3.3. POSTĂVARU MASSIF

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The Postăvaru Mountains are located in the Carpathians bend area and they are bordered to the north and to the west by the depression of Braşov, to the east by the Timiş valley, and to the south by Pârâul Mare, which separates them from Bucegi Mountains (D. BĂLTEANU, N. BĂCĂINŢAN, 1980). By considering the wide spectrum of landforms that their diversified lithological constitution had generated, three distinct geomorphological sub-units have been separated: the actual Postăvarul massif, also known as Cristianul Mare, the Mountains of Poiana Braşov, and Predeal Mountains. The latter entity occurs southward of Râşnoavei valley and of its tributary, Cheia, and consequently it is not addressed by the present work. In the following, the "Postăvaru Massif" designation shall cover only the first two indicated geomorphological sub-units.

The Cristianul Mare Massif develops essentially around an axial cuesta, which begins by extending from Cheia Valley toward the NE (Fig.1) as an impressive limestone escarpment (designated as Muchia Cheii), to reach a maximum elevation in Postăvaru peak (1799 m), and to additionally extend as far as the southern reaches of Braşov, across a series of less and less prominent summits and ridges: Ruia peak (1659 m), Crucuru Mare ridge (1371.2 m), and Verna peak (1428 m).

Eastward of Cristianul Mare, in the Timiş river catchment area, over a distance of 2-3 km only, the ground elevation drops down to 600-700 m. The corresponding topography consists of a series of transverse ridges which are separated by deep valleys. The latter are subject to torrential flow and along their upper courses a multitude of waterfalls occur.

The Mountains of Poiana Braşov, located northward of Cristianul Mare, include a plateau occurring at 900-1100 m altitude, as well as a series of gentle ridges which descend toward the depression of Bârsa and toward the embayment of Zărneşti. The plateau is bordered by ridges that are shaped in a limestone substratum and which have rounded appearances and elevations close to 1100 m (Dealu Negru, Spinarea Lungă, Pisac, Dealu Cernit).

Tributaries occurring along the Poiana stream upper course, as well as the right-hand side tributaries of Ghimbăşel stream collect their water from the western part of the plateau. Waters from the north-western section of the plateau are collected by Cristianului and by Cetăţii valleys, while Răcădăului and Valea cu Apă streams collect their water from the north-eastern part of the plateau.

Geology

The geological constitution of Postăvaru Massif incorporates formations belonging to a crystalline basement, plus sedimentary formations of Triassic, Jurassic, Cretaceous and Quaternary ages (Fig.1).

In Cristian area, the Triassic age formations include Anisian bituminous limestone with insertions of marly shales, while in Râşnov area they consist of white reef limestone of Ladinian age.

Early Jurassic formations include Gresten-facies deposits that incorporate coal and fire-clay, Medium Jurassic formations consist of detritic deposits, while Late Jurassic formations prevalently occur as Stramberg-facies limestone, of Kimmeridgian-Tithonic age. The latter carbonate formation develops as a compact, 300-500 m thick limestone series, underlain by thinly bedded, red nodular limestone of 5-10 m overall thickness.

Alternating marls, clays and carbonate marls (the Braşov marls), which extend as isolated patches and whose overall thickness reaches 20-30 m, occur at the bottom of the Cretaceous age deposits. Those older formations are disconformably overlain by a thick stack of massive sandstones and conglomerates of Late Vraconian age (M. KUSCO et al., 1970, 1978). The latter deposits outcrop over most of Postăvaru Massif area.

The Postăvaru Massif rocks build up complex tectonic structures, which certain authors have interpreted as nappe structures, with slices and thrust outlayers (SĂNDULESCU M., 1964), while other assumed them to be blocks initially separated by gravitational faults and subsequently displaced by strike-slip faults (KUSCO M. et al., 1970).

Within Postăvaru Massif, M. SĂNDULESCU (1964) has identified several tectonic compartments belonging to the Crystalline-Mesozoic Zone:
- Postăvaru compartment, including the actual Postăvaru mountain and the main ridge which extends between the valleys Cheia and Schei;
- Cristian compartment, located to the west of the previous one, which partially overlaps it;
- Râşnov compartment, whose main characteristic is the Late Cretaceous deposits abundance;
- Braşov compartment, located in the northern part of the considered region and being subject to a structural positioning in-between the first two indicated compartments.

Meteorological and hydrological data

In order to assess the groundwater resources potential of Postăvaru massif, the national observation network of the National Institute of Meteorology and Hydrology has been expanded over the hydrologic year X.1992-IX.1993 by a series of additional flow-gauging stations installed on the main stream courses, in those places where the latter left the massif. The network has been installed and operated in co-operation with Gh. and Paraschiva Hoţoleanu and Luminiţa Tibacu, and it has been monitoring the runoff that occurred over an area of 81.3 sqkm (Figure 2).

By processing and interpreting the rainfall data which had been provided for the hydrologic-year X.1992-IX.1993 by the meteorological and flow-gauging stations of Braşov, Poiana Braşov, Predeal, Dâmbul Morii and Râşnov, there has been constructed the rainfall contour-map illustrated by Figure 2.

The significant fluctuations recorded in terms of rainfall distribution from one area to another are in full compliance with the position of the massif at the incidence of air masses subject to contrasting amounts of humidity and to distinct directions of displacement (Figure 3). An average rainfall value of 857 mm has been computed for the entire considered area.

The experimental evaporimetric station set up at Poiana Braşov (932 m elevation) has recorded over the indicated hydrologic-year a real evapotranspiration value of 436.3 mm (Luminiţa Tibacu). The monthly water supply available for runoff and infiltration (computed as the difference between the monthly rainfall amount and the monthly real evapotranspiration recorded at the Poiana Braşov evaporimetric station) has displayed negative values only in the months of October 1992 and of June 1993.

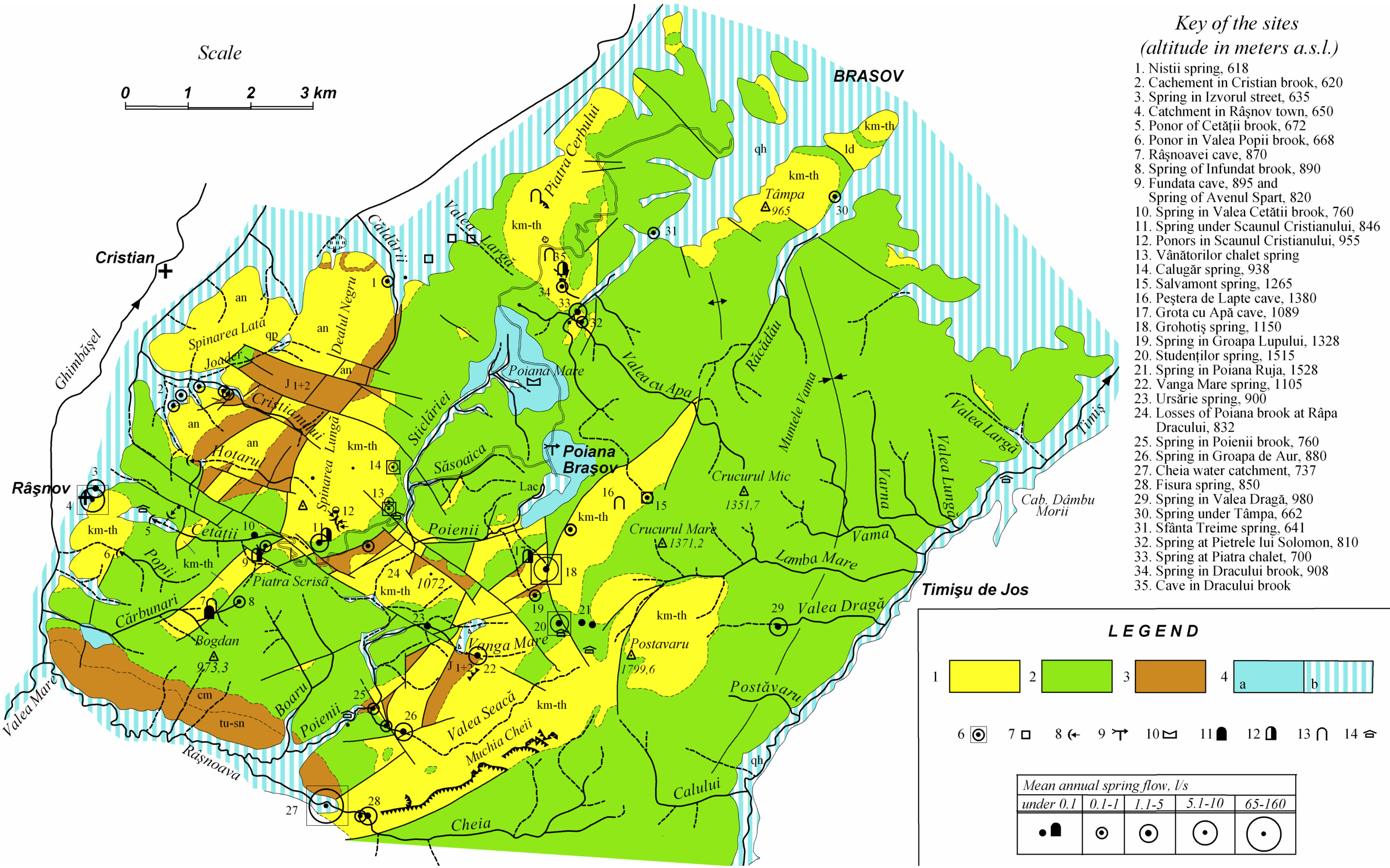
Surface runoff

The topography of Postăvaru Mountains is subject to a strong dissection, induced by a surface streams network which has a radial distribution with respect to the top of the mountains body. Surface streams are collected by the river Timiş toward the east, by the channel Timiş toward the north, and by the river Ghimbăşel and by its tributary Râşnoava toward the west and the south.

Over the hydrologic-year X. 1992 - IX. 1993, there has been monitored the surface runoff discharged by 14 surface streams (Figure 2 and Table 1).

Figure 1. Hydrogeological map of Postăvaru Massif (Geological data after M. Kusko, T. Cibotaru, R. Damian (1978) and M. Săndulescu, D. Patrulius, M. Ștefănescu (1972).

Legend: 1 - Mesozoic carbonate series, highly fractured and karstified, characterized by very high effective infiltration and prevalently conduit porosity with intensive groundwater flow. Important water resources in large karst systems; 2 - Upper Cretaceous molasse deposits (sandstones, conglomerates and less frequently shales) with double porosity. Extensive fracture networks and well-developed weathering zones provide a continuous and important supply for the river flows and for the karst systems. Spring flow rates up to 1 l/s; 3 - Marly and argillaceous deposits, devoid of groundwater flow; 4 - Pleistocene (a) and Holocene (b) deposits hosting poor water resources of local importance; 5 - Spring tapped for drinking water supply; 6 - Dug well; 7 - Swallet; 8 - Meteorological station; 9 - Evaporation station; 10 - Perennial outflow cave; 11 - Temporary outflow cave; 12 - Fossil cave; 13 - Foresty and tourist chalet.


Key of the sites
(altitude in meters a.s.l.)
1. Nistii spring, 618
2. Cachement in Cristian brook, 620
3. Spring in Izvorul street, 635
4. Catchment in Râşnov town, 650
5. Ponor of Cetății brook, 672
6. Ponor in Valea Popii brook, 668
7. Râşnoavei cave, 870
8. Spring of Infundat brook, 890
9. Fundata cave, 895 and
Spring of Avenul Spart, 820
10. Spring in Valea Cetătii brook, 760
11. Spring under Scaunul Cristianului, 846
12. Ponors in Scaunul Cristianului, 955
13. Vânătorilor chalet spring
14. Calugăr spring, 938
15. Salvamont spring, 1265
16. Peştera de Lapte cave, 1380
17. Grota cu Apă cave, 1089
18. Grohotiş spring, 1150
19. Spring in Groapa Lupului, 1328
20. Studenților spring, 1515
21. Spring in Poiana Ruja, 1528
22. Vanga Mare spring, 1105
23. Ursărie spring, 900
24. Losses of Poiana brook at Râpa
Dracului, 832
25. Spring in Poienii brook, 760
26. Spring in Groapa de Aur, 880
27. Cheia water catchment, 737
28. Fisura spring, 850
29. Spring in Valea Dragă, 980
30. Spring under Tâmpa, 662
31. Sfânta Treime spring, 641
32. Spring at Pietrele lui Solomon, 810
33. Spring at Piatra chalet, 700
34. Spring in Dracului brook, 908
35. Cave in Dracului brook
Scale
0 1 2 3 km
BRASOV
Cristian
Râşnov
Ghimbăşel
Timişu de Jos
Poiana Braşov
Poiana Mare
Piatra Cerbului
Câldării
Valea Largă
Tâmpa
965
Spinarea Lată
Joader
Dealul Negru
Cristianului
Hotaru
Spinarea Lungă
Sticlăriei
Săsoaica
Lac
Valea cu Apa
Răcădău
Muntele Vama
Crucurul Mic
1351,7
Crucurul Mare
1371,2
Varna
Valea Lungă
Vama
Lamba Mare
Valea Dragă
Postavaru
1799,6
Postăvaru
Cab. Dâmbu Morii
Timiş
Cetății
Popii
Poienii
Piatra Scrisă
1072
Cărbunari
Bogdan
973,3
Boaru
Vanga Mare
Valea Seacă
Muchia Cheii
Cheia
Calului
Valea Mare
Râşnoava
LEGEND
1
2
3
4 a b
6 7 8 9 10 11 12 13 14
Mean annual spring flow, l/s
under 0.1
0.1-1
1.1-5
5.1-10
65-160

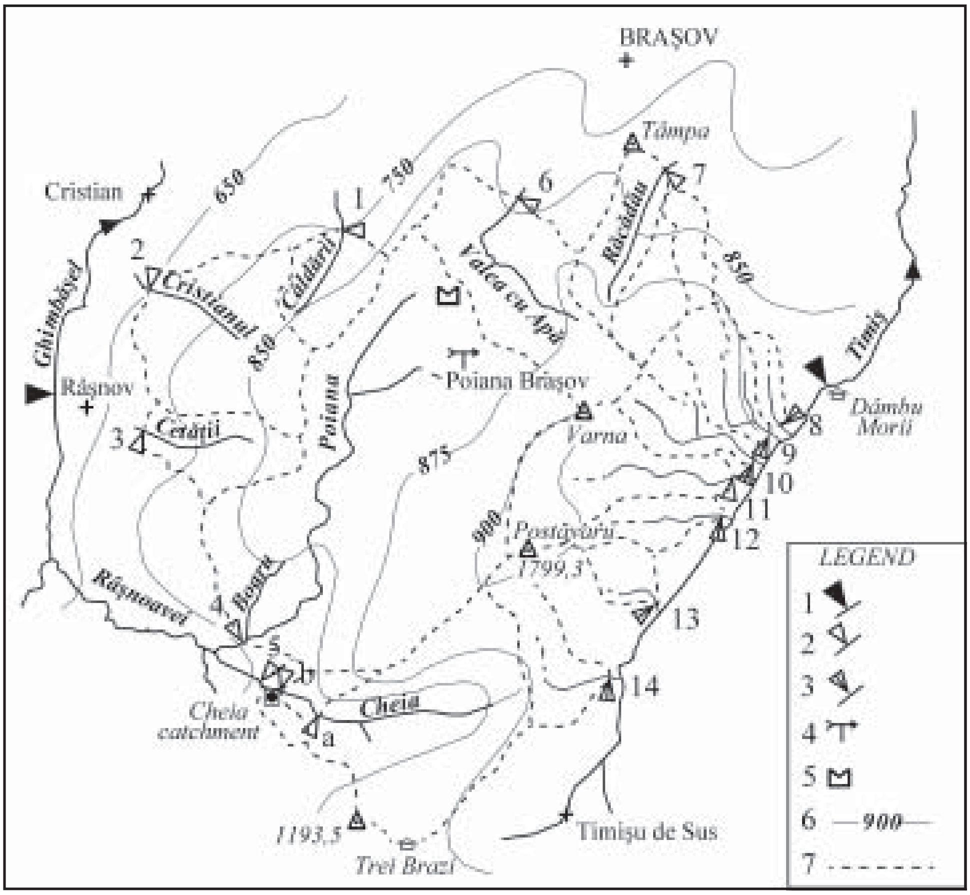


Figure 2. Hydrometeorological network in Postăvaru Massif.
Legend:
1- Flow-gauging station belonging to the national network;
2- Flow-gauging station operating during the water-year X.1992-IX.1993;
3- Site where monthly flow measurements were performed;
4- Meteorological station belonging to the national network;
5- Evaporimetric station belonging to the national network;
6- Rainfall contour;
7- Water-divide between surface streams

Specific discharges computed for most streams located within that mountains-body are small, a circumstance which appears to be rather unusual for such a high elevation environment (Table 1 and Figure 4). The smallest values are recorded in the western part of the massif (Căldării, Cristianului, Cetăţii and Poiana valleys), where catchment areas develop mostly on a carbonate substratum. Deficient in terms of surface flows are also certain streams which flow over terrains built up of Postăvaru conglomerates, a formation that consists of mostly limestone pebbles embedded in a carbonate matrix; additionally, that formation is directly underlain by Tithonic limestone deposits.

Hydrogeoloy of Postavaru Massif

Postăvaru Massif extends over an area of 115.2 sqkm, 69% of which include terrains occupied by sandstones and conglomerates of Vraconian age, 25% include terrains consisting of Triassic and Jurassic limestone, and 6% include terrains consisting of prevalently pelitic deposits. By taking into account the highly diversified lithological constitution and the dissimilar signatures recorded in terms of tectonic features, as well as hydrogeological characteristics of each category of deposits, there have been separated 4 distinct categories of formations with specific features:

- Mesozoic carbonate series (limestone) of large thickness; they underwent extensive fracturing and karst processes and they display an elevated infiltration capacity, as well as intense groundwater flows;
- Late Cretaceous molasse deposits (conglomerates, sandstones); they display fissures and pores permeability and they exhibit an elevated capacity of infiltration, as well as important groundwater flows;
- Unconsolidated detritic deposits (sands, gravel, clays) of Quaternary age; their extent and thickness within that mountain area are small, the corresponding aquifer resources being rather poor. Extensive Quaternary deposits occur in the areas of Poiana Mare and Poiana Mică, additionally building up a detritic corridor along Sticlăriei stream which drains most of the water collected from Poiana Braşov tourist resort. Quaternary deposits at the border of the massif also extend deeply inside it, along the streams Valea cu Apă, Răcădău, Căldării, Cristianului and Cheia. Aquifer accumu-

No	Stream	F sqkm	H m	Q mean l/s	q l/s/sqkm	Lithology, % in F		
						L	Cg	S
1	Căldării	2.84	811	2	0.79	31	50	19
2	Cristianului	7.42	789	3.5	0.47	62	11	27
3	Cetăţii	2.94	833	1.5	0.51	25	67	8
4	Poiana	22.4	1123	47	1.78	31	66	3
5	Cheia	12.26	1004	90.3	7.37	22	76	2
6	Valea cu Apă	8.68	999	26	3.00	12	86	2
7	Răcădău	4.91	896	6.4	1.30	6	94	
8	Valea Lungă	0.73	828	4	5.48		100	
9	Varna Mică	2.35	904	12	5.11		100	
10	Vama	2.57	1114	30.5	11.87		100	
11	Lamba Mare	5.51	1214	52	9.43	32	68	
12	Valea Dragă	1.32	1055	14	10.60	8	92	
13	Postăvarul	1.17	1088	11.5	9.83	2	98	
14	Calului	2.51	953	13	5.18	8	92	

Table 1. Characteristics of streams and of the corresponding catchment areas.
F - surface; H - average elevation; Q mean - annual average flow rate; q - specific discharge; L - limestone; Cg - conglomerates and sandstones; S - shales.

lations in such deposits are poor and they are subject to local use.
- Marly and clayey deposits devoid of water accumulations. Prevalently marly-clayey deposits of Late Cretaceous age outcrop in the southern part of the considered mountains body, within the right side slope of Râşnoava stream. A prevalently pelitic constitution is characteristic also to the Early Jurassic deposits that occur mainly in the central-western section of the considered mountains body.

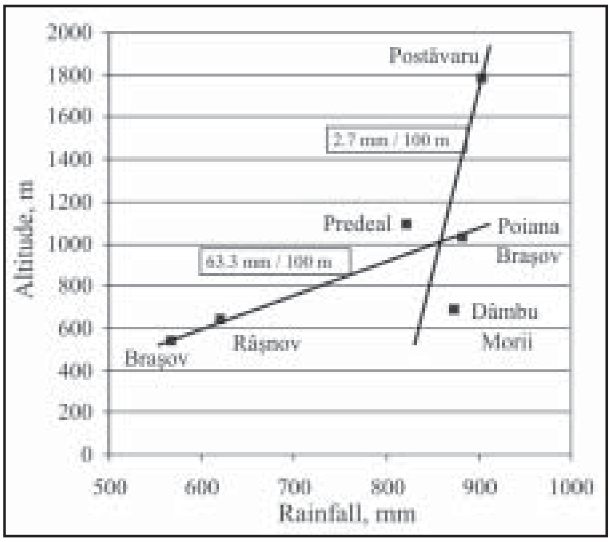


Figure 3. The relationships between the rainfall amount and the rainfall-gauging station altitude.

The hydrogeological characteristics of the distinct tectonic compartments of Postăvaru Mountains are discussed in the following.

a. Cristianu Mare compartment. On the Upper Jurassic limestone substratum located in the axis of the Cristianul Mare compartment, perennial surface flow is virtually absent. Rainfall water is subject to fast seepage in the underground, yet during periods of heavy rainfall or rapid snowmelt abundant surface flow still occurs. The various surface streams display highly dissimilar specific flow rates, which are essentially controlled by the lithological constitution of each catchment area, and by the limestone basement position with respect to the overlying conglomerates. In this respect, the spring occurrence in the Dragă valley (Fig.1, no.29), subject to a chemical composition analogous to that of limestone-derived groundwater and accompanied by abundant deposits of travertine, suggests either a quite shallow location of the limestone reservoir, or a fast conveying fault for the karst water being discharged there.

The western section of Cristianul Mare compartment is included in the catchment area of the temporary surface stream Poiana, located in the Râpa Dracului region (Fig. 1, no. 24), which is shaped in Upper Jurassic limestone deposits. That

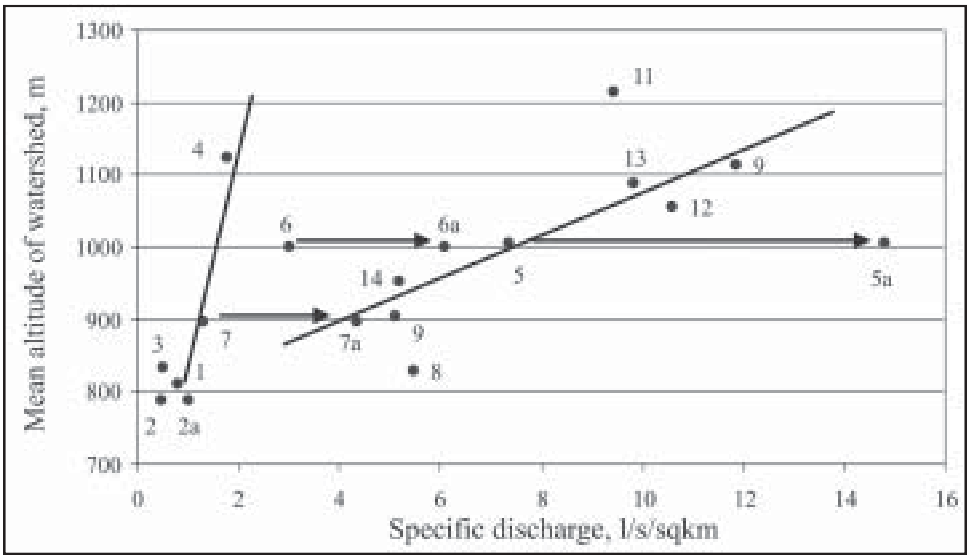


Figure 4. Average elevations of the various catchment areas, plotted versus the corresponding specific annual average discharge (q) computed for the period X. 1992 – IX. 1993. Significance of numbers as in tabel 1.

stream has the most extended catchment area in the massif (22.4 sqkm) and its very small specific flow rate (1.78 l/s/sqkm) indicates that a significant amount of infiltration is diverted into the underground, specifically up to 90% of the total amount of water which is available for runoff and infiltration in the concerned catchment area.

In the northern and the eastern sections of the concerned compartment, a few springs occur which discharge up to 5 l/s and which in most cases are related to fracture occurrences or to boundaries that separate reservoir formations (limestone or conglomerates) from impervious rocks: the springs Salvamont (Fig. 1, no. 15, 0.5 l/s), Grohotiş (no. 18, 1.5 l/s), Studenţilor (no. 20, 1.5 l/s), Poiana Ruia (Fig. 1, no. 21, 0.3 l/s), Vanga (Fig. 1, no. 22, 4.0 l/s), and a few springs in Groapa de Aur (no. 26, 3.0 l/s). The first three springs have been tapped in order to provide water supply for certain tourist huts in their neighborhood.

To the South, Cristianul Mare compartment is bordered by Cheia stream. Its catchment area is developed on a substratum that consists mostly (76%) of Late Cretaceous sandstones and conglomerates, and only to a smaller extent (22%) of limestone. At the southern end of Muchia Cheii the stream has excavated an impressive gorge: about 1 km in length and with its walls raising more than 200 m above the streambed. Several temporary springs, discharging significant flow rates during rainy periods, occur in the median section of the gorge.

Flow-gauging performed during the water-year X.1992-IX.1993 at gauging stations installed upstream and respectively downstream with respect to the gorge of Cheia (Fig. 2), yet still upstream with respect to the Cheia water intake, have indicated the occurrence of a permanent recharge-discharge relationship between the stream and the karst aquifer (Fig. 5). The difference in the debits upstream and downstream is positive in dry seasons, mainly in winter when the stream feeds the karstic aquifer and is mostly negative throughout the year, in rainy seasons when the aquifer feeds the superficial drainage.

Over the time interval 22 December 1992-20 January 1993, the recession coefficient calculated for the springs discharging in Cheia gorge has indicated an α value of 0.042, which was characteristic for a well-drained karst aquifer, that was highly conductive and poorly capacitive.

As soon as the stream Cheia leaves the section which is excavated in a limestone substratum, the most abundant groundwater outlet in Postăvaru Massif, designated as "Cheia water intake", becomes visible in the alluvial plain located on the left bank of the stream. The water intake consists of three chambers excavated down to about 2 m depth in the alluvial-deluvial deposits that host the water up flows occurring in that area. The water collected in the three chambers is conveyed to a half-buried tank, which is the starting point of the pipeline that supplies drinking water to the town of Râşnov. The excess flow is evacuated by an overflow conduit that reaches Cheia stream.

In the year 1980, the water supply services of Râşnov have been tapping from the Cheia water intake a flow rate amounting to 60-63 l/s, while the discharge conveyed through the indicated overflow conduit was fluctuating between 39.5 and 93 l/s (A. Cineti, 1980).

Since the Cheia water intake configuration definitely precluded the setting up of a weir-box was, volumetric measurements of the tapped flow rate have been performed each month at the tank in Râşnov town. Recorded flow rates ranged between 65 and 160 l/s, with an average value of 90 l/s.

A tracer test has been conducted on 23 October 1993, by injecting 20 g of In-EDTA in the swallet at Râpa Dracului (Fig. 1, no. 24), where the entire flow (10 l/s) of Poiana stream was sinking. Both the Cheia water intake (Fig.1, no.27) and the tapped spring of Râşnov (Fig. 1, no. 4) have been monitored for tracer detection, yet none of them provided a positive result. Since the tracing test had been performed during a draught period, we presume that most of the sunken water was carried away by a deep flow toward discharge areas located in the deposits which fill the depression of Braşov.

b. Râşnov Compartment includes mostly Late Vraconian sandstone and conglomerate terrains. Cetăţii stream runs across the northern part of that compartment, before sinking into the Early Jurassic limestone substratum through the alluvia that fill the depression inside which the sports and recreation ground "Cetatea" is located. The sunken flow presumably reaches the tapped spring in Râşnov (Fig. 1, no. 4), an outlet whose annual average discharge amounts to 6.0 l/s.

Within the limestone strip that occurs in Dealul Cernit and which occupies, according to M. Kusko et al., 1978, a tectonically up-lifted position (horst), or, according to M. Săndulescu et al, 1972, the position of a thrust outlier, there are located (Fig. 1, no. 7) the Râşnoava caves (across which the Infundat stream flows), as well as the pothole Spart and the cave Fundata (Fig. 1, no. 9), the latter having been extensively investigated by Margareta Dumitrescu and T. Orghidan (1958).

c. Cristian Compartment. The geological structure of the north-western section of Postăvaru Massif includes a multitude of normal and strike-slip faults, a setting which results in a puzzle-like distribution of various compartments which are built up of Anisian age limestone, of Jurassic age sandstone and clay, or of Late Jurassic age conglomerates.

Along the stream courses which flow across that area (Hotarul, Cristianul and Joaderul) there occur alternations of sections which, as a function of the streambed lithology (i.e. impervious rocks or limestone), exhibit or not a perennial surface flow. Significant in terms of the local hydrogeology is the swallet in Valea Hotarului, where the entire stream flow (2 l/s) sinks in the underground.

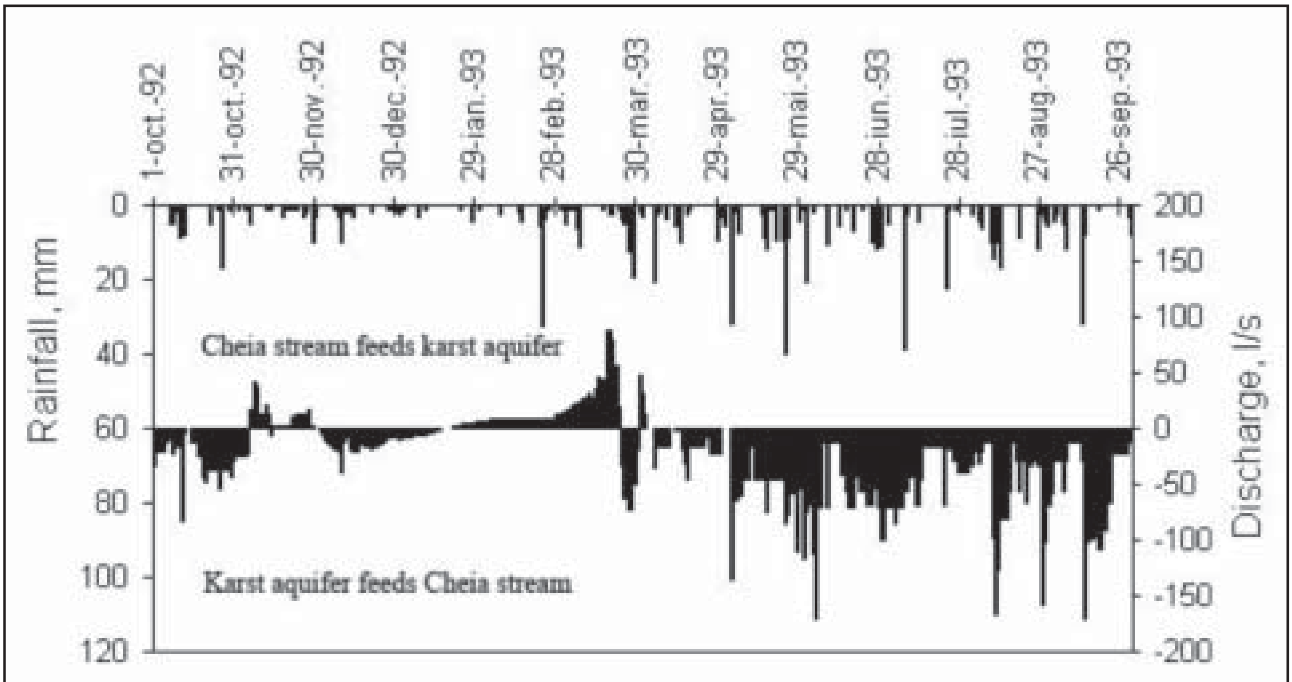


Fig. 5. Evolution of the recharge-discharge relationship existing between the karst aquifer and the stream Cheia, as the latter flows down the gorge. Rainfall recorded at Predeal meteorological station is indicated at the top of the chart

A few springs with a total average flow rate of 4 l/s, subject to a variation range between 1 and 8 l/s, occur in the alluvial plain located at the junction of the streams Cristian and Hotar. Căldării stream, that all the year round displays a small flow rate, runs across the northern section of Cristian Compartment. In the lower section of its stream course there is situated the outlet Fântâna Nistrii (Fig. 1, no. 1), which discharges a fraction of the groundwater accumulated in Dealul Negru.

The hill Spinarea Lungă exhibits mature surface karst landforms that consist of a multitude of sinkholes occurring at various levels, as well as some small sized caves. In the western section of that hill, the springs of Cabana Vânătorilor (Fig. 1, no. 41, 2 l/s) and Călugăr (Fig. 1, no. 14, 0.2 l/s) emerge from the limestone formation, close to the contact of that latter with the Braşov marls. Groundwater accumulations in that area discharge also toward the south-west, through the springs occurring at the headwaters of Cetăţii stream.

d. Braşov Compartment. Toward the north, the geological formations that outcrop in Postăvaru Mountains are progressively overlain by the deposits which filled the Braşov depression. Through the depression sediments however, two limestone hills (Tâmpa and Piatra Cerbului) still protrude, being bordered by valleys (Valea cu Apă and Răcădău streams) whose upper reaches are located deep into the main mountains body. In terms of hydrology, that area is frequently subject to a temporary surface flow whose discharges are small, but in any case larger than those of streams flowing on a limestone substratum. There are no springs at the border of the mountains body, a circumstance which implies that the groundwater accumulations in the mountain area directly discharge into aquifers hosted by the deposits that fill the depression.

In the catchment areas of the streams Răcădău and Valea cu Apă, an extended network of surface ditches and of ceramic pipes is used for tapping large water flows amounting to about 15, and 25 l/s respectively. When the indicated tapped discharges are considered in addition to the flow rates actually measured at the gauging stations (Table 1), the specific annual average discharges plotted in Fig. 4 increase to 6.11 l/s/sqkm for Valea cu Apă (point 6a) and to 4.36 for Răcădău (point 7a), the resulting values falling close to the q/H overall linear trend established for the entire massif. If, additionally, the flow rates measured at the flow-gauging station 5 are supplemented with the discharge of the Cheia water intake (located further upstream with respect to that gauging station), a much larger annual average discharge is obtained (14.8 l/s/sqkm). That circumstance indicates that the areal extension of the karst system which discharges through Cheia water intake significantly exceeds the surface catchment area of the stream which bears the same name.

As a conclusion, we can estimate that during the water-year X.1992-IX.1993, rainfall that occurred in the area considered for the water budget assessment has resulted in 1055 l/s of water available for runoff and infiltration, 30% of which discharged as surface flow, while 70% infiltrated in the underground. Out of the total amount of infiltrated water, only 19% (140 l/s) discharged through the springs located at the boundary of the considered area and by the network of water-intake drains existing in the catchment areas of the streams Răcădău (15 l/s) and Valea cu Apă (25 l/s), the remaining 81% (602 l/s) providing the underground flow that supplied groundwater accumulations located in the Braşov depression, an area bordering to the north and to the west the mountains body.

In order to investigate the groundwater chemical composition, water samples have been collected from springs discharging from Anisian limestone (3 samples), from Kimmeridgian-Tithonic limestone (16 samples), and from the Postăvaru conglomerates (3 samples). All water samples proved to be of calcium bicarbonate type and devoid of magnesium. The largest mineralization (513.7 mg/l) was that of water samples associated to Anisian limestone, with water samples originating in Late Jurassic limestone coming next (472.6 mg/l), while water samples originating in conglomerates displayed the smallest value (364.3 mg/l).

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