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HYDROGEOLOGICAL STUDY OF DÎMBOVICIOARA PASSAGE

BY

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A comprehensive hydrogeological study was performed in a 230 km^2 essentially carbonatic area of Piatra Craiului massif. Based upon the classical hydrogeologic research, the microtectonic observations, the radioactive and chemical tracers and the hydrometeorological data, the surface and groundwater balance is calculated, the hydrogeological basins of the main sources are delimitated, the relation between infiltration and surface drainage is established and the underground water resources are calculated.

1. INTRODUCTION

The syncline area developed between Leaota and Bucegi massifs on the east and the crystalline massif of Meridional Carpathians on the west, geologically known under the name of Dîmbovicioara passage, and including two distinct geomorphological units namely Rucăr—Bran passage and Piatra Craiului massif, has the shape of a fan widely opened to the North, to Brașov depression and closed to the south by crystalline basement uplift in Dragoslavele area.

The passage rough relief, having the western side raised in the Piatra Craiului massif, has a structure consisting of a succesion of synclines and antichines strongly divided by transverse faults, forming thus three large tectonic depressions: Bran, Podul Dîmboviței and Rucăr.

The present geological and structural image of this area, schematically represented in sketch no. 1, is the result of syntheses made by PATRULIUS (1969), PATRULIUS et al. (1971, 1972, 1974), and POPESCU (1964—1965).

The crystalline basement of the passage has a continuous dipping to the north, interrupted by a transverse uplift area along the alignment Coacăza Valley — La Om peak. It supports Jurrasic and Cretaceous deposits, having in their lower half massive and stratified, highly fractured limestones, 700—1200 m thick, of Kimmeridgian—Tithonic age. Two horizons having a maximum cumulated thickness of 100 m, including marly limestones, sandstones, microconglomerates and marls (lower Callovian-Bajocian) and massive limestones, marly and gresous limestones with cherts (upper Callovian—Oxfordian) are discontinuously developed between the crystalline shists and the limestones.

The cretaceous deposits have a succession consisting of glauconitic limestones, bioclastic limestones, marls and marly limestones (Hauterivian), marls and marly limestones with reef limestone lenses (Barremian), marls and reef limestones (lower Aptian), limestone conglomerates, polymictic conglomerates and limestone breccia (upper Aptian). The final part of the Cretaceous has a transgressive character and includes massive sandstones, polymictic conglomerates, carbonatic and micaceous sandstones alternating with siltites (Vraconian—Cenomanian) clayely marls (Turonian—lower Senonian), clays and conglomerates (upper Senonian).

To the north-east of the passage there are eocene deposits represented mainly by marls and secondarily by conglomerates and limestones. Sands, gravels and Quaternary clays have a local development.

2. HYDROGEOLOGICAL ZONES OF DÎMBOVICIOARA PASSAGE

The stratigraphic complexes in the Dîmbovicioara Passage have been distributed into 4 hydrogeological zones, according to their geological and hydrological characteristics :

— Zones of aquiferous accumulations of great extension, located in carbonatic rocks ;

— Zones of aquiferous accumulations of great extension located in consolidated detritic rocks ;

— Zones of unimportant or absent aquiferous accumulations.

The great extension aquiferous accumulations located in carbonatic rocks zones include the development area of the deposits of low Bajocian—Callovian age, medium Callovian—Oxfordian age, Kimmeridgian—Tithonic and Hauterivian age ; these deposits are located at the bottom of Dîmbovicioara passage sedimentary series and they are transgressive accros the crystalline shists of the basement. The aquiferous accumulations are located in the karstic voids and cracks of the carbonatic deposits.

The zones of great extension aquiferous accumulations located in consolidated detritic rocks occupy the largest area, and include the upper Aptian, Albian, Vraconian—Cenomanian age terranes, mainly represented by conglomerates and sandstones. Water accumulation and circulation through deposits occurs in cracks and intragranular spaces.

As there are no impervious rock packets with regional development between the carbonatic deposits and the sandstone-conglomeratic ones (the Barremian marls and low Aptian marls are thin and of local extension) the two hydrogeological zones form a unique aquiferous system, having a direct and permanent hydraulic connection.

The aquiferous system water recharge is acquired mainly from precipitation and secondarily from surface waters, collected from the crystalline frame in the passage southern part, wich infiltrate totally (Fundăţica Valley, Crov Valley, Raţa Valley), or partially (Cheia, Ghimbav and Rudăriţa Valley) through alluvial deposits in river bed to the limestone or sandstone-conglomeratic sub-layer. The precipitation that fall on the limesone ridge and slopes of Piatra Craiului and Gîlma Pleşii primarily infiltrate almost directly on the outcrop surface of the limestones, the sandstones, the conglomerates and secondarily, after a short organization and a short route, disappear through sinks (Lupu, Seaca Pietrelor, Peştera and Izvorului Valley).

The aquiferous system is discharged by means of a series of sources (Table 1) as for example :

Table 1

The main sources of the Dîmbovicioara Passage

Denomination	Discharge l/s	Remarks
Hydrographic basin of Bîrsa River		
Valea Prăpastiei sources	790 [1])	75 % collected
Toplița source	100	Collected
Măgura I source	15	Collected
Măgura II source	5	Collected
The sources near Ulmului Valley and Coacăzei Valley junction	30 [1])	Uncollected [4])
Valea Sbîrcioarei sources	25 [1])	Uncollected [4])
Valea lui Nenu source	7	Uncollected [4])
Gîlgoaie sources on the Ulm Valley	10	Uncollected [4])
Valea Grădiștei sources	8	Uncollected [4])
Valea Moeciu sources (La Cascadă)	50	Uncollected [4])
	1040	
Hydrographic basin of Dîmbovița River		
La Gîlgoaie sources on the Dîmbovicioara Valley	320 [1])	Uncollected [4])
Cheile de Jos ale Dîmboviței sources	800 [1])	Uncollected [5])
Plai sources	50	Uncollected [2, 4])
Uluce Cave source	40	Uncollected [2, 3, 4])
The source located in the front of Uluce Cave	60	Uncollected [4])
Valea Izvorului sources	20	Uncollected [4])
	1290	

2330 l/

[1] Cumulated discharge.
[2] The water muddied in the abundant precipitation period.
[3] Pollution danger.
[4] Optimal conditions for collect.
[5] Hard conditions for collect.

— The springs in Prăpastia Valley. The sources of Prăpastia basin have a yearly medium cumulated flow rate of 790 l/s and radially concentrate the waters infiltrated from the bottom of the limestone slopes of Piatra Craiului massif curving area and partially the waters from Piatra Mică and Măgura area. These springs appear both from limestones and from conglomerates, in a highly fractured and folded area. They are collected in a 3/4 degree for water supply of Zărnești town.

— Toplița spring. It is located on the northern slope of Piatra Craiului syncline, some 1,5 km away from Zărnești town. It emerges from colluvial deposits, having a yield of some 100 l/s and discharges the waters from the northern flank of Piatra Craiului syncline using Toplița fault and its breakage area as a drain for the accumulations discharge. It is collected for Zărnești town water supply.

— „La Gîlgoaie“ springs. These springs are located on the right side of Dîmbovicioara creek, about 1 km upstream the junction with

Muierea Valley and emerge in a highly tectonised area, from the bottom of a Neojurasic limestone deposit, covered by Hauterevian limestones and Barremian marls. The group is represented by 4 springs disposed on a 30 m distance, having a total flow rate of about 50 l/s and represents the southern end of a spring line extending upstream on about 400 m up to the point called "La Bile". The springs along this line are temporary or permanent, with a cumulated flow of about 20 l/s and some of them release gases having a composition similar to that of the atmospheric gas ($N_2 = 77\%$, $O_2 = 20{,}7\%$, $CO_2 = 1.04\%$, $Ar = 0.916\%$, $CH_4 = 0.0112\%$ — volumetric percentages).

— The springs of Plai. They are located immediately downstream the Peştera Valley and they represent partially the resurgence of the waters infiltrated through the sinks on Peştera Valley (CONSTANTINESCU, 1976). They come out on bedding planes of the Neojurasic limestones and are represented by a permanent source having a medium flow of 50 l/s and an overflow located about 10 m upstream.

— The springs in "Cheile de Jos" of Dîmboviţa river, are located on the southern end of Dîmbovicioara passage on both sides of the river, between the junctions with Cheia Valley and Ghimbav Valley, on a distance of about 2 km. By these sources, that are to be found close to the boundary with the crystalline area, in a highly tectonised environment where the crystalline basement together with the sedimentary cover was steplike uplifted along a transverse faults system, a great part of the aquiferous system of Dîmbovicioara passage is discharged. These springs come out both above stream level and in riverbed and have a cumulated flow of about 800 l/s out of which about 300 l/s belong to the first category.

The microtectonic profiles through the limestones and the conglomerates of the Piatra Craiului syncline evidenced two main systems of open cracks: a system of cracks directed normally to the folds axis, paralel to the compression forces direction that generated the folding and a system of cracks paralel to the syncline axis. The first system has mainly the role of concentrating the ground waters to the middle of the structures wherefrom they are conducted by the second cracks system to the large discharge areas located in the axis ends of the synclinal structure (The springs from "Prăpastia Valley" and from the "Cheile de Jos" of Dîmboviţa river).

Three tracing experiments have been performed by means of radioactive and chemical tracers to establish the main directions and the hydrogeological parameters of ground waters drainage from Dîmbovicioara creek and "Cheile de Jos" of Dîmboviţa river basins. The first tracer, a Bromine — 82 solution was injected in a seepage zone through alluvial deposits in the bed of "Valea Seacă a Pietrelor" at 1265 m altitude (0.5 l/s flow rate). The tracer came out in "La Gîlgoaie" springs located 4 km downstream and at 940 m altitude, after 120 hours from injection and the last labelled molecules passed through the measuring point after 260 hours (fig. 1).

The second tracing experiment was performed in the diffuse sink (975 m altitude, 5 l/s flow), in the tithonic limestones on the "Izvorului"

Valley, a left hand tributary of Dîmbovicioara river. The injected tracer, Iodine—131, was detected on ions exchanger filteres located in "Cheile de Jos" of Dîmbovița springs at a horizontal distance of 4.25 km. and 725 m altitude. As these springs emerge along a line of about 2 km. length, the filters have been located in three points : upstream, downstream and in the median part of the springs line. Tracer transfer curve is presented in fig. 2.

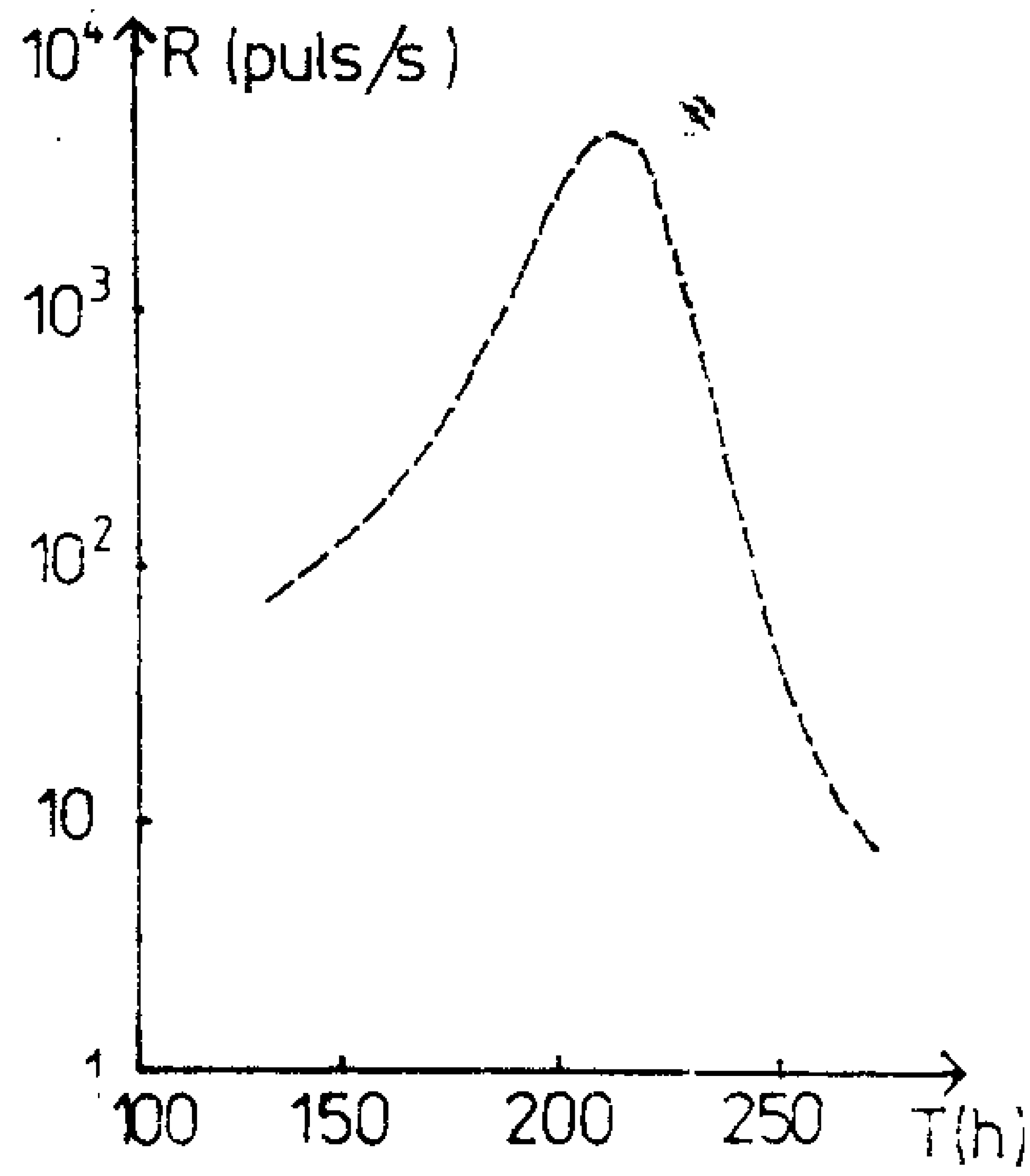

Fig. 1. Diagram of the counting rate variation during 29.07.1980 — 08.08.1980 at Gîlgoaie springs (Dîmbovicioara valley) Bromine — 82 as tracer.

The karstic waters dynamics in Cheia area was studied with two tracers : fluorescein for tracing the waters entering in the sink of Cheia and sodium dichromate for the waters of Cheia brook, downstream the sink (Fig. 3). Both tracers have been detected in the Uluce Cave resurgence (fig. 4). The sodium dichromate presence indicating difuse infiltrations through the valley bed alluvial deposit.

The reduced aquiferous accumulations located in unconsolidated detritic rocks are restricted to the alluvial plains of the main rivers, to the slope detritus and to the dejection cones. The water accumulations in these deposits are reduced and have a strictly local importance.

The unimportant or absent aquiferous accumulation areas include the crystalline grounds on the frame and in the middle of the passage, as well as the surfaces covered mainly by marly deposits of Barremian, low Aptian, low Turonian—Senonian, upper Senonian and Eocene age. All these rocks have a low permeability and do not practically contain aquiferous accumulations.

3. WATER CHEMISTRY

The waters of Dîmbovicioara passage sources are calcium-bicarbonate whith a very low mineral concentration. The springs emerging from Aptian conglomerates, sandstones and Vranconian-Cenomanian conglomerates have a similar chemistry variation range showing a very small difference to that of waters emerging from limestones. This uniformity is mainly due to the very tectonised geological structure that alows the seepage waters to cross the deposits with various lithologic structures, being enriched with ions characteristic for both deposit categories.

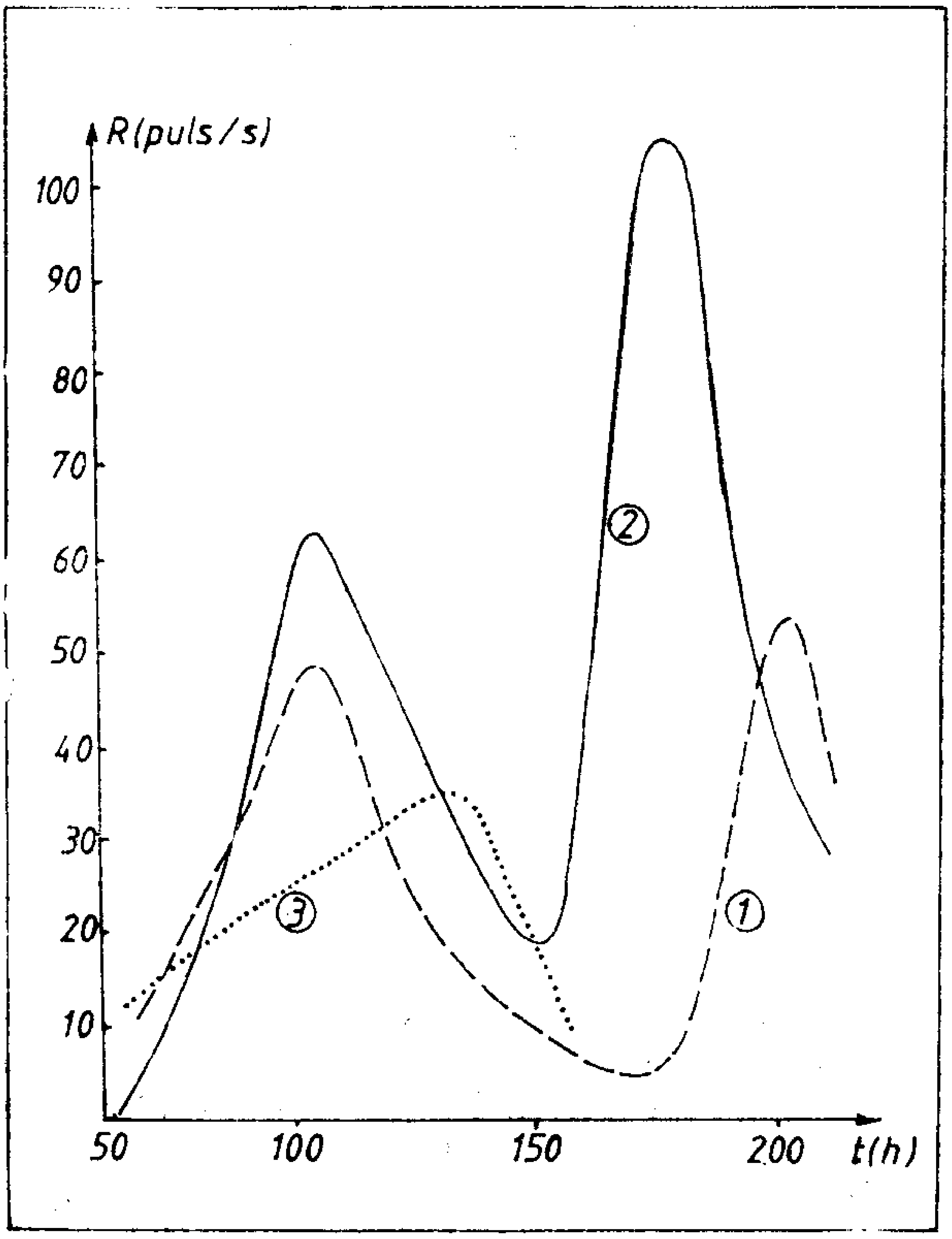

Fig. 2. Diagrams of the counting rate variation during 29.07.1980 — 07.08.1980 at the springs of the upper (1), middle (2) and lower (3) reaches of the Lower Dîmboviţa Gorges. Iodine — 131 tracer.

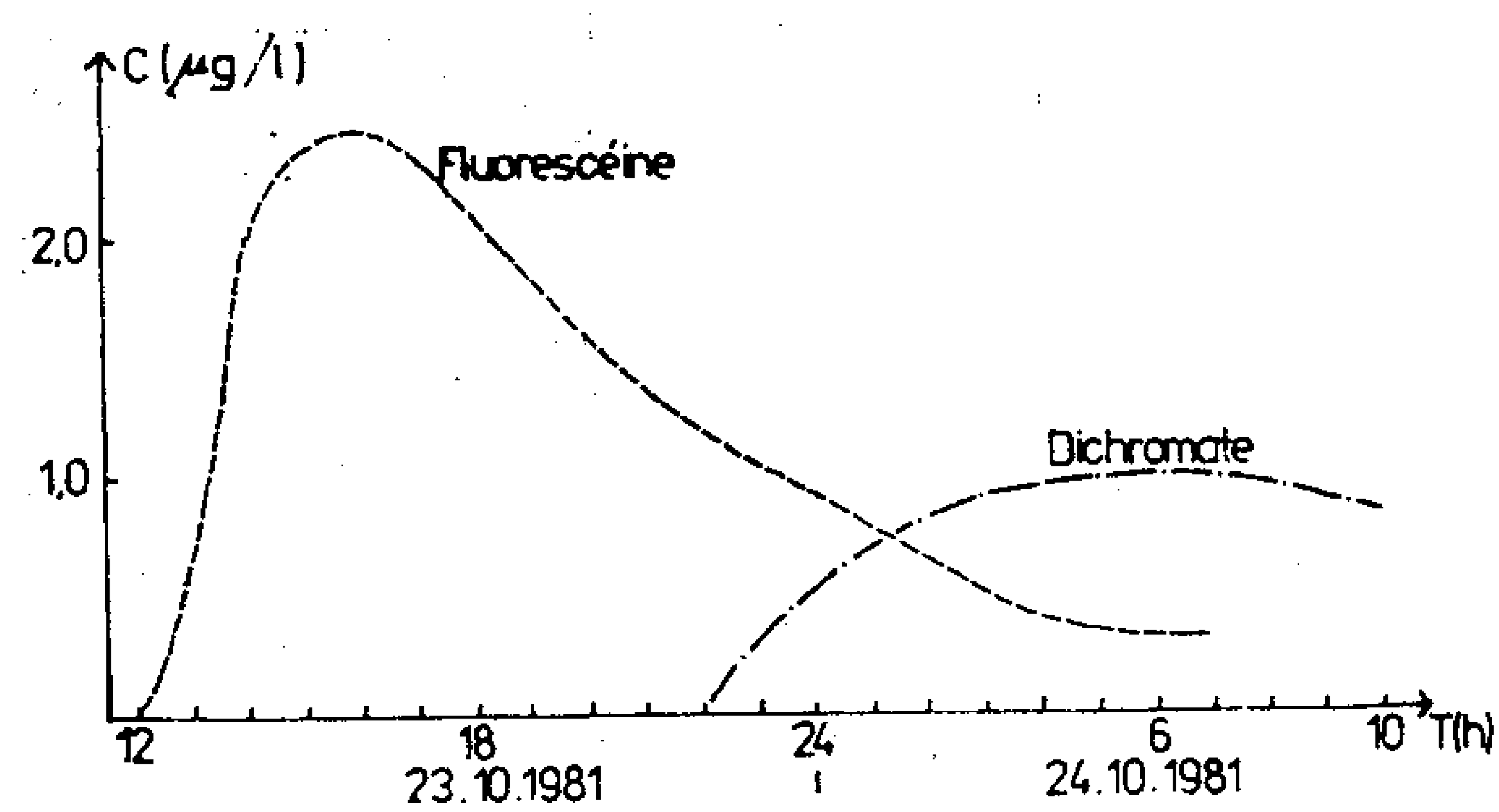

Fig. 4. Diagrams of the variation of fluorescein and dichromate concentration in Uluce outflow cave.

4. HYDROLOGICAL BALANCE EVALUATION OF SURFACE AND DEEP WATER

The high value of infiltration on the surface covered by carbonatic deposits produces the reduction of the quantity of the water available for runoff and evaporation. Due to the irregularity of the field of frac-

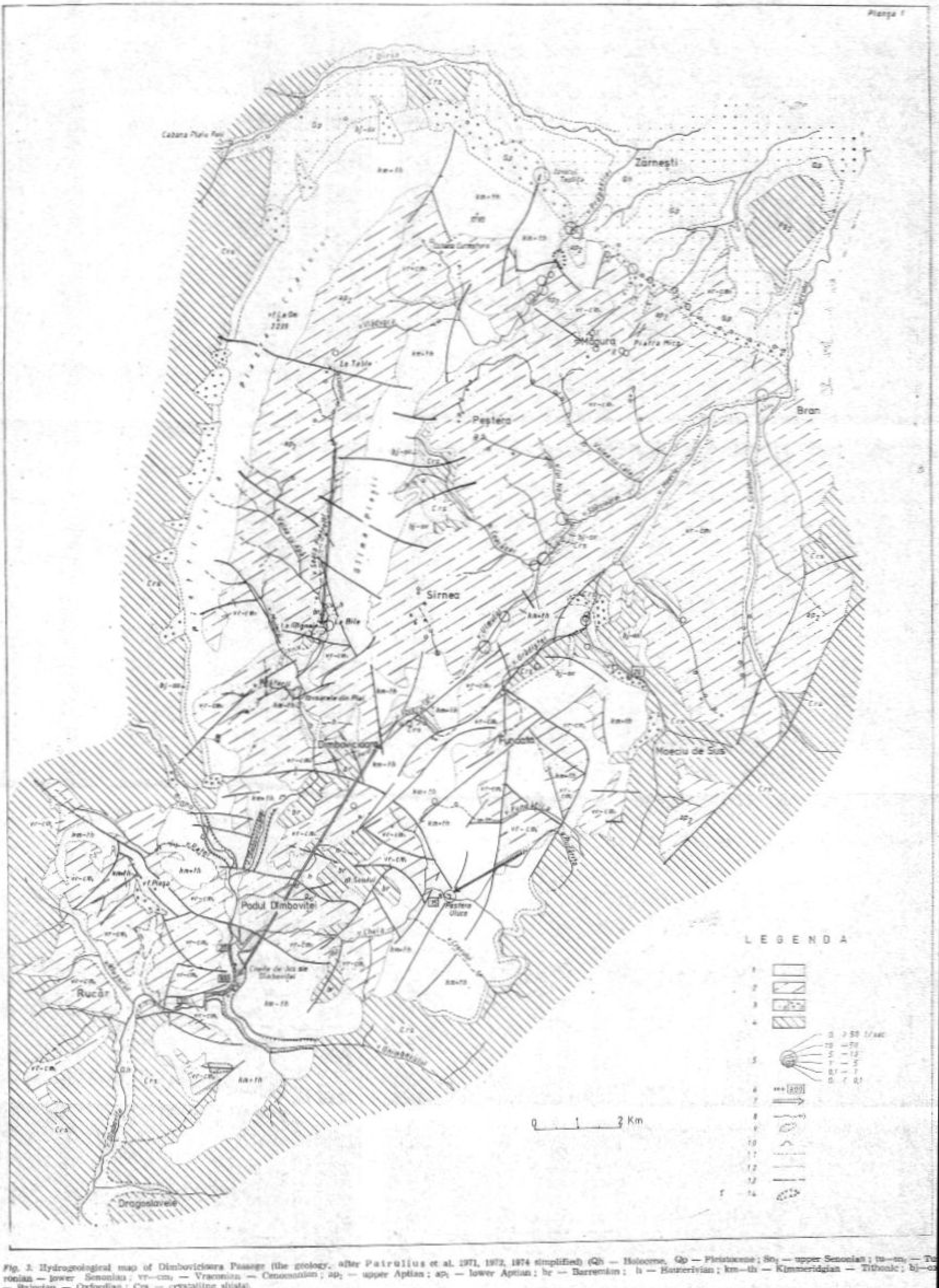

Fig. 3. Hydrogeological map of Dimbovicioara Passage (the geology, after Patrulius et al. 1971, 1972, 1974 simplified) (Qh — Holocene, Qp — Pleistocene; Sn_2 — upper Senonian; tu—sn_1 — Turonian — lower Senonian; vr—cm_1 — Vraconian — Cenomanian; ap_2 — upper Aptian; ap_1 — lower Aptian; br — Barremian; h — Hauterivian; km—th — Kimmeridgian — Tithonic; bj—ox — Bajocian — Oxfordian; Crs — crystalline shists).

Explanation; 1 — zones of aquiferous accumulations of great extension located in carbonatic rocks; 2 — zones of aquiferous accumulations of great extension located in consolidated detritic rocks; 3 — zones of aquiferous accumulations of low extension, located in detric unconsolidated rocks, a — in sand alluviums; b — in rocks slope debris; 4 — zones of unimportant or absent aquiferous accumulations; 5 — spring; 6 — line of springs with a cumulated flow of 800 l/s; 7 — flow direction of underground waters, as established by tracers; 8 — swallet; 9 — sinkhole; 10 — cave; 11 — normal geological boundary; 12 — transgression boundary; 13 — fault; 14 — quarry.

tures and to the different karstification degree, establishing the amount of infiltration in the karstic area is very difficult; that is why this evaluation is performed indirectly, using hydrological methods for river sections and the water balance method for surfaces.

An infiltration detailed analysis (probable maximum values, infiltration capacity of karstic areas, infiltration and circulation velocity according to the underground storage state, etc.) must take into consideration a number of short time periods (a decade, a month) when the ground water storage variation should be considered and a very accurate calculation of evapotranspiration shold be performed, as the water infiltrated in the karstic areas is always to be recovered after a shorter or a longer period of time in the flows of spirngs or rivers from the karstic area boundary. If the period is long enough (a hydrological cycle for instance), the losses are compensated by suppplies, achieving thus only a gross infiltration estimation for which the flow-rates recording is sufficient.

The runoff at the outlet of a basin is composed of several components, such as direct surface runoff, interflow and groundwater discharge, contributed by different natural storage and conveyance systems existing in the basin. These systems are not isolated from each other and are in general closely interrelated. For example, when direct surface runoff occurs as a result of a storm over the basin, change in subsurface contribution is also observed. Depletion of soil moisture also strongly influences the runoff process, etc.

The first step in studying these hydrologic systems and their interrelation is to proceed to a hydrograph analysis and separate each component.

The yearly hydrologic balance elements for surface and ground waters in a karstic area are shown in Table 2. When computing the

Table 2

Annual hydrologic balance elments of deep and surface waters from Dîmbovicioara Passage

Imputs (mil. m^3)	Outputs (mil. m^3)	
Precipitation, P	Evapotranspiration,	E
	Discharge,	Q
	— runoff,	R
	— emergences (sources),	Q
	Effective infiltration,	I

$$I=P-E-R-Q$$

decade period balance, the ground water storage variation, S is also introduced in the calculations :

$$P=E+R+I\pm S \qquad (1)$$

where P is the precipitation, E, evapotranspiration, R, direct surface runoff, I, the effective infiltration. The effective infiltration shall be calculated by difference, using for the decade balance, the following expresion :

$$I=P-E\pm S-R \quad (2)$$

and for the yearly evaluation, the following :

$$I=P-E-R \quad (3)$$

P—E±S term and P—S respectively, from relations (2) and (3) represents the precipitation amount available for runoff and infiltration, and the difference between this quantity and the R runoff may have a negative or positive value, as a result.

A positive value of the infiltration obtained from a yearly balance indicates that the inputs into the basin are higher than the losses (outputs), that part of the water volume infiltrated on the hydrographic basin surface is directed to other hydrogeological units, that the hydrographic basin surface for which the balance is computed, is actually larger than the hydrogeological basin surface initially taken into account. When a negative value of infiltration is obtained, all elements mentioned above have a reverse significance.

In the case of a decade balance, the significance of a positive or negative value for the effective infiltration may be restricted, indicating only a taking into or releasing from storage of ground water, without mandatarily implying any hydrodynamic relations with other hydrogeological units.

The hydrogeological balance is computed for November 1979—Octomber 1980 period. The studies performed at Curmătura (1460 m) alt.), Dîmbovicioara (960 m alt.), Podul Dîmboviţei (725 m alt.), Rucăr (695 m alt.), Zărneşti (720 m alt.), Plaiu Foii (831 m alt.), Fundata (1400 m alt.) and Moeciu de Sus (1530 m alt.) have been taken into account for precipitation both vertical and yearly seasonal distribution analysis. The direct surface runoff regime was controled by 10 hydrometric stations, the actual evapotranspiration was established based upon the studies carried out at Poiana Braşov, Moeciu de Sus and Dîmbovicioara stations. The distribution of the water storage was performed according to the measurements from 8 stations located on different pedogeographic formations in respect to bedrock characteristics, altitude, slopes and afforestation degree.

Interpretation of variation graphs for efficient infiltration obtained by the decade balance computation shows for Prăpastia creek hydrographic basin (Fig. 5.1.) an infiltration value much lower than that of the discharged yields, the infiltration deficit displaying high values (up to 940 l/s) for long periods. Only during spring time, the large infiltration occured as a consequence of snowmelting may be accounted for the value of the total volume released from this basin. For the hydrographic basin of Dîmbovicioara creek an opposite phenomenon is noticed, namely the infiltration has mainly positive values and the maximum infiltrated yields may achieve 1800 l/s on the whole basin surface (Fig. 5.2.).

The yearly hydrologic balance of surface and deep waters in the Prăpastia creek hydrographic basin (Table 3) indicates an additional supply exceeding the available water quantity of the hydrographic basin surface (22,5 km^2) by about 13 mil. m^3 of water. The flow discharged by the sources existing in the Prăpastia creek catchment area accounts for a basin surface of 52 km², and if the surface of about 5 km², corresponding to the Toplița spring, partly discharging the same structure, is added a total recharge surface of about 57 km² is obtained.

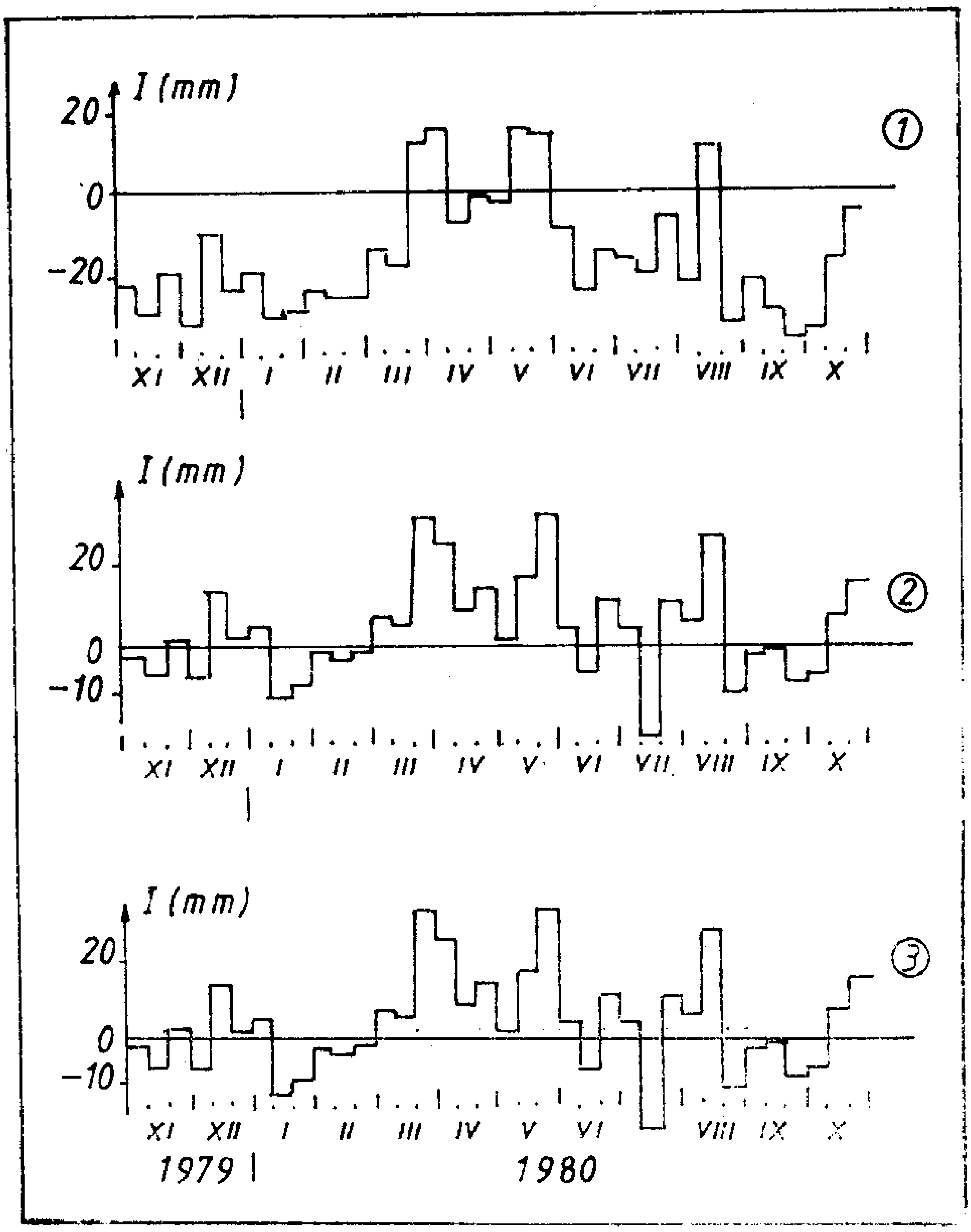

Fig. 5. Decadal variation of the efficient infiltration on the hydrographic basins of Prăpastia (1) and Dîmbovicioara (2) creeks and of the karstic area of Dîmbovița river (3).

Table 3

Annual hydrologic balance elements of deep and surface waters from Prăpastia creek basin

Input (mil. m³)	Output, (mil. m³)	
Precipitation, P=19.2	Evapotranspiration, Runoff, Emergences,	E = 6.30 R = 7.55 Qw = 18.21
	Total output	32.06

$$I = P - E - R - Q_w = -12.86 \text{ mil. m}^3/\text{year}$$

The additional surface of about 34 km² that takes part to the supply of Prăpastia Valley and of Toplița spring sources includes the outcrop area of limestones on the northern part of the Piatra Craiului up to „La Om" peak (about 9 km²) and a great part of Turcului brook hydrographic basin. The accurate delineating of the underground water-shed between the hydrogeological basins of Prăpastia basin sources and the Turcului brook basin is possible only in the western part where it follows the outcrop boundary of the crystalline schists.

The reduced discharge variation of sources in the Prăpastia Valley in respect to the precipitation regime (Fig. 6) suggests important under-

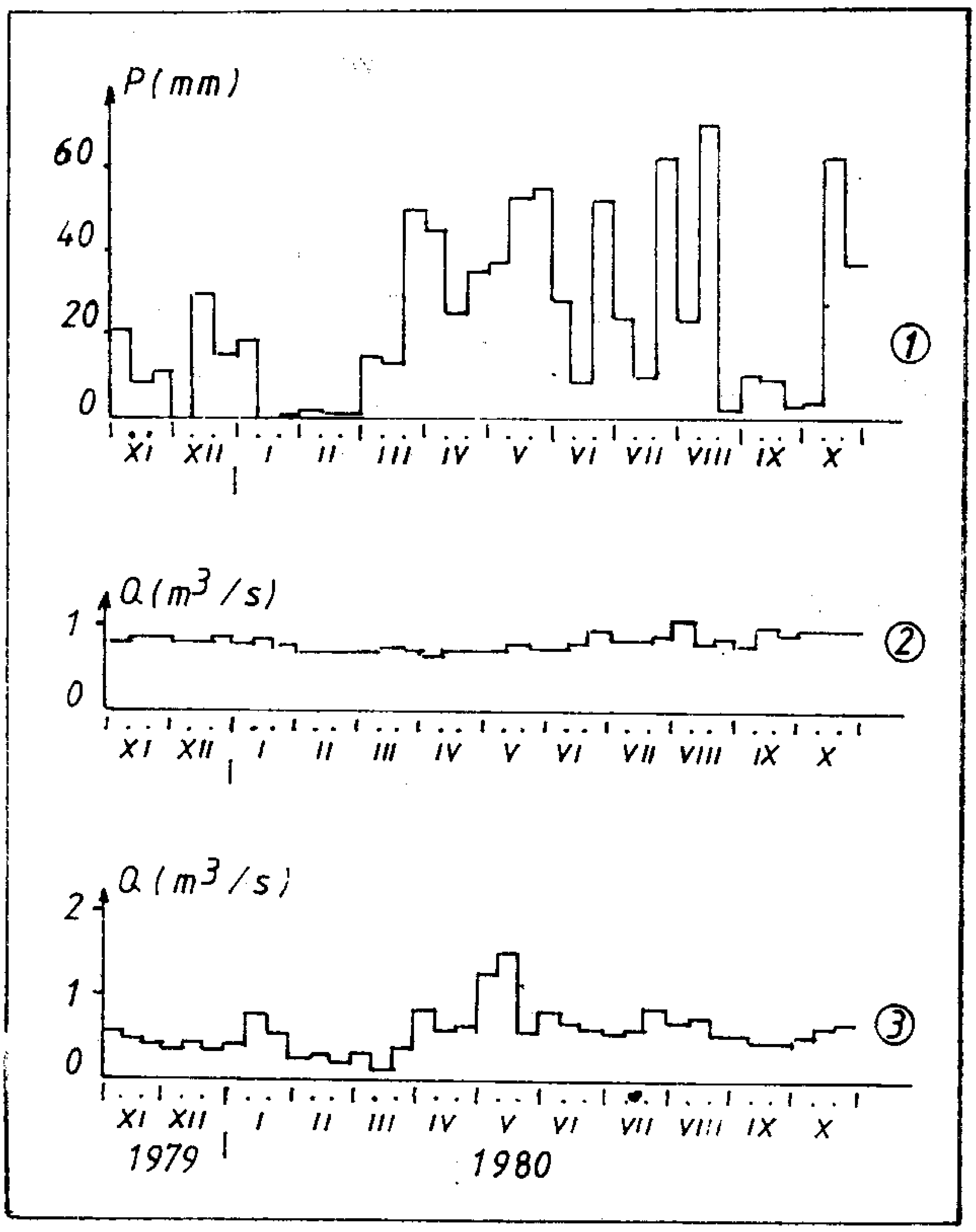

Fig. 6. Decadal variation of the rainfall on the investigated area (1) and of the cumulated yields discharged on Prăpastiei (2) and Dîmbovicioarei (3) valleys.

ground water storage, located mainly in the limestone joints, in the sandstones and conglomerates joints and intergranular spaces and only secondarily in great karstic voids and pipes. These characteristics indicate at the same time the existence of a young, incipient karst in the Piatra Craiului massif.

The yearly hydrologic balance of surface and deep waters in the Dîmbovicioara creek hydrographic basin (Table 4) indicates a drainage deficit of 8.6 mil. m^3 water, a water volume that is partially recovered in the "Cheile de Jos" of Dîmbovița river sources discharge.

The study of the respective perimeter hydrogeological conditions evidenced that are partially directed to the sources from the "Cheile de Jos" of Dîmbovița river, besides the waters infiltrated on the Dîmbovicioara basin also the waters infiltrated on the limestone surface of the Piatra Craiului western side, starting from "La Om" peak to the south (5.5 km^2) as well as the surfaces covered with sedimentary deposits in the catchment areas of Cheia creek (19 km^2), Ghimbav creek (5 km^2) and Dîmbovița river (10 km^2), situated in the Podul Dîmboviței — Rucăr area, away from the hydrographic basins of the above mentioned creeks.

Table 4

Annual hydrologic balance elements of deep and surface waters from Dîmbovicioara creek basin

Imput, (mil. m^3)	Output (mil. m^3)	
Precipitation, P=41.7	Evapotranspiration,	E =13.60
	Runoff,	R = 9.15
	Emergences,	Q =10.35
	Total output	33.10

$I=P-E-R-Q=8.6$ mil. m^3/year

The volume of annual infiltrations occured on these additional surfaces of 39.5 km^2 is of 16.86 mil. m^3; if this volume is added to that in filtrated on the hydrographic basin surface of Dîmbovicioara creek, a total water volume discharged by the sources from the „Cheile de Jos" of Dîmbovița river of 25.46 mil. m^3 (about 800 l/s) is obtained. The hydrometric measurements performed on this section of Dîmbovița river indicated similar supplies to those obtained by means of water budget calculations.

Determination of hydrogeological basins surfaces for Prăpastia and Dîmbovicioara creeks as wel as the knowledge of the yields discharged annually from these, permit the calculation of the specific infiltration value, i=508 mm/year (16 l/s/km^2) and i=425 mm/year (13.5 l/s/km^2).

On the surface covered by Dîmbovicioara passage sedimentary deposits (about 230 km^2) the precipitation during the hydrologic year November 1979 — October 1980 created an available amount of 571.6 mm to which a water volume of about 131 mil. m^3 (4.1 m^3/s) corresponds. From this volume, an amount of about 99 mil. m^3 (3.1 m^3/s) namely 75% has been infiltrated underground and a volume of about 32 mil. m^3 (1m^3/s) that is 25% was discharged by direct runoff. The infiltrated fraction contributed to the continuous rebuilding of the ground water storage, that is permanently tapped by the springs located mainly at the passage boundary.

From the total quantity of the infiltrated water, which accounts for the total dynamic reserves of the perimeter, more than one half is discharged by three big spring groups (the springs of Prăpastia Valley, the springs of „Cheile de Jos“ of Dîmboviţa river and the springs „La Gîlgoaie“ from the Dîmbovicioara Valley“). The dynamic reserves from the northern part of the perimeter are exploited under 75% and those from the southern half are entirely unused.

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STUDIUL HIDROGEOLOGIC AL CULOARULUI DÎMBOVICIOARA

Rezumat

Lucrarea prezintă rezultatele studiilor hidrogeologice complexe efectuate într-o zonă muntoasă cu o suprafaţă de 230 km^2. Această zonă de formă sinclinală, cu şisturi cristaline în fundament şi pe flancuri, are în bază un complex carbonatic, iar la partea superioară unul consolidat detritic (gresii şi comglomerate). În cele două complexe sînt localizate acumulări acvifere cu extindere mare care formează un sistem acvifer unic, în legătură hidraulică directă şi permanentă.

Pe baza cercetărilor hidrogeologice clasice, a observaţiilor microtectonice, a marcărilor cu trasori radioactivi şi chimici şi a datelor hidro-meteorologice este întocmit bilanţul hidrogeologic al apelor de suprafaţă şi adîncime, sînt delimitate bazinele hidrogeologice ale principalelor surse, este stabilit raportul dintre infiltraţie şi scurgerea superficială şi sînt calculate resursele de ape subterane.

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