	105	f
9	Oneştilor (207)	525	Lazuri basin	82	153	a
10	Ciungii Scoci	870	Iad basin	67	144	f
11	Măgura Dosului	705	Damiş area	61	61	a
12	Groapa Sturzului (31)	610	Damiş area	55	85	f

1) After Goran (1981) and Matoş (1982–1988);
2) In brackets number of pothole on hydrogeological map;
HR = Hydrologic regime of cavity: a — active; f — fossil.

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 sq.km; 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 and dolomites, subsequently covered by the detritic deposits of the Eojurassic transgression It is well known in the Suncuiuş 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 hydrometeorological conditions were highly suitable for-karst formation.

5. GEOLOGIC SETTING

The Pădurea Craiului Mountains are mostly formed of deposits belonging to the Bihor Autochton. Deposits ascribed to the Codru Nappes (the Vălani, Ferice and Arieşeni nappes), as well as eruptive rocks of the Vlădeasa banatitic massif can also be found on small areas on the southern and south-eastern sides.

The sedimentary formations of the Bihor Autochton outline a vast monocline with a crystalline basement in the East and South-East, covered, towards the North-West newer and newer formations, to the Eocretaceaous depositions in the Băile 1 Mai area, in the vicinity of Oradea. Towards the North-East and South-West the geologic structure of the Pădurea Craiului Mountains sinks under the Neogene deposits of the Vad and Beiuş depressions.

The sedimentary cover of the Autochthon boast a German-type, slightly folded structure, with numerous vertical or slightly inclined faults that generated five sections that dip in steps towars the West (The hydrogeological map – the Structural sketch B, according to Patrulius in Ianovici et al., 1976).

The Vîrciorog zone, which is the westernmost, is formed of Cretaceaous and Jurassic deposits. The fall of this zone protected the Permian deposits of the Arieşeni Nappe, located to its south, from erosion. In the central area, the respective section is affected by faults facing the East-West, which divide it into blocks going down to the South.

East of the Vîrciorog zone, the higher Zece Hotare compartment is formed of Upper Jurassic deposits that make up two brachianticlines (the Butan and the Crucea Hill). It boast numerous faults and it is separated from the first section by the Mnierii fault and from the following compartment, the Cărmăzan horst, by a system of faults that develops South of the Izbîndiş spring.

The Cărmăzan horst is shape and boast a synclical structure which is rendered more complicate by an axial uplift and by a large number of faults.

The area of the Antithetic Steps zone Lorău – Damiş – Roşia is mostly formed of Triassic deposits, grouped in a number of blocks that successively dip towards the North-West along some fractures. The Remeţi graben, which is in direct contact with the eruptive massif of Vlădeasa, is situated South of the aforesaid section. The Mesozoic formations of that section make up an east-westwards anticline.

The microtectonic measurements made throughout the entire areal of the Pădurea Craiului Mountains showed there were two major systems of fissures, which affect the carbonate deposits. They face the North West — South East and North East — South West, and they have deep-going implications for the underground karst drainage.

5.1. CARBONATE SERIES

Three large carbonate series of special hydrogeological importance distinguish themselves in the succession of sedimentary formations of the Bihor Autochthon, a succession which is outlined in detail on the enclosed hydrogeological map.

— the Triassic carbonate series, which is up to 1,500 m thick, is formed of Anisian limestones and dolomites and Ladinian limestones and is underlain by a Permo-Werfenian detritic series;

— the Jurassic carbonate series, which is 150—200 m thick on an average, is formed of Middle and Upper Jurassic limestones and is separated from the Triassic carbonate series by a Lower Jurassic detritic formation which has a maximum thickness of 70 m;

— the Cretaceous carbonate series, which is discordantly located over the aforesaid carbonate series and formed of two packages of Lower Neocomian-Aptian limestones, each 50—350 m thick, separated by a monotonous succession of gray marls, 100—700 m in thickness (the Ecleje layers) and covered by an Aptian-Albian, predominantly detritic, complex.

The carbonate deposits of the Bihor Autochthon crop out along 304 sq.kms — of which 29 sq.kms develop in the Remeţi graben.

After the Mediterranean diatrophism that underlaid the location of the Codru Nappes, the sedimentation of Cretaceous deposits in the Pădurea Craiului Mountains continued with the deposition of Senonian, predominantly detritic. They crop out in the Roşia depression, in the Remeţi graben, as well as in several other points that were spared the effects of erosion.

The formation ascribed to the Codru Nappes in the Pădurea Craiului Mountains develops on narrow sites, which also limits the spread of carbonate deposits (17 sq. kms in the Vălani Nappe, 9 sq. kms in the Ferice Nappe and 0.2 sq. kms in Arieşeni Nappe).

In the south-western part of the massif, Sarmatian gravels, sands and sandstones with volcanic-clastic streaks, crop out transgressively over older deposits, while in the north-western part the outcrop is formed of marls and clays, with Volhynian limestone and sandstone streaks, as well as sands, gravels, sandy marls and Pannonian clayey sands.

The Quaternary formations in the Pădurea Craiului Mountains are represented by periglacial and deluvial-karst deposits, alluvial deposits (terraces and meadows), proluvial deposits and Pleistocene and Holocene diluviums (gravels, dejection cones). Of all these deposits, the blocks at Oarzăna make the characteristics feature of the area at issue. They are formed of large blocks of Werfenian quartzitic conglomerates, located on the summits of the relief, which have been spared the effects of erosion. They reach a maximum thickness in the Oarzăna Hill, south-west of Cornet, and are also to be found in the ridges between the Surducel-Vida and Vida-Albioara valleys.

6. CLIMATE AND SURFACE WATERS RUNOFF

6.1. CLIMATIC FEATURES

The Pădurea Craiului Mountains are situated on the western side of the sector of moderate continental climate, in an area where the average solar radiation stands at 100 cal/sq.cm.

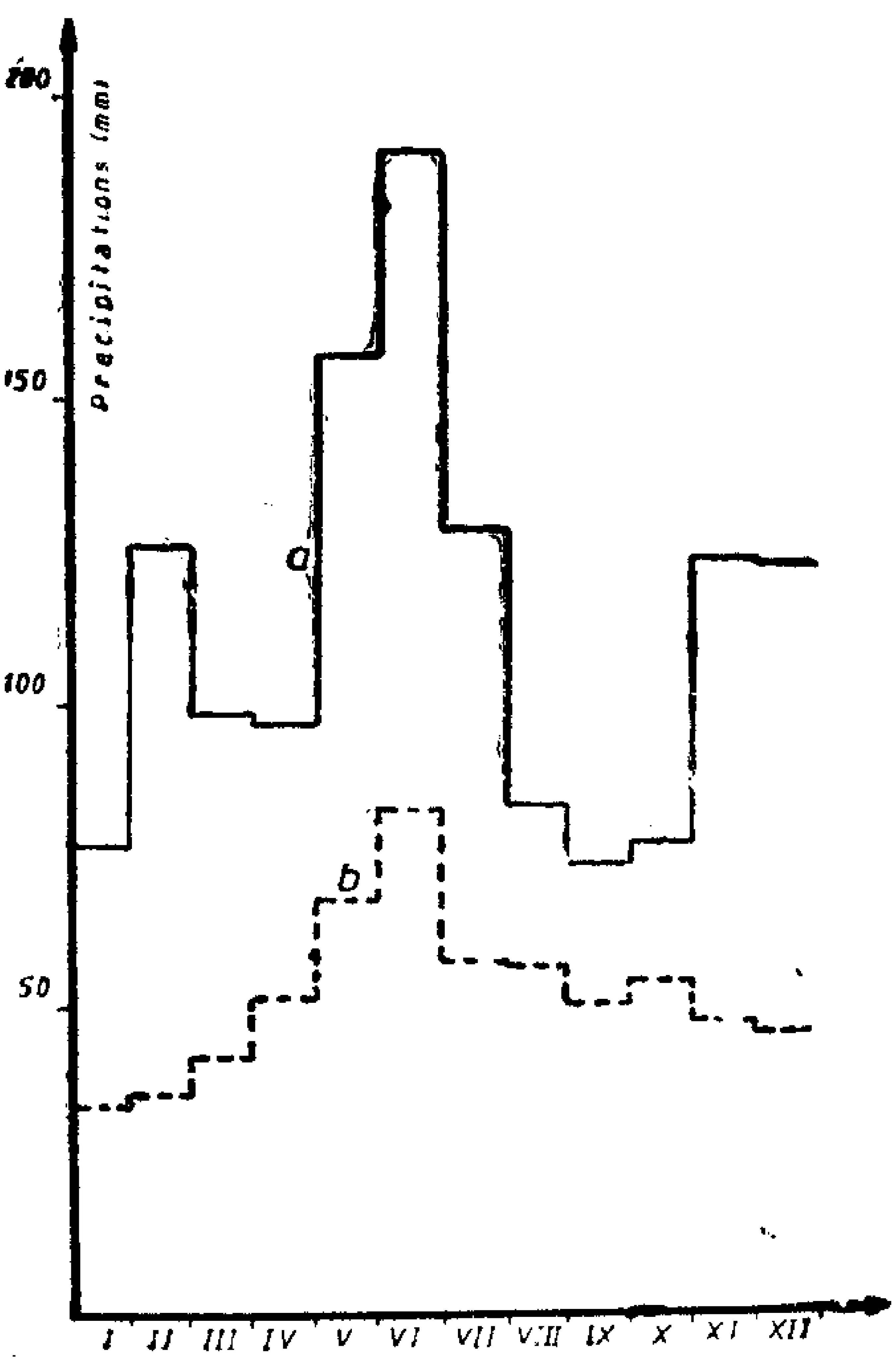

Fig. 2 — Mean monthly rainfalls distributions in Stîna de Vale (a) and Oradea (b) in 1886—1915 and 1921—1955 time intervals.

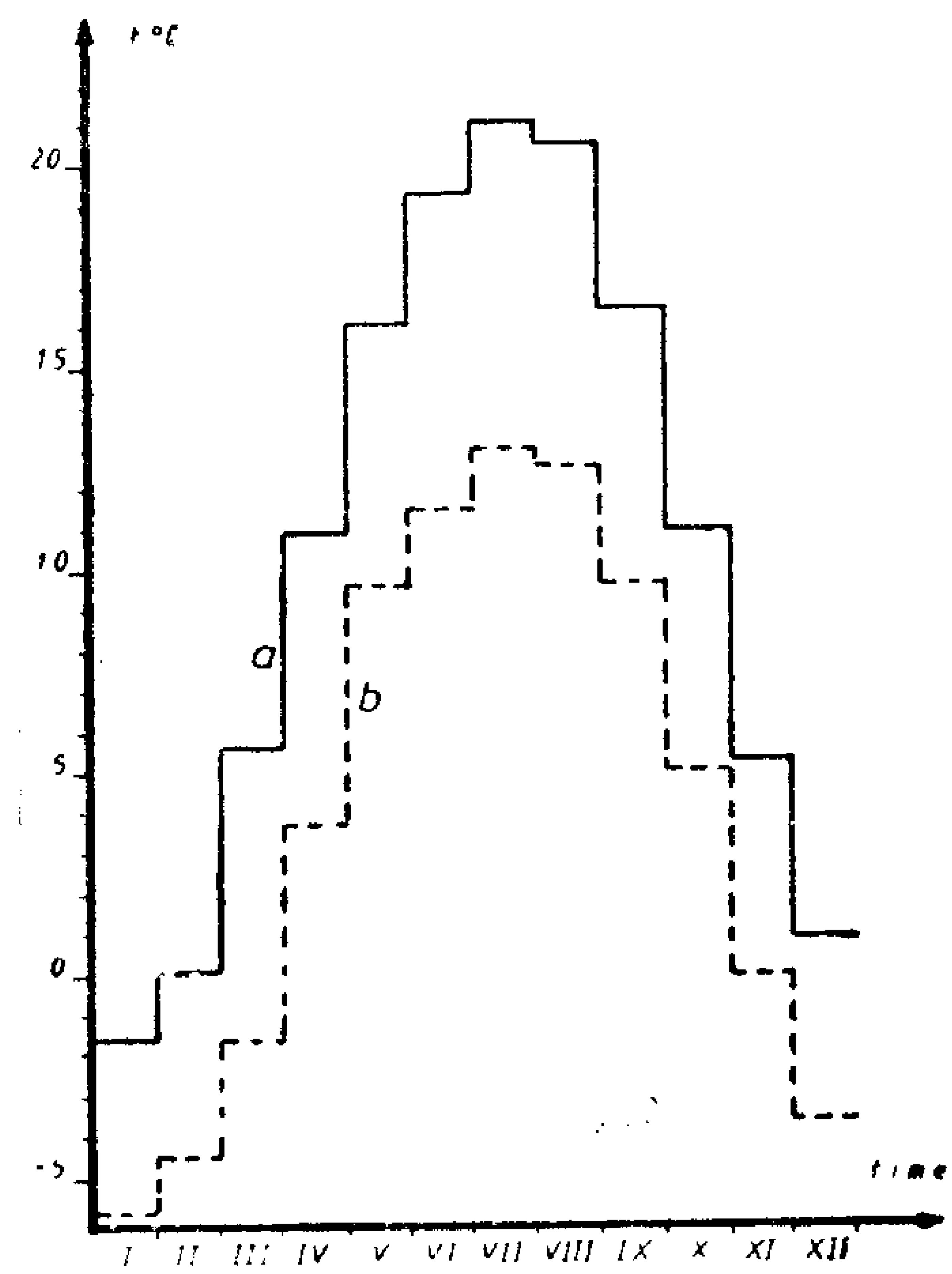

Fig. 3 — Mean monthly temperatures distributions in Oradea (a) and Stîna de Vale (b) in 1896—1955 time interval.

The amount of annual precipitations decreases from the eastern to the weatern side of the massif, its average multiannual values ranging from 800 to 1,200 mm. January values oscillate between 60 and 80 mm, and Jully values range from 80 to 140 mm. Figure 2 shows the monthly multiannual variation of precipitations recorded at Oradea and Stîna de Vale, two extreme points inbetween which the area under investigation is situated. The average multiannual values registered at the two monitoring stations tood at 635.0 and 1,364.0 mm. Precipitation in the Pădurea Craiului Mountains over X.1982—IX.1983 ranged from 712.6 mm at Vîrciorcg, to 843.7 mm at Zece Hotare and 1,390.5 mm at Remeţi.

Temperature variations are inversely proportional to precipitation, increasing from the East to the West. Mean multiannual values range from 4 to 8 degrees centigrade, with the mean temperatures of January standing at — 3 to — 6°C, and those of July amounting to 14—16°C (Figure 3).

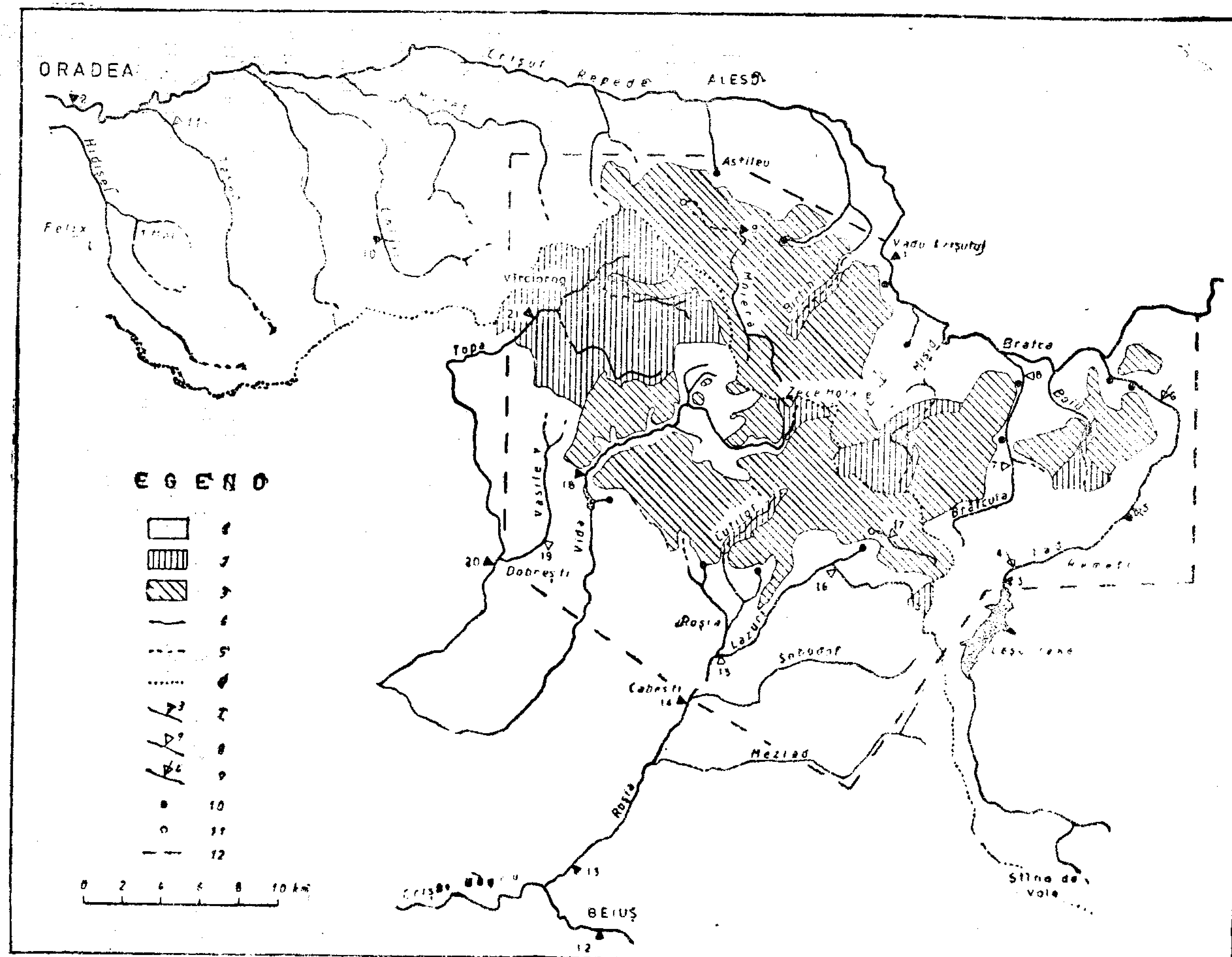

Fig. 4. — Distribution of main endorheic areas and diffluence surfaces and location of gauging sections in the Pădurea Craiului Mountains. 1 — Exorheic area ; 2 — Diffluence surface ; 3 — Endorheic area ; 4 — Permanent surface course ; 5 — Temporary surface course ; 6 — Watershed between Crişul Repede and Crişul Negru rivers ; 7 — Gauging sections in national hydrometric network ; 8 — Gauging sections in X.1982-IX.1983 time interval 3-number of section in table 3 ; 9 — Gauging section in 1950–1974 time interval ; 10 — Main spring ; 11 — Ponor ; 12 — Limit of hydrogeological map.

The values of evapotranspiration increase from the East to the West. In the hydrologic year X.1982—IX.1983 these values ranged from 540.4 mm at Zece Hotare to 695.8 mm at Oradea.

6.2. SURFACE WATERS RUNOFF FEATURES.

The karst-capture processes of the surface hydrographic network led to the creation of a vast endorheic area, which extends on 224 sq. kms. (Figure 4). The water resulting from precipitations, after the elimination of the evapotranspiration fraction, which flows over this area, infiltrates totally and reapears to the surface through the peripheral sources situated in the exoreic area of Pădurea Craiului Mountains.

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

Alongside endorheic zones, diffluence surfaces, resulting from basin karst diffluence processes, represent another element of broad development and major importance in the distribution of surface flow. According to those processes, the available water of a hydrographic basin, in the wake of partial capture, is distributed as an infiltrated fraction, which is taken outside that hydrographic basin through underground drainage and as another fraction, which continues its permanent or temporary surface flow, downstream of the capture area (Orăşeanu, 1985).

Diffluence surfaces extend on 94 sq. kms.[3)], and their presence poses difficult problems when a hydrogeological balance is to be worked out, more particularly, as an outcome of the need to create a dense hydrometric monitoring network to characterize the relationship between infiltration and outlets from every diffluence surface.

With the view to assessing runoff, a number of hydrometric observations and measurements were performed in the hydrologic year X.1982—IX.1983 on a number of surface courses situated at various altitudes and in geologic underlayer (Figure 4). Table 3 shows the discharges for the respective period, as well as the values registered at the permanent hydrometric stations in the national network.

Hydrometric measurements were made also 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[5)], function of altitude. The results obtained (Table 3 and Figure 5) bespeak a fine correlation between the two parameters and indicate a value of 3.3 l/sec. sq.kms 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 5 and knowing the mean altitude of the hydrographic basins whose runoff is infuluened by the

[3)] In this cummulated surfaces it is not included the diffluence area Miniera valley—Moara Jurjii spring. This area is situated in the north of the endorheic area of the Pădurea Craiului Mountains, on the medium and upper course of the Miniera broux, upsteem of Călățea, and has a surface of about 13 km^2.

Table 3

MORPHOMETRIC AND HYDROLOGIC DATA OF RIVERS

No. [1]	River	Gauging station	h [2] m	H [3] m	F [4] sq · kms	Period of data recorder	Q_{mean} cu. m/s	Q_{max} cu. m/s	Q_{min} cu. m/s	q [5] l/s sq · kms	q_a [6] l/s sq · kms
1	Crişul Repede	Vadu Crişului	280.0	821.0	1325.0	1950–1974	20.400			15.4	
	Crişul Repede	Vadu Crişului	280.0	821.0	1325.0	X.1982–IX.1983	15.600	89.600	3.000	11.8	
2	Crişul Repede	Oradea	118.69		2126.0	1950–1974	24.200			11.4	
3	Iad	downstream Remeţi dam	425.00	979.0	101.0	X.1982–IX.1983	2.660	13.600	0.067	26.3	
4	Iad	Leşu				1950–1974	2.820			28.0	
5	Iad	Remeţi		914.0	163.0	1950–1974	3.970			24.4	
6	Iad	Bulz		849.0	223.0	1950–1974	5.060			22.7	
7	Brătcuţa	Upstream Rusu valey	435.0	771.0	15.0	X.1982–IX.1983	0.311	6.360	0.058	20.8	
8	Brătcuţa	Downstream Brătcani spring	335.0			X.1982–IX.1983	0.725	5.320	0.260		
9	Mniera	Călăţea	371.94			1950–1974	0.280				
	Mniera	Călăţea	371.94			X.1982–IX.1983	0.170	4.060	0.003		
10	Chijic	Copăcel	195.0	289.0	36.5	X.1982–IX.1983	0.162		0.007	4.4	
11	Tăşad	Oşorhei		190.0	52.3	X.1982–IX.1983	0.096			1.8	
12	Crişul Negru	Beiuş	176.84	551.0	792.0	1950–1967	3.100			16.6	
13	Roşia	Pocola	166.92	(427.0)	(267.0)	1950–1967	3.400			(12.7)	
	Roşia	Pocola	166.92	(427.0)	(267.0)	X.1982–IX.1983	2.710	59.200	0.431	(10.1)	
14	Roşia	Căbeşti	212.0	(584.0)	(155.0)	X.1982–IX.1983	1.570	38.800	0.303	(10.1)	
15	Lazuri	Între Râuri	305.0	599.0	47.0	X.1982–IX.1983	0.657			14.0	14.5
16	Soimuşuri	Upstream Toplicicara	372.0	685.0	16.5	X.1982–IX.1983	0.236			14.3	16.8
17	Runcşor	Moara Daruiui	600.0	750.0	6.8	X.1982–IX.1983	0.138			20.2	
18	Vida	Upstream Luncasprie	215.0	508.0	55.5	X.1982–IX.1983	0.624	16.100	0.085	11.2	12.0
19	Valea lui Vasile	Dobreşti	165.0		14.25	X.1982–IX.1983	0.075			5.3	
20	Topa	Hidişel	143.3	376.0	155.0	1950–1967	1.030			6.6	
21	Topa	Vîrciorog	275.0	474.0	72.5	1950–1966	0.494			6.8	
	Topa	Vîrciorog	275.0	474.0	72.5	X.1982–IX.1983	0.322	15.500	0.004	4.4	11.0

[1] Number of gauging section in figure 4;
[2] Altitude of gauging section;
[3] Mean altitude of watershed;
[4] Surface of wathersed;
[5] Measured specific annual mean discharge;
[6] Available specific annual mean discharge

Note: The values of H, F and Q in brackets are aproximate.

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.

Here are the main courses in the Pădurea Craiului Mountains which feature particular aspects in the distribution of runoff.

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 kms long and boast a reception basin of 17.5 sq.kms, which develops in the endorheic zone of the massif, primarily between the karst plateaus of Igreţ and Zece Hotare, which is why it is particulary difficult to assess the area of the hydrogeologic basin. The numerous springs in the upper course on the right-hand bank beaspek an extention of the basin to the terrains covered by the Zece Hotare plateau.

The discharge measurements conducted in different sections of the Mniera brook indicate the presence of a massive infiltration area in the valley thalweg in the Cornet area (Figure 6). According to the labellings performed, the infiltrated waters are guided towards the spring at Moara Jurjii. Figure 6 also shows a powerful rise in the slope of the brook inbetween Filip's Spring and the Cornet, which is an outcome of the successive karstic capture of the brook in the Saua Gurguiatu-Potriva Cave zone, accompanied by its erosive action to attain a new equilibrium profile. The major hydrologic effect of the karstic capture was the interruption of the flow of the Mniera brook waters towards the Beiuş basin and their underground direction towards the Vad basin.

The hydrometric station at Călăţea, located on the lower course of the Mniera brook, registered an mean multiannual discharge of 280 l/sec in the 1957–1974 interval (Figure 7), the mean seasonal flow being distributed, in terms of percentages, as follows: 31.6 per cent in spring, 17.7 per cent in summer, 16.3 per cent in automn, 34.4 per cent in winter. Runoff at the Călăţea hydrometric station stopped in the droughty periods of a prolonged autumn.

The Topa brook collects the waters in the western part of the Pădurea Craiului Mountains, from an area extending on 143 sq.kms, as was assessed at the Hidişel hydromettic station. The processing of the hydrometric data suplied by the hydrometric station at Vîrciorog, which hydrometrically controls the upper basin of the Topa brook, whose area is of 72.5 sq.kms, indicates a high runoff deficit (6.6 l/sec sq.kms for the hydrologic year X.1982–IX.1983), owing to the karst capture in the basin of the Poiana and Surducel tributaries, captures which direct surface waters to the underground towards the spring at Aştileu. Substantial water infiltrations in the carbonate rocks are also registered in the thalweg of the Topa valley between the confluences with the Copil valley and the Măgura valley, a sector that is completely dry during droughty periods.

The diffluence surface in the upper basin of the Topa brook, which is situated upstream of the confluence with the Măgurii brook, extends on 66 sq.kms, an area which contributes roughly 60 per cent of its available water to the supply of underground aquifers (478 l/sec in the hydrologic year X.1982–IX.1983), an amount only partially found in the discharge

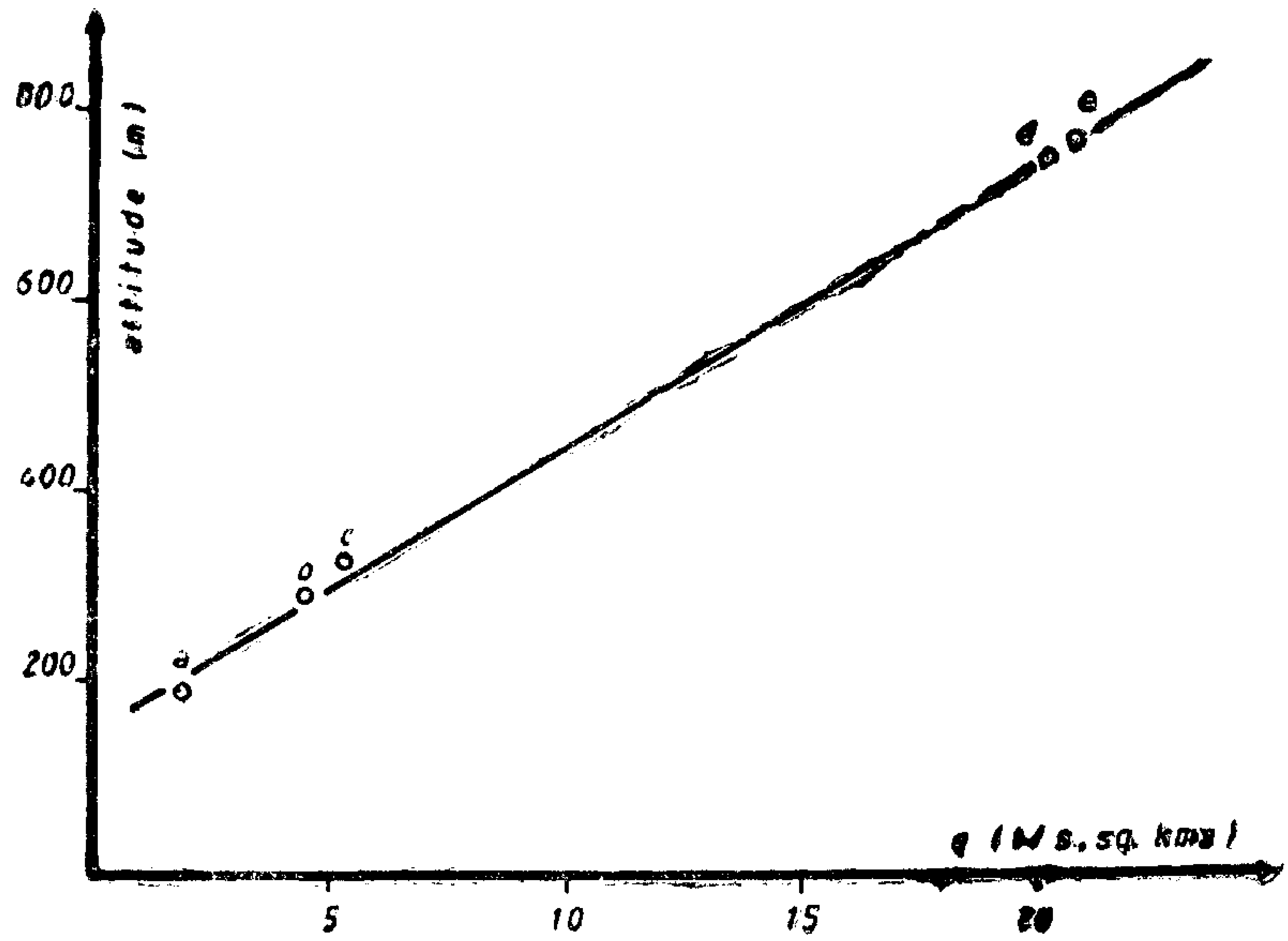

Figure 5 — The relation between the specific annual mean discharge and the mean altitude of hydrographic basins in X.1982—IX.1983 time interval : a — Tăşad brook at Oşorhei gauging section (g.s.) ; b — Chijic brook at Copăcel g.s. ; c — Valea lui Vasile brook at Dobreşti g.s. ; d — Runcşor brook at Moara Darului g.s. ; e — Brătcuţa brook upstream Rusu brook g.s.

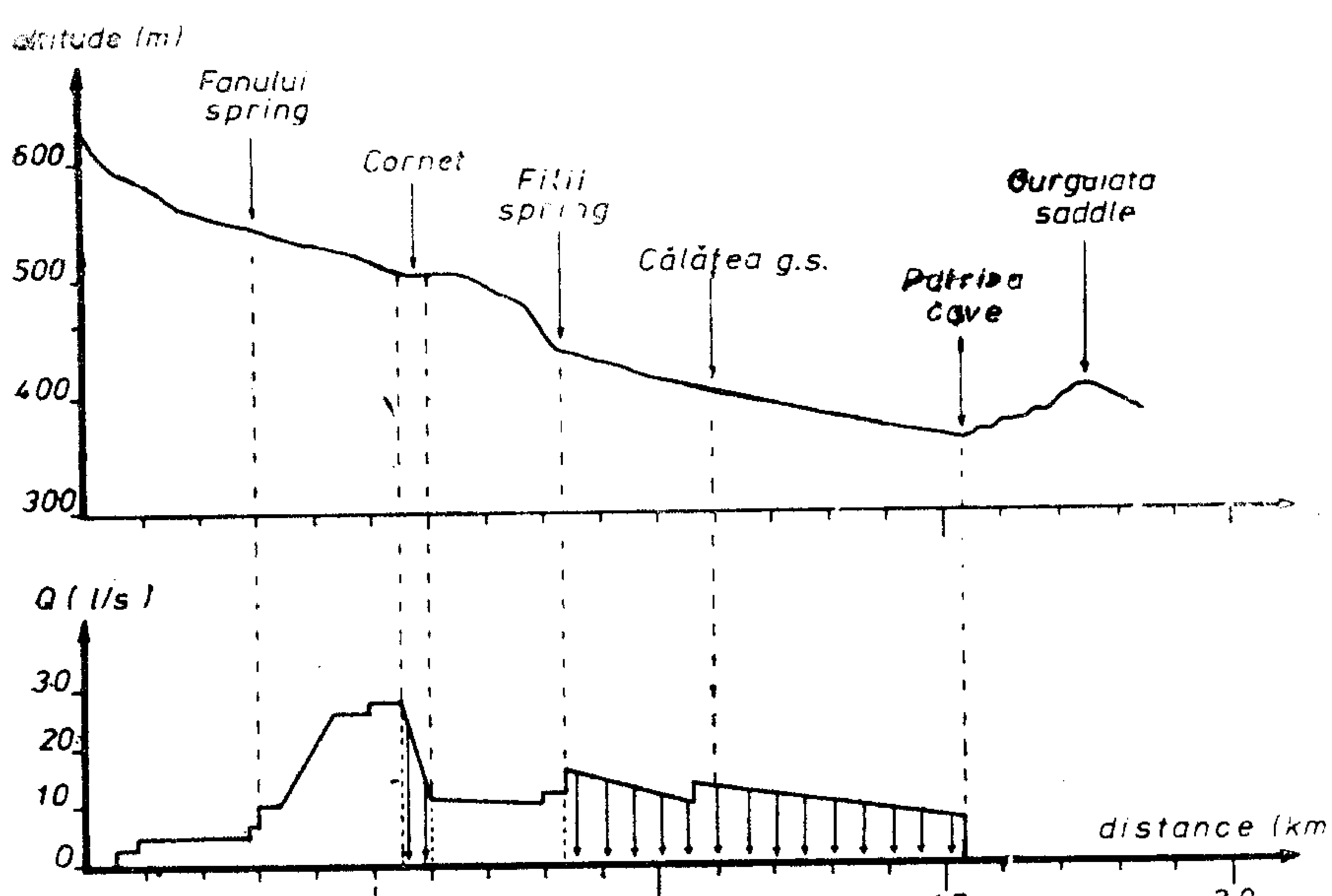

Figure 6 — Long profile of Mniera brook and variation of flow along the riverbed at 26.X.1982.

of the spring at Aştileu). Figure 8 shows the monthly variation of the specific annual mean runoff of the brook at the hydrometric station at Vîrciorog.

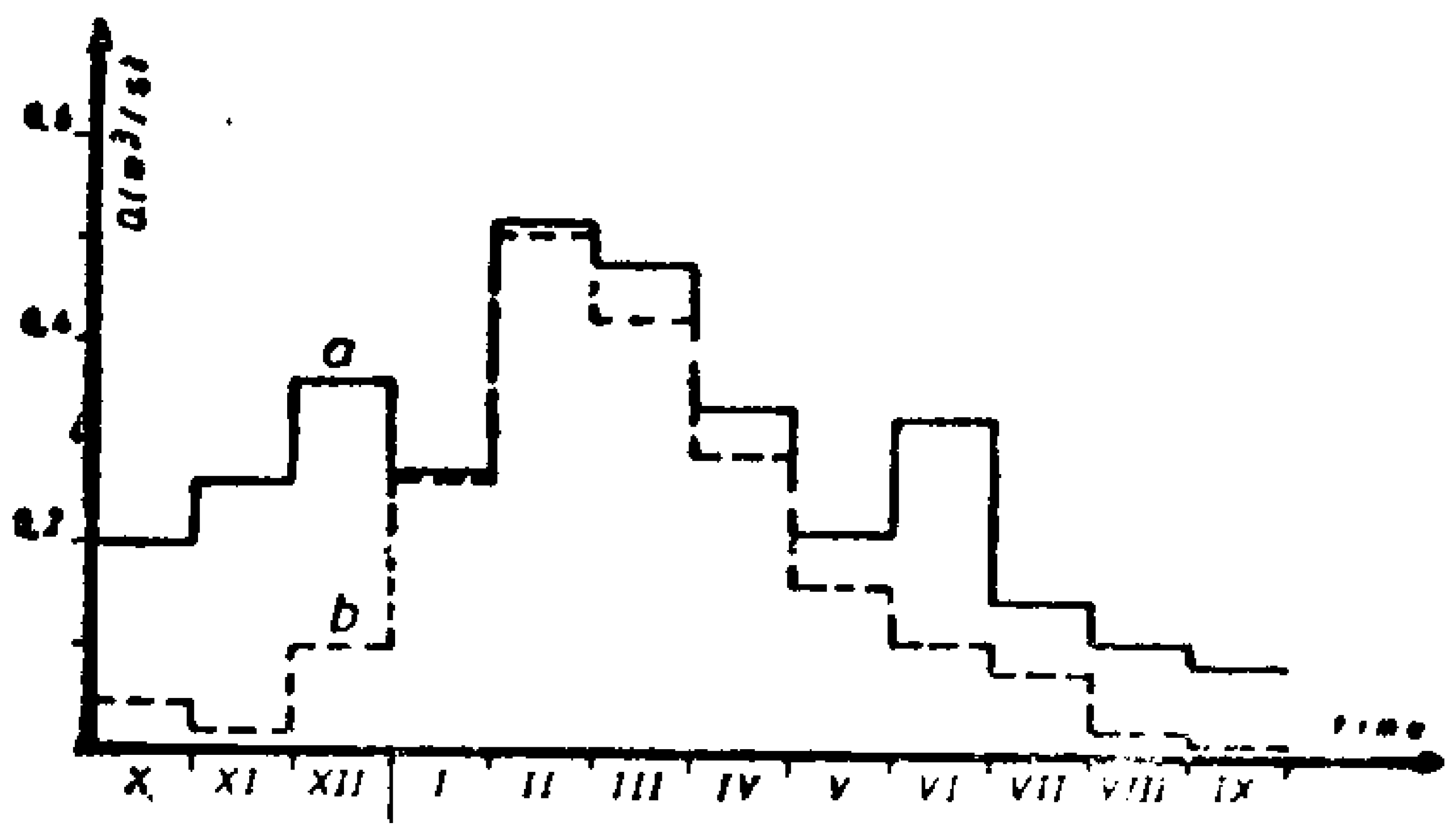

Figure 7 — Mean monthly discharge distribution of Mniera brook in Călăţea gauging station in 1957—1974 (a) and X.1982—IX.1983 (b) time intervals.

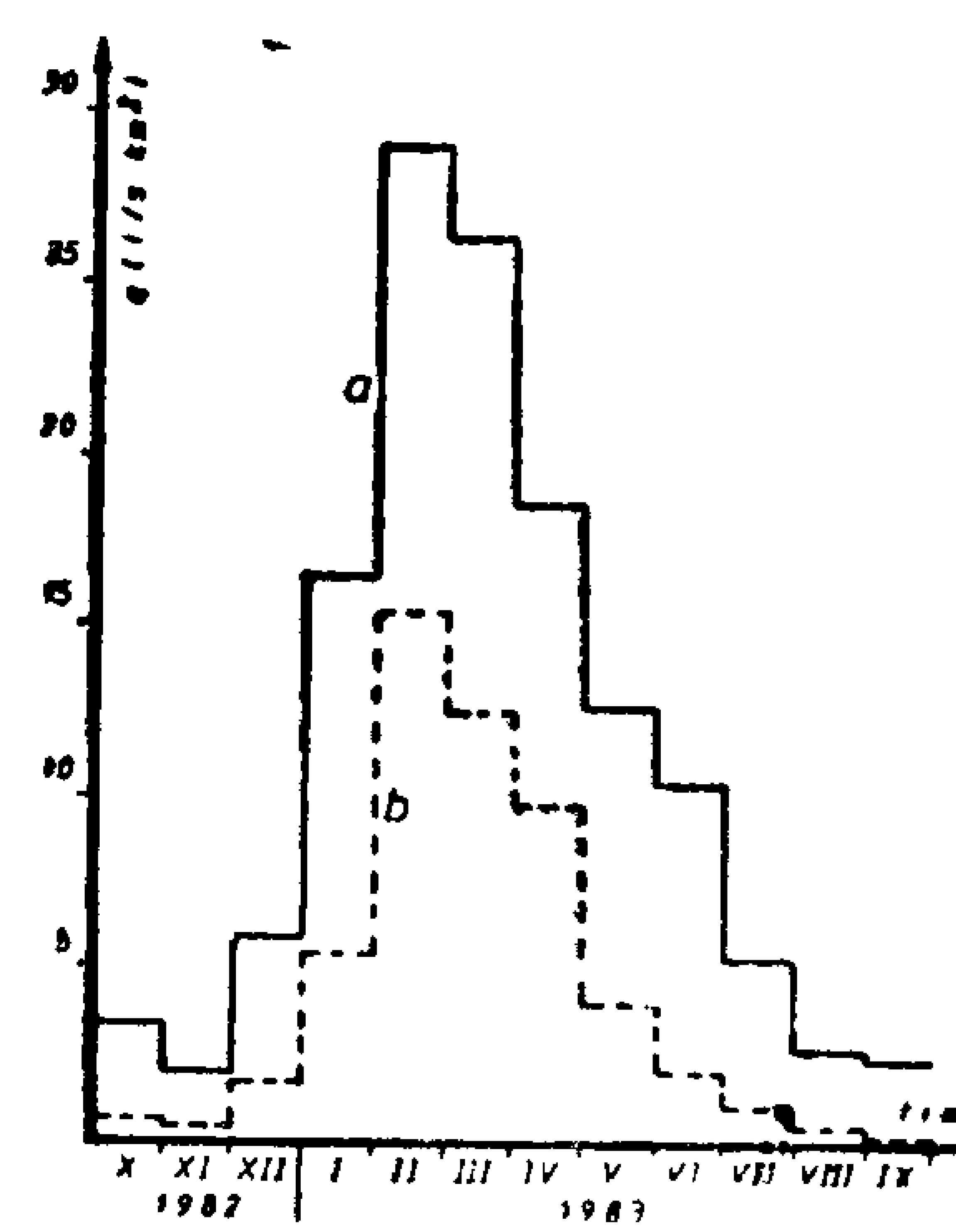

Figure 8 — Mean monthly discharge distribution of Vida brook in Luncasprie gauging station (a) and (b) and of Topa brook in Vîrciorog gauging station (b), in X.1982—IX.1983 hydrologic year.

The Vida brook is 21.5 km long and has a reception basin extending on 28 sq. kms and a hydrogeologic basin stretching on roughly 55.5 sq. kms, to the Luncasprie station, a device located upstream of Vida lake. The hydrometric data registered by that station do not indicate the presence of wide-scope hydrologic relationships with neighbouring basins. Figure 8 shows the monthly variation of the mean specific discharge.

Permanent water losses through the thalweg are recorded in the upper section of the Vida brook, situated upstream of Peştera cu Apă cave in the Letea valley. During periods of drought these losses amount to 10—15 l/sec, downstream of the Apa de sub Stan spring. We belive the infiltrated waters are drained towards the Izbîndiş spring, thus generating a diffluence surface extending on roughly 2.5 sq. kms.

The Mişid brook, in its upper course known as the Luncilor valley, shows partial flow losses in the section situated upstream of the Filii spring and total temporary losses in the section inbetween the Moanei cave and the confluence with the Bocoi brook. Tracer labellings show that the infiltrated waters were caught by the Brăteani spring, a diffluence surface extending on 12.5 sq.kms thus distinguishing itself. Downstream of the confluence with the Sesii brook, the Mişid brook boast a temporary flow regime, as a probable outcome of its drainage by the underground course in the Peştera Vîntului cave.

Karstic capture phenomena also occur in the case of the Boiu brook, a tributary of the Crişul Repede river. Upper-course infiltration generate a 5 sq. kms diffluence area. The fact is noteworthy that the underground course in the Sîncuta cave belonging to the hydrogeological karst system of the Peştera cu Apă de la Bulz cave, runs below the surface flow of the Boiu brook.

The Cuţilor Valley, a tributary of the Roşia brook, boast a temporary flow regime on the lower section, in between the spring of Cioroiul Vilii and Cioroiul, the massive infiltrations being directed underground towards the Topliţa de Roşia spring. In this way, a diffluence surface extending on 4 sq. kms o. s. is formed.

In the upstream sector formed of Anisian and Ladinian dolomites and limestones, structuraly belonging to the Remeţi graben, the Soimuşul Drept features total temporary infiltrations through the alluvia in the bed. The infiltrated water reappear in the Firez spring and in the permanent source below Peştera cu Apă din valea Leşului cave, sources situated in the Iad Valley basin. The diffluence surface area extends on roughly 1.5 sq. kms.

The value of the infiltrated specific annual mean discharge is of 2.5 l/s sq. kms (Table 3) in the Soimuşuri brook basin, which lies upstream of the confluence with the Toplicioara brook, in X.1982–IX.1983 hydrologic year. Infiltrations occur both in the previously mentioned diffluence area and in the basin of the Valea Seacă tributary and on the section of the Soimuşuri brook situated immediately downstream. Infiltrations are probably directed towards the Izbuneală spring in the Schodol brook basin.

The water of the Birtin brook, immediately downstream of the spring area under the Crucea Hill, infiltrate diffusely in the carbonate underlayer, the distance they manage to cover the epigene route being directly proportional to the volume of precipitations. The infiltrated waters probably contribute to the supply of the Vadu Crişului resurgence cave. The diffluence surface extends on 2.5 sq. kms o. s.

7. A HYDROGEOLOGIC CHARACTERIZATION OF THE PĂDUREA CRAIULUI MOUNTAINS

Owing to the great lithologic variety and the different tectonization degree of the deposits making up the lithologic structure of the Pădurea Craiului Mountains, five types of formations, boasting different modes of supply, circulation, storage and discharge of groundwater, were hydrogeologically individualized:

7.1. Carbonate mesozoic series (limestones, dolomites) of large thickness, highly fractured and karstified, exhibiting large infiltration capacity and storage groundwater flow. Numerous springs with flow rate up to 500 l/sec, and elevated variability index. Important resources stored below the discharge level of the spring.

7.2. Detritic deposits of Volhynian-Quaternary age (sands, gravels, boulders, shales), with reduced thickness and extension, hosting important groundwater pores-flow. They store limited aquifer accumulation, generally with water table. Local importance.

7.3. Mostly detritic deposits of Permo-Mesozoic age (sandstones, conglomerates and less frequently shists), with permeability of fisures and pores with discontinuous distribution and development. The groundwater flow is mostly confined to the fissured areas, which may supply springs with flow rate up to 5 l/sec. They frequently act as the bed and/or the essentialy impervious caprock for aquifer accumulations occuring in the adjoining carbonate deposits.

7.4. Subsequent alpine magmatites (banatites) and metamorphites, with permeability of figures with discontinous distribution and intensity. The groundwater flow confined to the weathered surficial strata and to the fractured areas, supply springs with reduced flow rate (up to 1 l/sec.).

7.5. Marly and shaly deposits, devoid of groundwater flow and flysch-like series including rock-complexes of variable permeability (shales, shistes, marls, sandstones, limestones), hosting occasionnary discontinuous aquifers accumulations occuring in the more permeable terms.

The attached hydrogeological map shows these five types of formations, as well as their detailed lithologic structure.

8. THE HYDROGEOLOGY OF KARSTIC TERRAINS

The karstic aquiferous accumulations in the Pădurea Craiului Mountains are relatively scattered and of variable expanses, as prompted by the development of karstic terrains. They make up a gigantic aquiferous complex, lithologicaly constituted by the three aforesaid carbonate series (Triassic, Jurassic-Cretaceous and Cretaceous), separated by two impermeable streaks (Eojurassic quartzitic sandstones an Aptian Ecleja marls). On a regional scale, due to the intense cracking, consequence of the tectonic action on the rock-massif, the water-bodies from the above-mentioned carbonate series are interconnected. Yet on restricted areas these carbonate series may include isolated aquiferes, thus allowing distinction between triassic, jurassic-cretaceous and cretaceous aquifer-complexes.

On its entire expanse, the impermeable bed of the aquiferous complex is chiefly made up of Permo-Werfenian detritic deposits. They cropout on the eastern side of the Pădurea Craiului Mountains and slowly sink to the West, together with the structure as a whole. The sinking is broken by numerous, prevailingly inverse,vertical faults of relatively low heights, which are not enought to bring the impermeable bed above ground.

Aquiferous accumulations are located in the channels and fissures of the carbonate rocks and they are supplied both by the precipitations that fall on the outcropping area of limestones and dolomites, and by surface flows developing on the non-karstic terrains in the vicinity. Entering the karstic terrains, the water of the epigene flows penetrates into the underground in a concentrated manner (ponors or inflow caves) or diffusely (either totally or partially) through alluvia in karstic-catchment areas.

The aquiferous accumulations in the carbonate deposits discharge through springs that sensibly differ in point of supply, discharge and flow conditions. Most of the springs in the massif, which are called „izbucuri" on the local plane, discharge aquiferous accumulations supplied by both precipitations and ponors well-deliniated in the relief (Aştileu, Brătcani, Moara Jurjii, a.o.). Springs exclusively supplied by the diffuse infiltrations of precipitations are rare and their flow rate are low (the spring in Poiana Damiş, Fîntîna lui Onuţ. Pisnita spring, a.o.). The springs are either permanent or temporary and their dischaiges directly depend on precipitations.

In broad lines, the springs on the northern flank of the Pădurea Craiului Mountains are gravitational (Aştileu, Vadu Crişului, Brăteani, a.o.) and those at the foot of the southern slope are lithologic-contact 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 to be found on the terrains covered by the Senonian deposits of the Roşia depresion, in calcareous streaks. They develops on à limited area and do not modify the generally impermeable character of those deposits, a character lent by the broad development of marls and clays.

8.1. TRACER LABELLINGS.

So far 78 tracer labellings have been performed in the Pădurea Craiului Mountains and their technical features are given in Table 4. The average apparent velocity of these labellings stood at 46 m/h. 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.

8.2. HYDROGEOLOGICAL FEATURES OF KARSTIC SOURCES.

The outflow cave at Vadu Crişului is the only karstic source in the Pădurea Craiului Mountains included in the national hydrometric monitoring network. Measurements of this source have been conducted uninterruptedly even since 1950. Over 1957—1974, the mean discharge stood at 0.220 cu.m/sec. Figure 9 shows the annual distribution of mean monthly discharges recorded in that cave.

With a view to understand the hydrologic conditions of the major karstic sources in the Pădurea Craiului Mountains, 13 main sources were

Table

RESULTS OF TRACING OPERATIONS ON PĂDUREA

Number of drainage on the map	Insurgence (number on the map)	H(m)	Resurgence (number on the map),
1	2	3	4
1	Potriva cave	347	Aştileu spring
2	Losses of Poienii valley	390	,,
3	Peştişului valley ponor	325	,,
4	Ticlului cave (88)	373	Peştera de sub Stan cave (87)
5	Losses of Groapa Peşteranilor (97)	520	Aurica mine (100)
6	Groapa Popii ponor (105)	555	Cioroaiele Tîrcului spring (103)
7	,,	,,	Brusturi mine (104)
8	Gălăşeni cave (7)	390	Groapa Moţului spring (6)
9	Losses of Mniera valley (3)	500	Moara Jurjii spring (8)
10	Bătrînului cave	574	Vadu Crişului cave
11	Tomii valley ponor (15)	639	Izbîndiş spring
12	Ponor of Groapa Blidireşti (16)	729	,,
13	Brezului ponor (17)	645	,,
14	Olfului ponor (18)	635	,,
15	Birăului ponor (19)	600	,,
16	Losses of Recea Valley (23)	600	Spring of Poiana Frînturii (38)
17	Losses of Luncilor valley	470	Brătcanilor spring
18 *)	Mocra valley ponor (26)	583	Moanei cave
19	Ponors of Ponoraş (29)	604	Brătcanilor spring
20	Huţii valley ponor (28)	620	,,
21	Ponor of Secătura Brătcanilor (32)	485	,,
22	Toaia ponor	675	Dămişenilor spring
23	Peşteruţa ponor (44)	687	,,
24	Munău cave (42)	705	,,
25	Losses of Groapa Ritii	583	Moara Dedii spring (62)
26	Sîncuţa ponor	725	Peştera cu Apă de la Bulz cave
27	Ponorului valley ponor (57)	625	,,
28	Brădeştilor valley ponor (58)	640	,,
29	Ponor of Ses (59)	680	,,
30	Stiopului valley ponor (60)	690	,,
31	Losses of Iadului valley (67)	450	Tăul fără Fund spring (Topleţ)
32	Losses of Caprei valley (65)	662	La Izvoară spring (66)
33 *)	Losses of Dişorului valley	562	Turii cave (70)
34	Losses of Pîrîul cu Soci valley (72)	625	Springs of Lunca Pizlii (71)
35 *)	Losses of Izvorului valley (73)	600	Davelii spring
36	Losses of Rea valley (76)	662	Peştera de la Faţa Apei cave (75)
37 *)	Losses of Daica valley	625	Peştera cu Apă din Valea Daica (80)
38 *)	Losses of Strivinoasa valley (77)	562	Dumiter spring (78)
39 *)	Losses of Sălătruculni valley (82)	550	Ciuhandru spring (83)
40	Acre ponor	815	Peştera cu Apă din valea Leşului (85)
41	,,	,,	Firez spring (84)
42	Fîntînele ponor (197)	679	Topliciora spring
43	Runcşorului valley ponor (194)	570	,,
44	Hîrtopul Bonchii ponor (204)	455	Gruieţului cave (205)
45	Losses of Barc valley (192)	615	Roşia spring
46	Botului valley ponor (190)	550	,,
47	Iezere valley ponor (198)	550	,,
48	Jurcanilor cave (188)	545	,,
49	Fiului valley ponor (199)	510	,,
50	Losses of Cuţilor valley	360	Topliţa de Roşia spring

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CRAIULUI MOUNTAINS KARSTIC AREA

H(M)	L(m)	ΔH(m)	Tracer ussed	t hours	V m/hour	Date of labelling	Authors of tracing operations
5	7	8	9	10	11	12	13
250	2620	107	Fluoresceine	10	262,2	44.04.1966	T. Rusu
,,	8350	140	In-EDTA	768	11,3	15.10.1983	I. Orăşeanu et al.
,,	11550	75	,,	2040	5,6	4.06.1983	I. Orăşeanu et al.
265	900	108	Fluoresceine	45	20,2	22.07.1972	T. Rusu
475	300	45	Iod-131, NaCl	7	43,3	3.10.1980	I. Orăşeanu et al.
490	1270	65	,,	122	10,4	,,	,,
460	180	95	,,	105	1,9	,,	,,
295	1750	95	Fluoresceine	13	134,8	19.06.1969	T. Rusu
400	4350	100	Rhodamine B	24	181,3	9.12.1982	I. Orăşeanu
305	4250	269	Fluoresceine	89	47,8	16.05.1962	T. Rusu
370	5400	269	In-EDTA	768	7,0	25.05.1983	I. Orăşeanu et al.
,,	3400	359	Fluoresceine	63	54,3	23.10.1964	T. Rusu
,,	5650	275	,,	80	70,1	18.06.1970	,,
,,	5320	265	,,	73	73,0	17.08.1971	,,
,,	5100	230	,,	62	82,3	2.07.1974	,,
365	3185	295	Iod-131	260	12,3	2.10.1980	I. Orăşeanu et al.
345	4800	125	R, In-EDTA	114	42,2	19.09.1982	I. Orăşeanu et al.
485	500	98	Fluoresceine	45	11,3	8.06.1975	T. Rusu
345	4800	250	,,	35	137,3	10.10.1969	,,
,,	5700	325	,,	27	211,2	19.06.1969	,,
,,	1700	140	,,	27	63,0	7.07.1970	,,
420	3550	255	,,	90	39,5	12.07.1968	,,
,,	5060	267	Rhodamine B	96	52,8	21.05.1983	I. Orăşeanu et al.
,,	2770	285	Fluoresceine	12	230,9	6.07.1970	T. Rusu
350	1850	233	,,	168	11,1	07.1971	D. Grigorescu
370	6000	355	Rhodamine B	77	78,0	12.07.1981	I. Orăşeanu, A. Jurkiewicz
,,	2950	242	Fluoresceine	38	77,9	11.10.1966	T. Rusu
,,	3160	270	,,	29	106,9	15.05.1966	,,
,,	2750	310	,,	20	138,4	13.05.1966	,,
,,	2560	320	,,	17	150,6	11.05.1966	,,
435	600	15	,,	220	2,7	1964	E. Jekelius
540	700	122	,,	114	6,2	15.06.1972	T. Rusu
470	500	92	,,	23	21,8	18.07.1972	,,
470	700	155	,,	68	10,3	16.08.1980	,,
480	900	120	,,	78	11,6	8.07.1972	,,
480	700	182	,,	94	7,5	15.06.1972	,,
580	300	45	,,	12	25,0	9.07.1972	,,
490	500	72	,,	50	10,0	15.06.1972	,,
516	500	34	,,	25	20,0	30.10.1980	,,
650	1550	165	,,	102	15,2	14.06.1972	,,
545	2520	300	,,	185	17,0	14.06.1972	,,
430	3070	249	,,	220	~3,6	26.05.1983	I. Orăşeanu et al.
,,	950	140	,,	11	86,4	10.07.1966	T. Rusu
320	1200	135	,,	22	54,6	19.09.1970	,,
290	5700	325	In-EDTA	624	9,1	25.05.1983	I. Orăşeanu et al.
,,	5050	260	Fluoresceine	146	34,6	5.07.1966	T. Rusu
,,	3400	260	,,	350	9,7	13.06.1967	,,
,,	5110	255	Rhodamine B	168	30,4	26.05.1983	I. Orăşeanu
,,	2100	220	Fluoresceine	300	7,0	21.09.1970	T. Rusu
275	1000	85	,,	17	59,0	20.09.1970	,,

condinued *Table*

1	2	3	4
51	Tinoasa valley ponor (184)	539	,,
52 *)	Ponor of Groapa Ciurului (182)	480	,,
53 *)	Losses of Ciur Izbuc cave (183)	535	,,
54	Doboş cave (181)	467	,,
55	Albioara valley ponor (178)	430	,,
56	Marchiş ponor (153)	510	Topliţa de Vida spring
57	Fîntîna Rece ponor (156)	456	,,
58	Merişor ponor (157)	458	,,
59	Bichi ponor (161)	458	,,
60	Baia Niţului ponor (162)	458	,,
61	Poiana Prie ponor (185)	455	,,
62	Ponors of Prislop (140)	666	Groieşului spring (131)
63	Ponor of Fundătura Roşiorului (125)	640	Springs of Gura Ursului (122)
64	Ponor of Hîrtoapele Hododii (123)	620	,,
65 *)	Gropilor (Coş) valley ponor (211)	520	Meziad cave resurgence (214)
66 *)	Losses of Peşterii valley (213)	470	,
67 *)	Cave of Băroaia Bătrînă (186)	529	Downstream spring of Groieşu (130)
68	Iacoboaia ponor (136)	680	Izbîndiş spring
60	Ponor of Groapa Brăjeşti	615	Spring of Ruştiului valley
70 *)	Ponor of Tinoasa de Vida valley (126)	574	Peştera cu Apă din Valea Vida (129)
71	Perje ponor (187)	485	Roşia spring
72 *)	Ponor of Fîntîna cu Soci (171)	400	Cave of Strîmtura valley (173)
73 *)	Ponor of Cioroi (172)	390	Spring of Cailii valley (174)
74 *)	,,	,,	Cave of Strîmtura valley (173)
75	Groapa Morăreştilor ponor (213)	715	Izbuneală spring
76	Groapa Dealului ponor (214)	635	,,
77	Losses of Soimuşul Drept valley (222)	660	Spring of Peştera cu Apă din valea Leşului (85)
78	,,	,,	Firez spring (84)

H — Elevation above the mean sea level;
L — Horizontal distance between losses and spring;
ΔH — Vertical drop;
t — Time of first arrival of tracer;
V — Apparent velocity.
*) Drainage direction is not drown on the hydrogeological map.
Note : The tracing operations were performed by the author in cooperation with : E. Gaşpar, 72, 73, 74), A. Jurkiewicz, E. Gaşpar, Nicolle Orăşeanu, I. Pop (drainages no. 17, 56, T. Rusu (drainage no. 61).

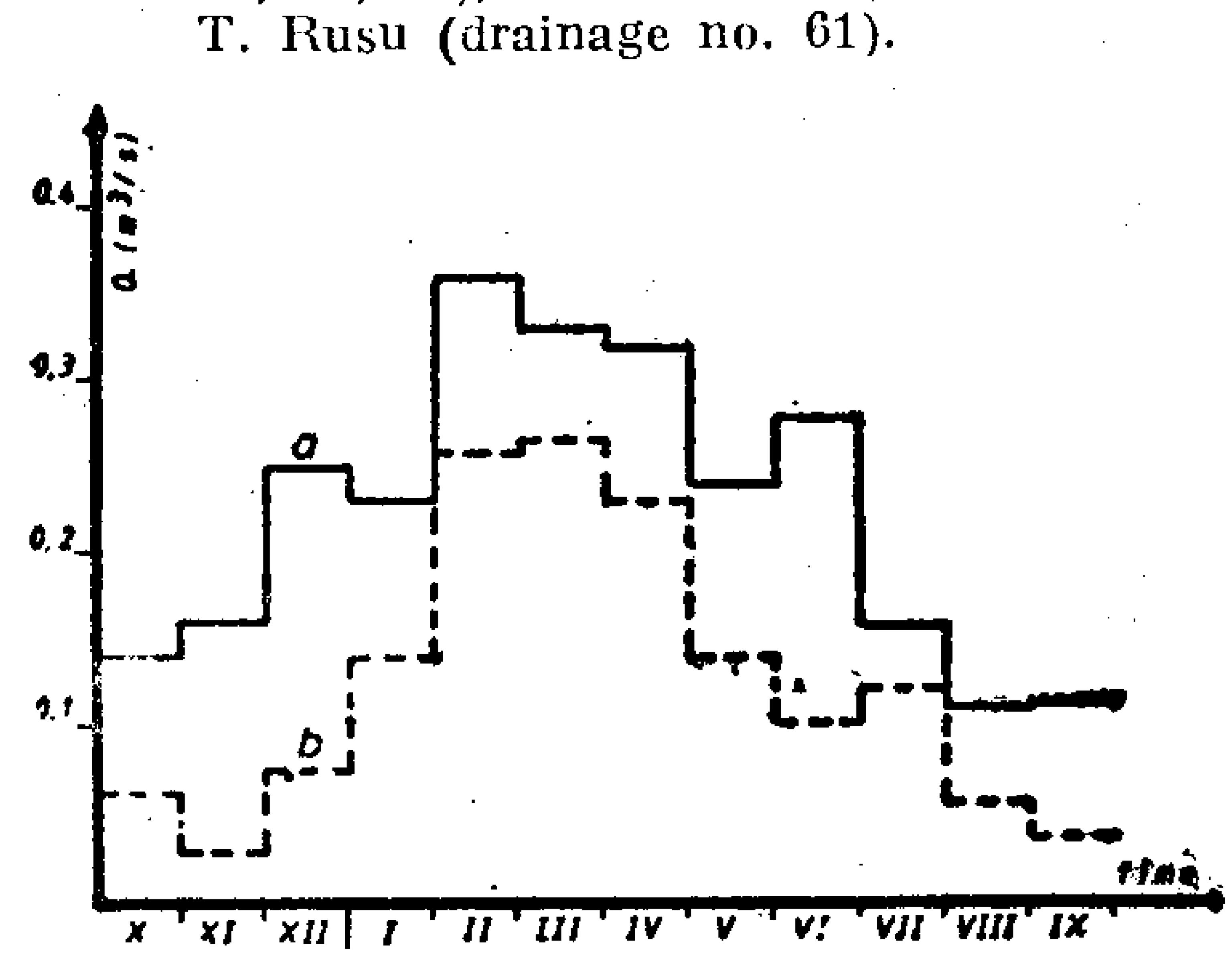

Figure 9 — Mean monthly discharge distribution of Peştera de la Vadu Crişului cave in 1957—1974 (a) and X.1982—IX.1983 (b) time intervals.

4

5	6	7	8	9	10	11	12
,,	3000	264	,,	78	38,5	4.05.1968	,,
,,	2400	205	,,	93	25,8	5.07.1968	,,
,,	2800	260	,,	70	40,0	4.05.1968	,,
,,	1600	192	Rhoadmine B	22	72,8	4.08.1981	I. Crășeanu, A. Jurkiewicz
,,	2500	155	Fluoresceine	89	28,1	20.07.1978	T. Rusu
245	3400	265	,,	168	20,6	24.05.1982	I. Orășeanu et al.
,,	3370	211	Iod-131	552	6,1	,,	,,
,,	4320	213	NaCl	276	15,6	21.05.1982	,,
,,	4800	213	In-EDTA	1224	3,9	6.08.1982	,,
,,	4580	213	,,	1536	3,0	21.12.1983	,,
,,	6800	210	,,	48	141,7	21.05.1986	,,
490	2300	176	Fluoresceine	120	19,2	26.08.1971	T. Rusu
450	1380	190	$K_2Cr_2O^2$	168	8,2	22.09.1983	I. Orășeanu et al.
,,	1200	130	Rhodamine B	192	6,2	,,	,,
405	600	115	Fluoresceine	42	14,3	6.02.1974	T. Rusu
,,	400	65	,,	25	16,0	29.02.1974	,,
470	1300	59	Rhodamine B	50	26,0	24.09.1983	I. Orășeanu
370	5800	330	Fluoresceine	72	80,0	12.04.1986	C. Lascu, G. Diaconu
475		130	,,	210	4,3	12.04.1986	I. Povară, C. Lascu
458	820	116	,,	39	21,0	,,	,,
290	4020	195	,,	—	—	13.04.1986	,,
325	450	75	Fluoresceine	40	11,2	20.07.1987	I. Orășeanu et al.
320	360	70	In-EDTA	10	36,0	20.07.1987	,,
325	730	65	,,	20	36,5	,,	,,
325	1950	390	Rhodamine B	220	8,8	8.07.1987	I. Orășeanu, P. Brijan
,,	840	310	Fluoresceine	50	16,8	,,	,,
640	2100	20	In-EDTA	144	14,5	16.07.1987	I. Orășeanu, E. Gaișpar
545	2700	115	,,	168	16,1	,,	,,

Nicolle Orășeanu, I. Pop, T. Tănase (drainages no. 5, 6, 7, 11, 23, 42, 45, 63, 64, 57, 58, 59), E. Gașpar, Nicolle Orășeanu (drainages no. 2, 3, 16, 60) and E. Gașpar,

hydrometrically monitoring the hydrologic year spanning October 1826—September 1983 (Fig. 10). The data obtained by processing on the spot measurements are given in table 5. Noteworthy is the fact that the aforesaid hydrologic year was a droughty year, the last in a series of three, when discharge of the sources were ever lower owing to scarce precipitations. The discharges registered that hydrologic year account for roughly one half of the value of the discharges recorded in a mean hydrologic year.

Figure 10 shows the variation of the cumulated mean monthly discharge of the 13 sources in the mentioned hydrologic year. 48.4 per cent of the value of the underground runoff occured in winter, 27.0 per cent in spring, 13.1 per cent in autumn and 11.5 per cent in summer.

Discharge variability indices boast very different, generally high values, ranging from 183 in case of the Roşia spring to 23 in case of the Topleţ spring at Remeţi. They bespeak the high hydraulic conductivity

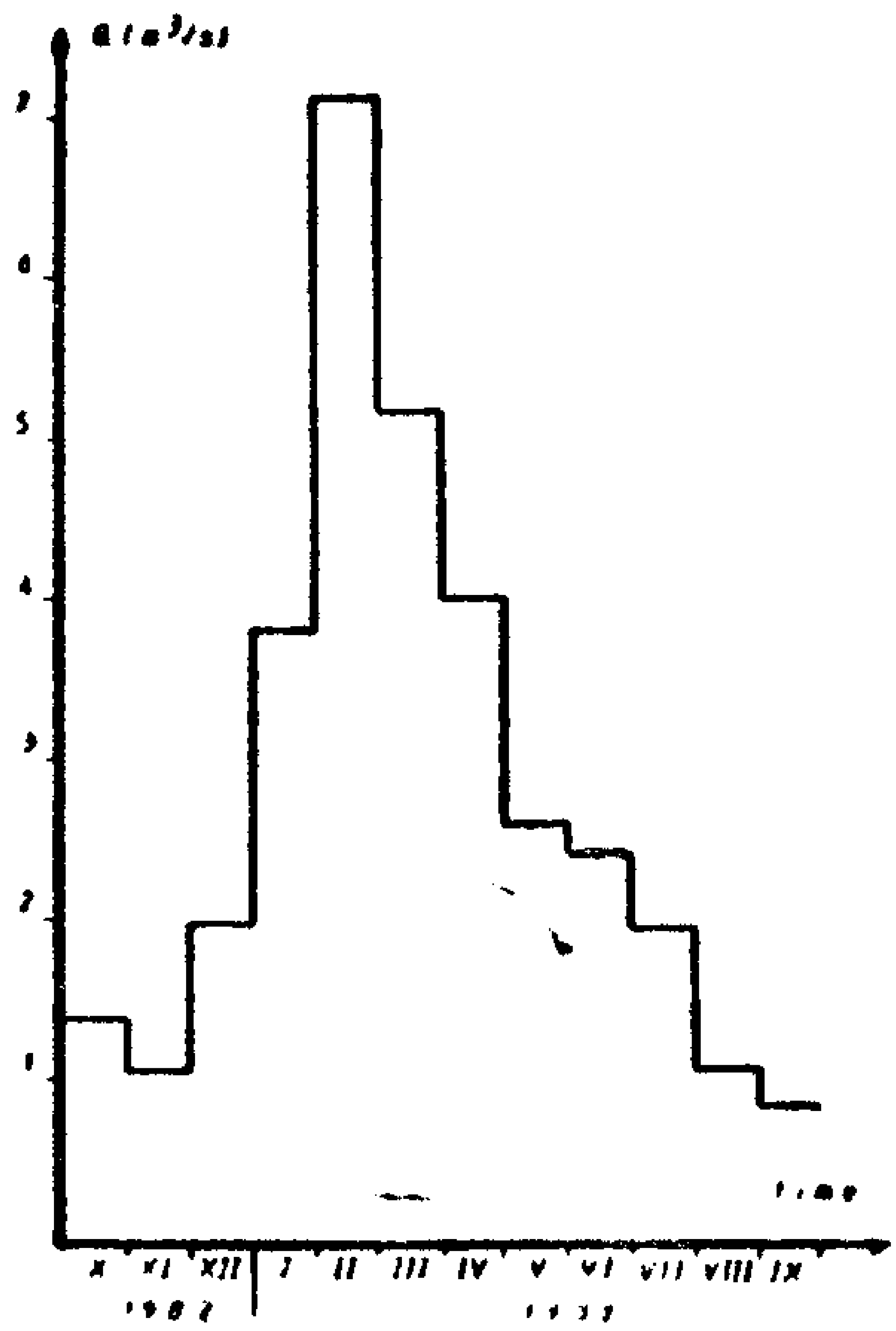

Figure 10 — Mean monthly discharge distribution of main springs of Pădurea Craiului Mountains (Table 5) in X.1982—IX.1983 time intevral.

of the karstic aquifer. The fact should also be underscored that the monitoring section of the Roşia and Toplicioara springs were located roughly 2 and respectively 3 kms downstream, the α discharge of the source,

Table

FLOW RATE OF MAIN SPRINGS IN X.1982—

No.	Source	1982			1983			
		X	XI	XII	I	II	III	IV
1	Aştileu spring	213	184	196	359	546	667	789
2	Moara Jurjii spring	86	63	92	185	540	240	216
3	Vadu Crişului cave	61	27	74	142	259	267	232
4	Izbîndiş spring	133	142	327	580	1114	601	369
5	Brătcani spring	139	124	280	402	585	576	447
6	Dămişeni spring	46	30	54	85	141	144	127
7	Ibanul spring (62)	29	14	34	60	108	113	93
8	Peştera cu Apă de la Bulz	56	56	96	240	445	240	148
9	Topleţ spring	125	126	147	175	237	171	152
10	Topliţa de Vida spring	70	28	52	167	484	357	246
11	Topliţa de Roşia spring	54	29	65	133	196	174	97
12	Roşia spring	230	129	362	919	169[illegible]	989	643
13	Toplicioara spring	119	90	185	397	794	624	443

n_v = The discharge variability index;

as given in Table 4, being greater than the real one. Furthermore, the value assigned to the variability index is higher than the real one, as it is increased by the large water contributions from the hydrogeographic basin in time intervals with rich precipitations.

The recession curve discharge coefficient (given in Table 5) boast a maximum value in the case of the source in the cave of Vadu Crişului, which indicates preferential water storage and circulation through karstic channels. This statement is supported by the result of speological investigations, which put the expanse of the cave at Vadu Crişului at 1,000 m and that of the Bătrînului cave, the major supply point of that karst hydrogeologic system, at 1,633 m.

Drainage coefficients in case of the other karst sources boast values of 0.001—0.003 and point to the prevailing character of fissures and small channels in the underground water accumulation.

8.3. 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.

On the hydrogeological map, detail A, indicates the approximate boundaries of the hydrogeological karst systems 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

5

IX.1983 HYDROLOGIC YEAR (l/sec)

1983					Q mean	Q min	Q max	n_v	α
V	VI	VII	VIII	IX					
504	327	211	153	108	356	74	3410	46.0	0.0026 0.0043
124	91	135	120	70	163	18	1070	59.0	
139	103	124	55	38	127	22	1270	58.0	0.008 – 0.0125
263	270	211	87	59	346	49	3980	81.0	0.0020 - 0.0037
289	282	259	146	128	305	68	2412	35.0	0.0024
148	66	77	43	35	83	28	519	19.0	
59	45	54	26	19	55	12	410	34.0	
105	108	84	35	24	136	20	1600	80.0	
140	141	134	120	117	150	112	255	2.3	
134	270	53	40	31	161	22	3150	143.0	0.0017–0.0019
48	34	27	17	13	74	11	965	88.0	0.0022–0.0030
315	429	330	126	105	522	78	14300	183.0	0.0017–0.0020
312	233	229	93	70	299	66	3200	48.0	

α = The recession curve discharge coefficient.

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 — Oradea — 1 Mai zone, which is part of the vast karstic aquifer.

9. THE CHEMICAL COMPOSITION OF SURFACE AND UNDERGROUND WATERS

In 1981, C. Marin brought out a detailed study on the chemical composition of the carbonate waters in the Pădurea Craiului Mountains. L. Vălenaş and A. Jurkiewicz (1980—1981) 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 IPGG 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 calcium-carbonate and calcium—magnesium—carbonate water, with the exception of the area of the lower course of the Mişid, where calcium—sulfate water is also to be found.

Table 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 Vîntului caves, the surficial course of Hodoabe and Tare brooks) are aresult 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.

9.1. SPRING WITH GAS OUTFLOWS.

Several springs from Pădurea Craiului Mountains, the subthermal spring on the Topliţa de Vida brook, the spring from Vida forest range, the spring Tăul Fierbintea of Căbeşti, the spring „La sălcii" and the travertine spring on Brătcuţa valley, display gas outflows. The water of these springs is calcium—carbonate or calcium—magnesium—carbonate type, similar to the water of the other springs of the karstic aquifer complex.

The chemical composition of the outflown gases (Table 7) is close, if not identical, to that of the atmosphere. As compared to the atmospheric

Table 6

VARIATION RANGE OF CHEMICAL COMPOSITION FOR THE WATERS SAMPLED IN PĂDUREA CRAIULUI MOUNTAINS

Source		n	TDS	Cl^-	SO_4^{--}	HCO_3^-	Na^+	K^+	Ca^{++}	Mg^{++}
Springs from limestones	average		403.8	5.66	15.3	215.3	13.09	1.03	81.93	2.61
	min.	65	158.7	3.50	1.0	85.4	0.2	0.4	28.8	0.7
	max.		625.4	28.3	36.4	400.6	58.1	2.5	125.8	36.5
Springs from dolomites	average		369.2	7.2	8.08	237.5	13.6	1.2	61.07	14.3
	min.	42	254.0	7.0	1.9	134.2	0.4	0.4	29.6	0.5
	max.		732.1	21.3	30.7	518.8	71.9	3.0	106.6	49.1
Springs from Mişid area	average		591.6	8.7	245.6	47.5	29.6	2.4	52.7	20.9
	min.	10	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	average		255.1	8.2	13.0	147.4	18.5	1.5	35.7	3.5
	min.	6	100.7	7.0	6.4	36.6	1.5	0.7	12.0	0.1
	max.		555.1	14.1	25.0	341.6	48.5	2.4	86.5	20.9

n = number of samples analysed;
TDS = calculated total disolved solids.
Note: Analysis performed in the laboratories of IPGG Bucharest.

Table 7

CHEMICAL COMPOSITION OF THE GAS OUTFLOWING FROM SPRINGS

SOURCE*	T (°C)	Q (l/s)	Compound (% vol.)**					Date of collection
			CH_4	CO_2	O_2	N_2	Ar	
Toplița de Vida subthermal spring (141)	20.5	4	0.000606	0.00	12.146	87.225	0.538	XII.1981
Toplița de Vida subthermal spring (141)	19.5	5	0.0009	6.98	12.19	80.18	0.543	XI.1982
Tăul Fierbintea spring (175)	18.0	7	0.0	0.11	19.58	79.31	0.915	III.1984
„La Sălcii" spring (34)	11.2	8	0.0045	0.0	20.7	77.0	0.916	VIII.1981
Izvorul cu travertin spring (37)	10.3	5	0.000706	0.0	20.3	75.50	0.900	VIII.1981
Spring from Vida forest range (119)	12.9	1	0.0	0.87	12.42	86.03	0.55	V.1989

*) In brackets number of spring on hydrogeological map;
**) Other compounds for which the gases were analysed, C_2H_2, C_3H_8, C_4H_{10}, He, H_2 are lacking.
Note: Analysis performed in the laboratories of IPGG Bucharest.

gas, the concentration in oxygen is diminished, due to the biochemical and oxidation processes. Corresponding to the consumed oxygen fraction, the nitrogen concentration increases accordingly.

The water of the subthermal spring Toplița de Vida originates in the hydrogeological karst system Toplița de Vida and 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 Arieșeni Nappe and the cretaceous limestones of the Bihor Unit.

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HYDROGEOLOGICAL MAP OF THE PĂDUREA CRAIULUI MOUNTAINS
by IANCU CRĂŞEANU
0 1 2 3 4 5km
LEGEND
1 Carbonate mesozoic series (limestones, dolomites) of large thickness, highly fractured and karstified, exhibiting large infiltration capacity and strong groundwater flow. Numerous springs with flow rate up to 500 l/s and elevated variability index. Important resources stored below the discharge level of the springs.
APTIAN 2 ap Limestones, less frequently shists, Gugu brecia (BU)
NEOCOMIAN-LOWER APTIAN 3 ne+ap1 Limestones with pachyodonts (BU)
BARREMIAN 4 br Limestones with pachyodonts (VN)
UPPER JURASSIC 5 J3 Limestones with Saccocoma (VN)
UPPER CALLOVIAN-TITHONIAN 6 cl2-th Limestones (BU)
AALENIAN-LOWER CALLOVIAN 7 aa-cl1 Limestones, less frequently marls (BU)
UPPER SINEMURIAN - CARIXIAN 8 si2-cx Encrinitic sandy (BU, VN), limestones (BU)
LADINIAN+NORIAN 9 ld+no Roșia limestones (FN)
LOWER CARNIAN 10 cn1 Strimtura limestones (VN)
LADINIAN+LOWER CARNIAN 11 ld+cn1 Limestones, dolomites ± cherts (VN)
LADINIAN 12 ld Reefal limestones (BU)
ANISIAN 13 an Grey bedded dolomites (AN, FN, VN), dolomites and limestones (BU)
14 Detritic deposits of Volhynian-Quaternary age (sands, gravels, boulders, shales), with reduced thickness and extension, hosting important groundwater pores-flow. They store limited aquifer accumulation, generally with free surface. Local importance.
HOLOCENE 15 qh Sands, gravels, shales
PLEISTOCENE 16 qp Boulders, gravels, sands
PONTIAN 17 p Fine sands, shales, sandy shales
MALVENSIAN 18 mv Sands, gravels, shales, sandstones
VOLHYNIAN 19 vh Sands and gravels, carbonate sandstones, tuffs, shales
20 Mostly detritic deposits of Permo-Mesozoic age (sandstones, conglomerates and less frequently shists), with permeability of fissures and pores with discontinous distribution and development. The groundwater flow is mostly confined to the fissured areas, which may supply springs with discharge up to 5/s. They frequently act as the bed and/or the essentialy impervious caprock for aquifer accumulations occuring in the adjoining carbonate deposits.
SENONIAN 21 sn Sandstones, conglomerates (in Remeți graben)
SINEMURIAN si Quartzitic sandstones (VN)
HETTANGIAN+LOWER SINEMURIAN 23 he+si1 Quartzitic sandstone, plastic shales (BU)
WERFENIAN 24 w Quartzitic sandstones and conglomerates (AN, FN, VN, BU)
PERMIAN 25 p Sandstones and conglomerates (AN, VN, BU)
26 Subsequent alpine magmatites (banatites) and metamorphites, with permeability of fissures with discontinous distribution and intensity. The groundwater flow, confined to the weathered surficial stratum and to the fractured areas, supply springs with reduced flow rate (up to 1 l/s)
PALEOCENE 27 ρ δ γ ρ - Rhyolites, δ - dacites, γ - granites
PRECAMBRIAN 28 Pc Cristalline shists (Someș series)
29 Marly and shaly deposits, devoid of groundwater flow and flysch-like series, including rock-complexes of variable permeability (shales, shistes, marls, sandstones, limestones), hosting occasionnaly discontinous aquifers accumulations occuring in the more permeable terms.
SENONIAN 30 sn Shales, sandstones, conglomerates, limestones (in Roșia Basin)
VRACONIAN+MIDDLE TURONIAN 31 vr+tu2 Sandstones, shales, conglomerates (BU)
ALBIAN 32 al Sandstones with limestones and marls intercalations (BU)
APTIAN 33 ap2 Marls, less frequently limestones intercalations (VN, BU)
UPPER JURASSIC+NEOCOMIAN 34 J3+ne Marls, sandstones, limestones (FN)
NORIAN 35 no Shaly shists, sandstones with lenticular dolomites and/or limestones (Carpathian Keuper in FN and VN)
36 Hydrologic features of karstic cavities:
Hydrologic regime of cavity / cavity: perennial (source, ponor), temporary (source, ponor), absent (tapping a underground stream, fossil cavity)
cave
pothole
impenetrable
37 Losses in flow along the riverbed
a. Temporary total
b. Permanent partial
38 Permanent surface course
39 Temporary surface course
40 Karst depression
41 Cave passage
42 Surficial watershed between Crișul Repede and Crișul Negru rivers
43 Subthermal spring
44 Spring with gas release
45 Groudwater flow direction established by tracing method, 2 - the underground drainage path corresponding to the table in the text
46 Forest range
47 Mean year discharge of the sources (l/s):
under 1
1 - 5
5 - 20
20 - 50
50 - 100
100 - 500
48 Geological boundary
49 Fault
50 Overthrust front
51 Mine galery
52 Quarry
Location of study area
Oradea
BUCUREȘTI
Geological data after:
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A.
Distribution of large hydrogeological karst systems (H K S) in Pădurea Craiului Mountains
1. Approximate limit of H.K.S
2. Superficial watershed between Crișul Repede and Crișul Negru rivers
3. Diffluence surface (D.S)
4. Direction of „shallow" underground circulation
5. Direction of „deep" underground circulation
6. Karstic spring
7. Effluent cave
a - Topa valley - Aștileu spring D.S.
b - Birtin valley - Peștera Vadu Crișului cave D.S.
c - Mișid valley - Brătcanilor spring D.S.
d - Boiu valley - Peștera cu Apă de la Bulz D.S.
e - Cuților valley - Toplița de Roșia spring D.S.
f - Șoimușul Drept valley - Firez spring D.S.
g - Miniera valley - Moara Jurjii spring D.S.
B.
Structural simplified map of the Pădurea Craiului Mountains
(After I.G.G. Data)
1. Neogene and Quaternary formations
2. Subsequent alpine magmatites (banatites)
3. Post-overthrusting cover (Senonian)
4. Arieșeni Nappe (AN)
5. Ferice Nappe (FN)
6. Vălani Nappe (VN)
7. Bihor Unit (BU)
a. Remeți graben
b. Antithetic steps zone
c. Cărmăzan horst
d. Zece Hotare compartment
e. Virciorog zone
Aștileu
Vadu Crișului
Șuncuiuș
Bucea
Bratca
Bulz
Remeți
Roșia
Meziad
Căbești
Sohodol
Dobrești
Virciorog
Zece Hotare
Platoul carstic Zece Hotare
Platoul carstic Chicera Arsuri
Toplița de Vida
Peștera de la Vadu Crișului
Peștera cu Apă de la Bulz

Denomination of points numbered on th"ehydrogeological map. In brackets, altitude of point in meters a.s.l.

I. Hydrographic basin of Cri~ul Repede river: a - A~tileu - Zece Hotare - Bulz zone: 1 - Igrita cave (328),2 - Pi~nita cave (275) and spring of Pi~ni~a waterfall (255),3 - Losses of Mmiera brook at Cornet (495-505), 4 - Flntina lui lodiroi (435), 5 - Flntlna Subioani (658), 6 - Spring of Groapa Motului (295), 7 - Ponor of Deblei valleY/GaHi~enicave (394), 8 - Spring of Moara Jurjii(Moara Cornii (400), 9 - Clroiu spring (300), 10 - Springs of Funditura Birtlnului (425), 11 - Losses of Birtin valley (-150-460), 12 - Tomnatic ponor (635), 13 - FlnUna Popenii (670), 14 - Cave of Hoda (604), 15 - Tomii ponor (640), 16 - Blidire~ti ponor (729), 17 - Brezului ponor (645), 18 - Olfului ponor (635), 19 - Biraului ponor (600), 20 - Spring (304) and cave (315) of Napi~tileu, 21 - Ungurului cave (305) and spring of Tare brook (325), 22 - Izvorul cu Lapte spring (460), 23 - Losses of Recea brook (600), 24 - Valli.ul Bochli (585), 25 - PQnor of Morii/Carmazan valley (540), 26 - Ponor of Mocra valley (583), 27 - Stanul Ciutii ponor (575), 28 - Ponor of Hu!ii valley (620), 29 - Ponors (615, 610) and cave (604) of Ponora~, 30 - Po~i~taul Berna pothole (585), 31 - Pothole of Groapa Sturzului (610), 32 - Secli.tura Bratcanilor/Ponor of Pancului valley (487), 33 - "La Cioroi" spring (360), 34 - "La Salcii" spring (410), 35 - Spring of Rltu Ciirbunar (415), 36 - Sincuta Spring (424), 37 - Izvorul cu Travertin spring (455), 38 - Pe,tera Vlntului cave (320) and spring of Poiana Frlnturii (305), 39 - Spring of Lunca Negru-le,U (320), 40 - Spring of Monca (330), 41 - Pa~caliiu Mihal pothole (765), 42 - *Munaul* Balaj cave (710), 43 - Toaia ponor (675), 44 - Pe~teruta ponor (687), 45 - Po~i~tll"ulle la BQce~tipothole (535), 46 - Flntina Lupoii (530), 47 - Flntina Dupului (590), 48 - Stiubei spring (659),49 - Spring of Gura LlIn~orului (425), 50 - Valiiul Corhani (580),51 - Hlrtopul Verii pothole (698), 52 - Hirtopul din FlIndatura potJaol1l(710), 53 - FinUna Rusandrei (810),54 - Izvorul Mare spring (470),55 - Izvorul Buchii spring (500),56 ~ Fintina Dragoaia (565), 57 - Iovului cave (640) and pOllor of Pop.orului valley (612), 58 - Cociulut cave ponor of Briide~tilor valley (640), 59 - Ponor of Ses"(680), 60 - Ponor of Stiopului valley (690), 61 - Flntina Rl'ce (700), 62 - Spring of Moara Dedii (350).

b. Remeti zone: 63 - Teoreanu spring (440), 64 - Ponor of Valea" Fruntii (730), 65 - Losses of ClJprei valley (625-700), 66 - "La Izvoara" spring (540), 67 - Losses of Iaduilli valley at Dejoaia (445-455),68 - Losses of Sipotuilli valley (500-600), 69 - Cioatei spring (455), 70 - Turii cave (470), 71 - Springs of Lunca Pizlii (470), 72 - Losses of Pirlul cu Soc! valley (600-650), 73 - Losses of Izvorului valley (550-650), 74 - Pobraz pothole (830),75 - Cave of Fata Apei (480),76 - Losses of Valea Rea valley (625-700),77 - Losses of Strivinoasa valley (525-600), 7"8- Spring of Dumiter (490), 79 - Tirului cave (575), 80 - Tunel cave (580), 81 - Ponor of Secatura (735), 82 - Losses of SaHi.trucului valley (500-600), 83 - Ciuhandru spring (518), 84 - Fire spring (545), 85 - Pe~tera cu Api din Valea Le~ului cave (650),.86 - Ponorul de sub Dealul Chicerii ponor (885).

II. Hydrographic basin of Cri~ul Negru river: 87 - Pe~tera de sub Stan Cave.(265), 88 - Tic1ului cave (373), 89 - Ponor of Pe~ti~ valley (325), 90 - Biserica Huta cave (360), 91 - Handrii cave (405), 92 - FinOna Surdului pothole (475), 93 - Osoi cave (400) and losses of Poiana valley (350-450),94 - Gabor cave (445), 95 - Vichi spring (440),96 - Tambii lipring (460), 97 - Losses of Groapa Pe~teranilor valley (460-490), 98 - Spring of Ciungii Hore! (555), 99 - Pe~ti~t'!llluispring (475), 100 - Aurica mare (468), 101- Cave of Vii.laul Burdii (485), 102 - Tilharului spring (475), 103 - Cioroaiele Tlrcului cave (490), 104 - Brusturi mine (547), 105 - Ponor of Groapa Popii (555),106 - Flntlna Ulmului (580), 107 - Spring of Toplicioara valley (335), 108 - Spring of Cotetelor valley (310), 109 - Spring of Cadului valley (314), 110 - "La Featii" cave (280), 111 - Stanul Cerbului caves (285), 112 - Izvorul de sub Piciorul Bcnii spring (280), 113 - Po~i~taul Balaurului pothole (340), 114 - Jiloasa pothole (430), 115 - "La Vago"n" spring (370), 116 - Spring of Clmpul Liiutoare (280), 117 - Viduta II cave (350), 118 - Viduta I cave (370), 119 - Spring of Vida forest range (325), 120 - Cublcsului cave (400) and spring of Biajului Valley (395), 121 - Spring of Rocodal1 (389),122 - Springs of Gura Ursului (450),123 - Cave of Htrtoapele Hododii (610), 124 - Spring of Ziivoii cei Mic! (680), 125 - Cave of Fundii.tura ROlliorullli (620), 126 - Ponor of Tinoasa Videi (547), 127 - Izvorul de sub Bli.roaia spring (420), 128 - Cave of Stanu Ro~u (475), 129 - Pel1tera cu apa din Valea Videi cave (458), 130 - Izbucul din Gura Viiii Groie~ului spring (470), 131 - Groie~ului spring (490), 132 - Taurului cave (540), 133 - Izvorul de sub Dnlmul Letii spring (475), 134 - Pe~tera cu Apa din Valea Letii cave (480), 135 - Apa de sub Stan spring (525), 136 - lacoboaia ponor (680), 137 - Ponor of Corobii.t/Ghinii (627), 138 - Ponors of Pastaiasa (620), 139 - Marcon spring (704), 140 - Ponors of Pri slop (666), 141 - Toplita de Vida thermal spring (230), 142 - Avenlll de sub Dealul Osoi pothole (455), 143 - Potholes of (opaclul Mlndru· (455), 144 - Pothole of Dlmbul Tlllpo~ (465), 145 - Pietroc pothole (435), 146 - Cli.rbunar spring (485), 147 -

Cli.rbunu ponor (555),148 - Ponors of Poiana Hulpi (463),149 - Pothole of Dealul Glrbovului (480), 150 - Cave (519) and ponor (508) of Dealul Linzului, 151 - Spring of Culmea Ponicioara" (495), 152 - Pe,tera din Urzici cave (502), 152 - Spring (527) and ponor (510) ot Marchis, 154 - Preguz cave (467), 155 - Flntlna Ni,oarei (475), 156 - Spring (468) and ponor (456) of Flntlna Rece, 157 - Meri~oruI/Hodi~nul ponor (458),158 - Ituilli cave (528), 159 - Lander cave (450), 160 - BManei spring (465),151- Bichli ponor (458), 162 - Baia Ni~ului/Nitului ponor (458), 163 - Nulii spring (426), 164 - Izvorul de sub Rltul Domnesc spring (413), 165 - Cave of Onu~ (300), 166 - Izvorul de sub Coasta Codrii spring (160), 167 - Ponor of Mlnzli valley (264), 168 - Spring 'Of Condre~ti (170), 169 - Spring of MI~ii valley (320), 170 - Spring of Urzicarului valley (360),171 - Pothole of Fintinacu Soc!(400),172 - Cioroiul spring (430) and Cailii ponor (390), 173 - Cave of Strlmtura valley (325), 174 - Spring of Cl'ilii valley (320), 175 - Tli.ul Fierbintea thermal spring (220), 176 - Tarina spring (310), 177 - Valli.u cave (385), 178 - Albioara ponor (430), 179 - Izvorul Albastru sprill~J440), 180 - Groapa Sohodolului (350), 181"'Cave from Groapa lui Dobo~ (467), 182 - Ciur Ponor cave (480), 183 - Ciur Izbuc cave (395), 184 - Cave from Tinoasa (539), 185 - Ponor from Poiana Prie (455), 186 - Cave of Baroaia Biitrlna (529), 187 - Ponor of Perje valley (485), 188 - Jurcanilor cave (545), 189 - Sohodol pothole (545), 190 - Ponor of Botului brook (550), 191 - Cuculeasa ponor (613), 192 - Losses of Barc brook (615), 193 - Spring from Poiana Dami~ (580), 194 - Runcl10rului/La Intorsuri ponor (570), 195 - Ponor of Magura valley (655), 196 - Spring of Onut *(6U),* 197 - Ponors from Flntlnele (679), 198 - Ponor of lezere valley (550) and Stanul Foncii pothole (600), 199 - Ponorof Fiului valley (510), 200 - Cioroiul Villi spring (380), 201 - Flntina Miclii (308), 202 - Cioroiullui Mitireag spring (338), 203 - Ponor from Tii~ului valley (42;;) and Cioroiul spring (325), 204 - Ponor from Hlrtopul Bonchli (455), 205 - Gruietului cave (320), 206 - 1oplicioara/Bulbuci spring (430), 207 - Po~i~tiul One~tilor pothole (525), 208 - Spring from Halau (410), 209 - POl1i~taulFanea Babii pothole (600),210 - "La Magazln" spring (340),211 ~ Losses of Seaca valley (400-425) and Pe~tera Secata cave (390), 212 - Taul Negru (640), 213 - Groapa Morare~tilor (715), 214 - Groapa Delilului (635),215 - Spring from Chinc!u brook (380),216 - Ponor of Gropilor-Co~valley (520),217 - Losses of Bradului brook (500), 218 - Losses of Pe~terii Valley (470), 219 - Spring of Meziad cave (405),220 - Rali cave (350),221 - Spring under Oarz1i.na(475), 222 - Losses of Soimu§ul Drept brook (640-670), 223 - Springs from Stirbilei valley (640), 224 - Ponor (670) and spring (585) from Taul Gani!.