3.5. DÂMBOVICIOARA PASSAGE

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` The Dâmbovicioara Passage consists of a wide syncline structure that extends between the mountains Leaota and Bucegi to the east, and the crystalline body of the Southern Carpathians to the west. Within its fan-shaped domain, widely opened toward Braşov Depression (to the north), and closed (to the south) by the crystalline basement uplift of Dragoslavele area, two distinct geomorphologic units occur: Piatra Craiului mountains body and Rucăr-Bran trench.

1. Physiography

The rough topography of the passage, with its western limb uplifted in Piatra Craiului mountains body, includes a folded structure that consists of a succession of synclines and anticlines, highly dissected by transverse and longitudinal faults which delineate three large tectonic depressions: Bran, Podul Damboviţei and Rucăr.

Piatra Craiului mountains body, shaped entirely in a Tithonic limestone substratum, is striking mainly north-south and reaches its maximum elevation (2238.7 m) in the peak "La Om". The northern section of the mountain-ridge exhibits a gradual clockwise bending, so that eventually, starting from Turcului peak (1923 m), the ridge assumes an overall southeastward-directed strike, in a region that is designated as Piatra Craiului Mică.

The mountains body topography is dominated by the main ridge, which extends between the settlements Zărneşti and Podu Dâmboviţei (Fig. 1). With its jagged appearance and a width that occasionally does not exceed 1 m, the ridge dominates the region where the junction between the Eastern and the Southern Carpathians occurs. The total length of the ridge amounts to 23 km, while the width of the carbonate deposits which build it up ranges between 0.4 and 2 km. The considered limestone outcrops occupy an area extending over 25 km^2.

Rucăr-Bran trench lies sunken about 1000 m below the stone cliffs which border it to the east and to the west, its elevation being symmetrically distributed with respect to a maximum altitude central axis that strikes NW-SE, along the lineament Fundata-La Table-La Om peak. Divergently from that lineament, the ground elevation gradually falls by roughly 600 m to the NE, down to Zărneşti embayment – a distinct section of Braşov inter-mountain depression - and to the SE, down to the sub-Carpathian depression of Câmpulung. Considered as a whole, that region breaks the geographical continuity of the Southern Carpathians, being recognized and intensely used as a traveling pass since ancient times.

The limestone ridge Gâlma Pleşii, which extends between Vlăduşca valley and the settlement Ciocanu, is the central topographic feature of the passage area. Between that ridge and the main ridge of Piatra Craiului there occur the upper reaches of the Dâmbovicioara stream catchment area.

Streamflows located in the northern section of the passage - Prăpastiei, Turcului (Sbârcioarei), Moeciu and Simion - are tributaries of Bârsa river, while those occurring further to the south are tributaries of Dâmboviţa. That latter river has entrenched in the Late Jurassic limestone deposits belonging to the Piatra Craiului syncline southern sector a couple of spectacular gorge sections, which are separated from one another by the tectonic depression of Podu Dâmboviţei, where the junction with Dâmbovicioara stream occurs. Tributaries are absent along the gorge section designated as "Cheile de Sus", which precedes the above-indicated depression; conversely, two significant tributaries, Cheia and Ghimbavu, join the main river in the gorge section located further downstream ("Cheile de Jos").

The commissioning of Clăbucet hydropower station and of the associated reservoir-lake at Pecineagu (1983) has induced in the Dâmboviţa stream discharge a pulsatory regime. In terms of karst-related processes, the latter circumstance resulted in enhanced seepage through the streambed

- a consequence of alluvial deposits being washed out and of cracks becoming un-clogged. Consequently, nowadays, during the low water season, about 200 l/s of the total discharge of the river Dâmboviţa is sinking in the underground in the gorge section "Cheile de Sus".

The upper reaches of Dâmbovicioara stream occur south of the La Table area (1376 m elevation), with the corresponding various stream sections being designated as Valea Lupului (down to the junction with Grind brook), Seaca Pietrelor valley (down to the junction with Valea cu Apă), Brusturet valley (down to Gâlgoaie). In that latter spot, the Gâlgoaie - La Bile group of springs contribute with substantial amounts of water-inflows, while further downstream the watercourse bears the name Dâmbovicioara. During most part of the year, Valea Lupului and Seaca Pietrelor valley sections are devoid of water, which is sinking through the streambed alluvia into the conglomerate or limestone substratum. Actually, every right-side tributary coming from Piatra Craiului mountains body (namely Valea cu Apă, Valea Muierii, Valea Peşterii, Valea Popii) is subject to a hydrological regime analogous to that of the above mentioned valley sections. There occur no landforms which could be ascribed to the classical "swallet" or "blind valley" types.

At the junction with Valea Peşterii, inflows provided by the springs "din Plai" result in a significant increase of the flow-rate of Dâmbovicioara stream. Still further downstream, there occur only temporary and low discharge tributaries, both on the main stream left side (Valea Izvoarelor) and right side (Valea Popii, Brătoaia valley).

Dâmbovicioara stream catchment area extends over 49.1 km^2, at an average altitude of 1195 m, with the elevation drop between the head water area (La Table, 1376 m) and the junction with Dâmboviţa river (737 m), amounting to 639 m. When considered only down to Gâlgoaie region, the catchment area of Dâmbovicioara stream amounts to 24.4 km^2, extending at an average altitude of 1450 m.

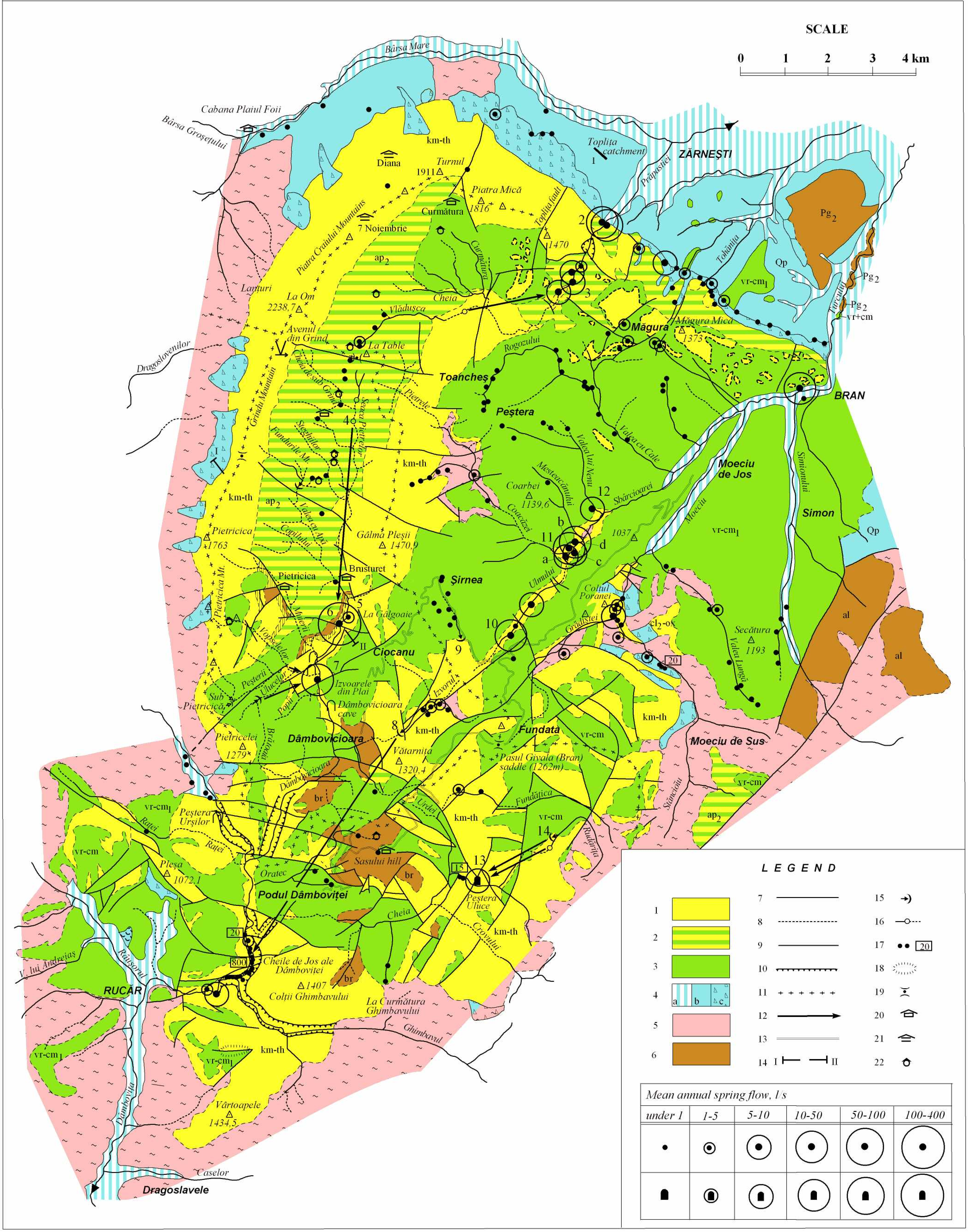
1.1. Climate data

A significant number of meteorological stations (6) and rainfall gauging stations (14) occur within the Rucăr-Bran trench realm, a circum-

Figure 1. Hydrogeological map of Dâmbovicioara Passage. (Geological data after R. Dumitrescu et al., 1971, 1974, D. Patrulius et al., 1971, M. Săndulescu et al., 1972).

Legend:

1 Thick series of Mesozoic carbonate deposits, highly fractured and moderately karstified, displaying very high effective infiltration values and being subject to intensive groundwater flows. Important water resources in large karst systems;
2 Coarse, prevalently carbonate molasse deposits of Late Aptian age (carbonate conglomerates and breccia), subject to groundwater flows through fissured, porous and karst media. High effective infiltration values are suggested by the temporary character of the surface flows. Important resources supplying the underlying karst aquifer;
3 Vraconian-Cenomanian molasse deposits (sandstones, conglomerates, shales) subject to groundwater flows through porous-fissured media. Aquifer accumulations supplying the underlying karst aquifer and permanent surface flows;
4 Quaternary unconsolidated detritic deposits (sands, gravels, occasionally clays) of reduced thickness and extent, subject to intensive groundwater flows and hosting reduced groundwater resources of local importance (1-Holocene; 2a-Pleistocene; 2b-slope debris);
5 Metamorphites with extensive fracture networks and a well-developed weathering zone, which provide a continuous and important supply toward river flows and binary karst systems;
6 Marly and argillaceous deposits, devoid of groundwater flows;
7 Perennial stream course;
8 Temporary stream course;
9 Fault;
10 Abrupt;
11 Watershed;
12 Underground flow connection proven by tracer tests;
13 Road;
14 Direction of hydrogeological cross section;
15 Swallow hole, swallet;
16 Site of tracer injection into flow sinking diffusely through the streambed;
17 Group of springs of 20 l/s cumulated discharge;
18 Karst depression;
19 Saddle;
20 Tourist and forestry chalet;
21 Shelter;
22 Shephards' hut.



SCALE
0 1 2 3 4 km
Bârsa Mare
Cabana Plaiul Foii
Bârsa Groşeţului
Topliţa catchment
ZĂRNEŞTI
Prăpăstiei
Diana
Turnul
1911
Piatra Mică
1816
Curmătura
7 Noiembrie
Piatra Craiului Mountains
Topliţa fault
1470
Pg2
Qp
Tohăniţa
vr-cm1
Lanţuri
La Om
2238.7
Vlăduşca
Cheia
Măgura
Măgura Mică
1373
vr+cm
Avenul din Grind
La Table
Dragoslovenilor
Toancheş
Rogozului
BRAN
Peştera
Grindu Mountain
Pietrele
Valea cu Calea
Valea lui Nenu
Moeciu de Jos
km-th
ap2
Coarbei
1139.6
Mesteacănului
Sbârcioarei
Simon
Pietricica
1763
Gâlma Pleşii
1470.9
Brusturet
1037
Şirnea
Ulmului
Colţul Poranei
Pietricica Mt.
La Gâlgoaie
Ciocanu
Grădiştei
Secătura
1193
Valea Lungă
al
cl2-ox
Izvoarele din Plai
Dâmbovicioara cave
Izvorul
Fundata
Dâmbovicioara
Pietricelei
1279
Vătarniţa
1320.4
Pasul Giuvala (Bran) saddle (1262m)
Moeciu de Sus
vr-cm
br
Peştera Urşilor
Raţei
Urdei
Fundăţica
Rudăriţa
Pleşa
1072.1
Oratec
Sasului hill
Peştera Uluce
Podul Dâmboviţei
Cheia
Croitului
V. lui Andreiaş
Râuşorul
RUCĂR
Cheile de Jos ale Dâmboviţei
1407
Colţii Ghimbavului
La Curmătura Ghimbavului
Ghimbavul
Vârtoapele
1434.5
Dâmboviţa
Caselor
Dragoslavele
LEGEND
Mean annual spring flow, l/s
under 1
1-5
5-10
10-50
50-100
100-400

stance which contributed to a proper knowledge of the topoclimate (local climate) of that area. That topic has been addressed in detail in the work of ELENA TEODOREANU: “Rucăr-Bran trench. A study of its climate and topoclimate”, published by the RSR Academy publishing house in 1980, and having served as a basis for the presentation of the data below.

The prevalent atmospheric circulation occurs from the west, and together with its associated components, from the northwest and from the southwest, it contributes to a total of 56% of the overall frequency of atmospheric circulation directions. The western air-circulation is chiefly associated to mild winters and to frequent precipitations that occur mainly as rainfall, while turning, at higher altitudes, into sleet and snow. There is a remarkable degree of thermal instability during the warm season, when rainfall is also accompanied by thunderstorms.

The areal distributions of the average annual air temperature and of the average amount of precipitations are a function of the variations in the topography elevation (Fig.2). The average annual temperature is 7.2°C at Rucăr and 4.4°C at Fundata, being estimated to reach about 0-2°C on the Piatra Craiului ridge, with thermal gradients varying from 0.49°C/100m in the lower section of the passage, to 0.60°C/100m on the bordering mountain slopes.

Up to 1700-2000 m elevation, the atmospheric precipitations amount increases along with the altitude, while further up it starts to decrease. By considering the passage as a whole, there has been estimated that the precipitations amount increased from south to the north, and from est to the weast. Precipitations reach their maximum amount in June, the lowest monthly amount being recorded in February-May. At Podu Dâmboviţei, the largest number of rainfall days is recorded in the month of May, while March and September are the months when the smallest number of rainfall days occurs.

During the X.1979-IX.1980 time-interval, when a temporary meteorological station had been installed at Dâmbovicioara settlement, the potential evapotranspiration (PET) was estimated to reach 42% of the total rainfall amount, while the real evapotranspiration (RET) amounted to only 22.4% of the same reference quantity.

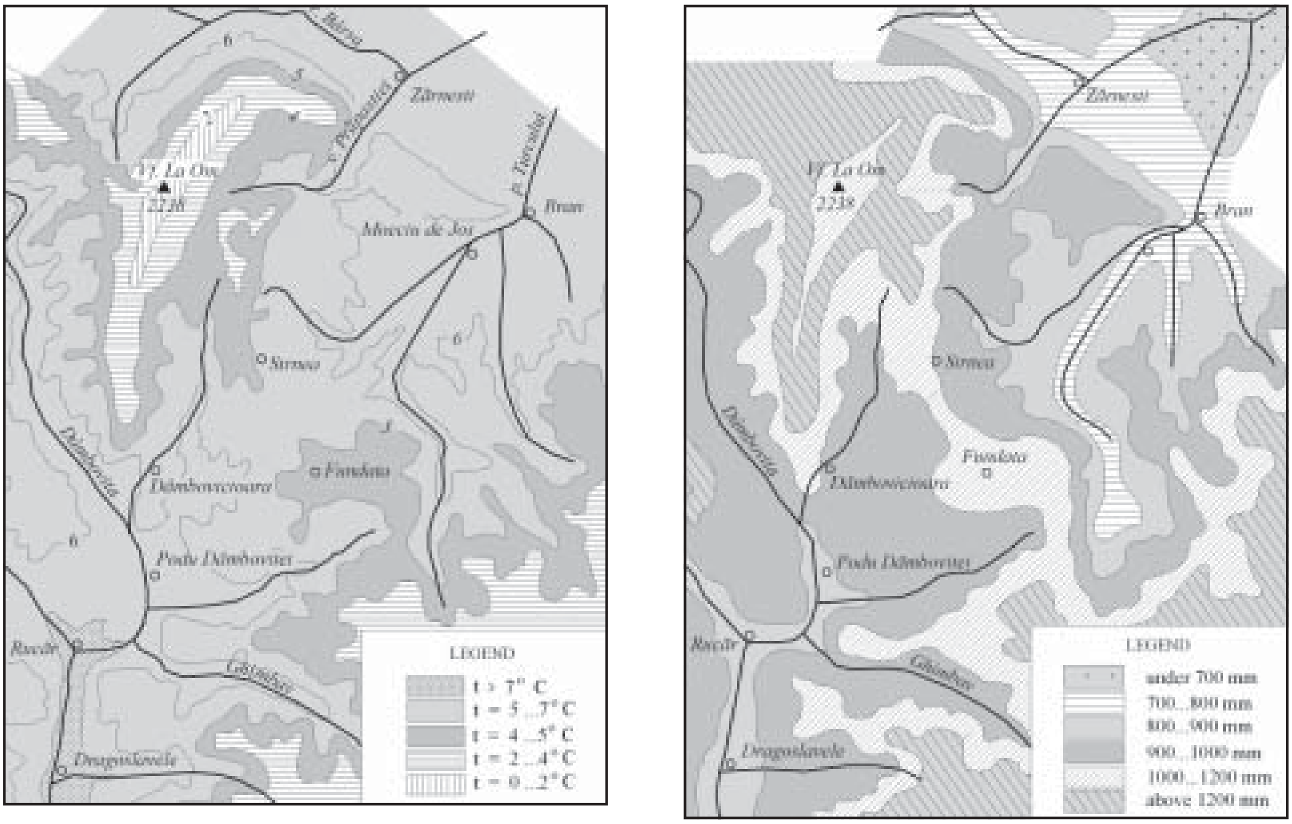


Figure 2. Distribution of the average air temperature (left) and of the average amount of precipitations (right) across Dâmbovicioara Passage (after Elena TEODOREANU, 1980).

2. A brief history of geographical and geological research

The distribution and the evolution of the landforms of Piatra Craiului mountains body have been addressed by detailed investigations conducted by A. BÂRSAN (1969), M. CONSTANTINESCU (1941), E. NEDELCU and Ş. DRAGOMIRESCU (1963). Several papers concerning the landforms, the flow network, and the overall evolution of that mountains body have been published by T. CONSTANTINESCU, the derived results being concentrated in that author's PhD thesis, the presentation of which was delivered at the University of Bucharest in 1994.

A study of Rucăr-Bran trench in terms of climate and topoclimate has been conducted by ELENA TEODOREANU (1980), who considered climate data series extending as recently as 1970.

The present-day knowledge concerning Dâmbovicioara Passage in terms of geology is the result of a multitude of studies and investigations. An early stage of research has been carried out between 1888 and 1940, including paleontology data inventories and monographic works devised by HERBICH (1888), Gr. COBĂLCESCU (1890), I. SIMIONESCU (1897-1899), and E. JEKELIUS (1926).

A new stage in the geological research of that area has been initiated by the publication of the detailed geological maps devised by N. ONCESCU (1943) and by D. PATRULIUS (1955, 1960, 1963, 1969); it has been later continued by investigations conducted by GR. POPESCU (1952), FL. MARINESCU (1955), I. NEDELCU (1957) addressing limestone and dolomite deposits, by investigations focused on stratigraphy and on paleontology, undertaken by ILEANA POPESCU (1966, 1969), and by geological prospecting for phosphates accumulations, performed by MAGDALENA RADU and ALEXANDRINA ANTONESCU (1977).

The sheets Bârsa Fierului, Zărneşti, Moeciu and Rucăr, of the geological map of Romania at the 1:50,000 scale, illustrate the current geological and structural concepts regarding that area.

Over the time-interval 1979-1980, the Geological Company for Solid Mineral Substances Prospecting (presently S.C. Prospecţiuni S.A.) has conducted a detailed hydrogeological survey of Dîmbovicioara Passage (IANCU ORĂŞEANU, NICOLLE ORĂŞEANU, N. TERTELEAC), additional contributions in terms of hydrological data collection and processing having been provided by the Institute of Meteorology and Hydrology (AL. BULGĂR, Ş. DĂSCĂLESCU, S. CRÂNGAŞU, V. BĂDESCU, I. MUNTEANU, GH. HOŢOLEANU, P. HOŢOLEANU and D. DEMETRIAN). Besides, T. CONSTANTINESCU from the Institute of Speleology "Emil Racoviţă" in Bucharest, has contributed to the assessment of the soil groundwater reserve, while E. GAŞPAR and T. TĂNASE, from the Institute of Nuclear Physics, have contributed to conducting tracer tests by means of radioactive and activable tracers. A series of limited results derived from the above-mentioned broad-scale hydrogeological studies have been published by I. ORĂŞEANU, AL. BULGĂR, E. GAŞPAR, N. TERTELEAC (1984). Over the time interval 1989-1990, S.C. Prospecţiuni S. A. resumed hydrogeological investigations addressing Dâmbovicioara Passage (IANCU ORĂŞEANU, NICOLLE ORĂŞEANU), then, between 2003-2005, S.C. Cheresta SRL Dâmbovicioara has funded additional hydrogeological studies aimed at the certification of Gâlgoaie spring as a still water source (I. ORĂŞEANU, S.C. Cheresta SRL Dâmbovicioara archives.).

3. Geological framework

The crystalline basement of the passage has a continuous dip to the north, interrupted by a transverse uplift extending between Coacazei brook and La Om peak. It underlies a thick sequence of Jurassic and Cretaceous deposits, including in their lower half highly fractured, 700-1200 m thick Kimmeridgian-Tithonic limestones, most of it compact and layered.

In the western part of the passage, limestones builds up a north-south striking structure, designated as Piatra Craiului syncline: its western limb is dramatically turned up, to build up Piatra Craiului ridge, the eastern limb is outcropping in Gâlma Pleşii ridge, while within the syncline axis there occurs a filling of Late Aptian carbonate conglomerates.

The Late Jurassic limestones is underlain by deposits which disconformably overlie the crystalline schists, and which consist of Bajocian-Callovian deposits (marly limestones, carbonate sandstones, carbonate marls, of 60 m cumulated thickness) and of Medium Oxfordian-Callovian deposits (limestones with cherts, arenitic limestones, of 40 m cumulated thickness), occurring as two parallel stripes on the western slopes of Piatra Craiului. Within the passage, they occur around the crystalline schists outcrops and their overall hydrogeological behavior is similar to that of the limestone.

The Late Jurassic limestones is overlain by limestone, marls and marly limestones of Hauterivian age, which underlie a thick stack that includes impervious Barremian marls and marly limestones, as well as Bedoulian marls and reef limestones.

Late Aptian deposits include carbonate and polymictic conglomerates, and carbonate breccias (designated by ILEANA POPESCU, 1961, as "Gura Râului conglomerates"), which outcrop over large areas in the Dâmbovicioara syncline axis. They are crossed by dense networks of cracks, their permeability is high, and valleys for which they provide the substratum are commonly dry, because of the fast infiltration rates favored by those rocks. They exhibit a mixed hydrogeological behavior, the high porosity induced by cracks and intergranular spaces being additionally associated with a karst component, induced as a result of the dissolution of the limestone pebbles and of the carbonate cement they are made of.

Vraconian-Cenomanian deposits include massive sandstones and polymictic conglomerates, micaferous sandstones and carbonate breccia, alternating with marly shales. They disconformably overlie older formations and extend over large areas, bordered by fractures, in the western and the southern regions of the passage. The aquifer accumulations they host are discharging through a multitude of low flow-rate springs.

4. Water budget

Ensuing to activities carried out in cooperation by S.C. Prospecţiuni S.A., INMH and ISER, there have been collected data concerning precipitations, surface runoff, and variations in the soil groundwater reserve which had occurred within Dâmbovicioara Passage during the time-period 1979-1980, the collected data being further used in devising the water budget of both surface and underground flows, over the water-year XI.1979-X.1980. A limited amount of the corresponding results has been published by ORĂŞEANU I., AL. BULGĂR, E. GAŞPAR and N. TERTELEAC (1984).

The devised water budget has once again proven that in terms of specific discharges, karst processes result in major alterations, which mirror the absence of correlation between the extension of the topographic watersheds, and the actual extension of the karst systems. Specifically, by taking as a reference the specific discharge recorded within the catchment area of Râuşor steam, a witness catchment area that extends over impervious rocks, there can be noticed that in terms specific discharges, major deviations occur in the case of catchment areas extending prevalently over a limestone substratum (Table 1 and Fig. 3).

No.	River	Flow rate gauging station	Period	F km²	H m	Q mean m³/s	q l/s/km²
1	Dâmboviţa	Valea lui Ivan	1954-1964	165.4	1530	3.82	23.1
2	Dâmboviţa	Podu Dâmboviţei	1949-1964	251	1375	4.73	16.8
3	Dâmboviţa	Malu cu Flori	1931-1949	679.7	1131	9.22	13.5
4	Râuşor	Rucăr	X.1979-IX.1980	52	1201	0.91	17.5
5	Dâmbovicioara	Podu Dâmboviţei	X.1979-IX.1980	49.1	1195	0.615	12.6
6	Prăpastiei	Zărneşti	X.1979-IX.1980	22.6	1390	0.857	37.9
7	Turcu	Moeciu	X.1979-IX.1980	45.5	1250	0.328	7.2
8	Dâmboviţa	Dragoslavele	X.1979-IX.1980	450	1310	8.39	18.6

F - surface of the catchment area; H - mean altitude of the catchment area; Qmean - mean annual discharge; q - mean annual specific discharge. (No. 1, 2 and 3 after AL. V. STĂNESCU, 1966.)

Table 1. Morphometric and hydrometric data.

Rainfall occurring on the surface occupied by the sedimentary deposits of Dâmbovicioara Passage (approximately 230 km^2) has generated during the time-interval XI.1979-X.1980 a water amount of 570.3 mm (4.1 m^3/s) available for runoff and infiltration. Out of it, 75% (3.1 m^3/s) infiltrated in the underground, while 25% was evacuated outside the surveyed area by surface flows. The infiltrated water amount has contributed to restoring the groundwater reserves, constantly drained by the springs which discharged at the passage-region boundaries. Out of the infiltrated water amount, almost half is discharged through three main groups of springs, those in Prăpăstiile Zărneştilor (790 l/s), those in "Cheile de Jos", along the streamcourse of Dâmboviţa (800 l/s), and those of Gâlgoaie, in the catchment area of Dâmbovicioara (320 l/s).

For the catchment area of Prăpastia stream, the annual water budget of the surface and underground flows outlines additional inflows exceeding by 3 mil. m^3 the water amount which would be available if solely the area bounded by the surface watershed (22.6 km^2) was taken into account. In fact, the flow discharged by this specific catchment area corresponds to a surface of 52 km^2. If there is in addition taken into account also the surface of about 5 km^2corresponding to the recharge area of Topliţa spring (which discharges about 100 l/s of water from the same structure, along a transverse fault) the actual recharge area amounts to a total of about 57 km^2.

The additional recharge of those groundwater outlets derives from a region extending over a surface of about 34 km^2, which includes the limestones outcrops on the northwestern slopes of Piatra Craiului (about 9 km^2) and a large part of the catchment area of Turcului (Sbârcioarei) stream.

The catchment area of Turcului stream extends over 45.5 km^2 and its annual discharge, as recorded by Moeciu flow gauging station, amounts to 10.35 mil. m^3. That catchment area is subject to a flow deficit of about 12 mil. m^3, the corresponding water volume being diverted toward Prăpastia valley. The underground water divide between the groundwater flow systems associated to Prăpastia and Turcului streams cannot be traced accurately, except for the western segment, where it follows the crystalline schists outcrop boundary.

Over the time-interval XI.1979-X.1980, rainfall occurring in the Dâmbovicioara catchment area (that extended over 49.1 km^2) amounted to an average value of 849.2 mm (41.7 mil. m^3/year), out of which real evapotranspiration eliminated 277.6 mm (13.6 mil m^3/year; 32.7 % of the rainfall amount), while 19.55 mil m^3/year (620 l/s; 46.9 % of the rainfall amount) discharged as surface flow.

The water budget of the surface and underground flows of the Dâmbovicioara stream catchment area indicated a deficit of 8.6 mil.m^3 (272.7 l/s = 5.55 l/s/km^2; 17.4 % of the rainfall amount), that groundwater amount being diverted out of the Dâmbovicioara stream catchment area, to finally emerge as part of the discharge (800 l/s) of the outlets in "Cheile de Jos", along the streamcourse of Dâmboviţa.

Out of the total surface flow discharged by Dâmbovicioara catchment area (620 l/s), the 320 l/s contribution of Gâlgoaie springs represents 51.6 %, which amounts to 24.2 % of the rainfall occurring in that catchment area.

There is estimated that within the catchment area of the Dâmbovicioara stream segment which extends upstream the springs-group Gâlgoaie

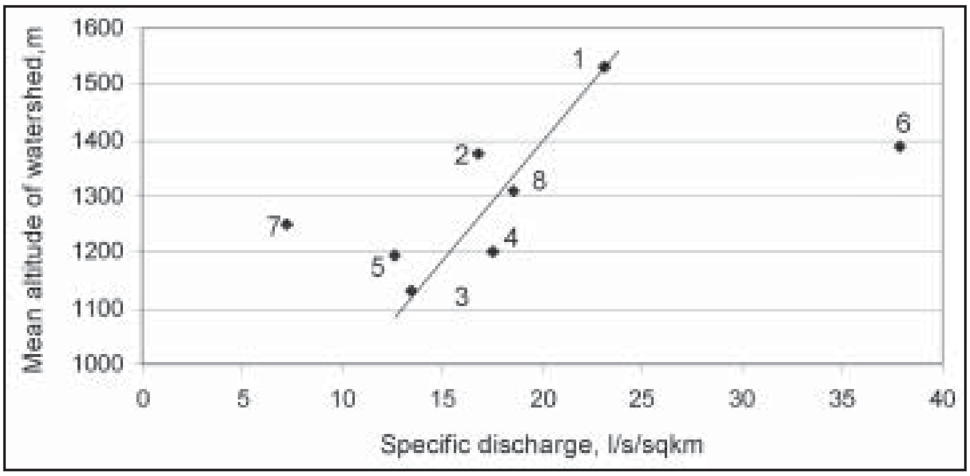


Figure 3. The relationship between the mean annual specific discharge (q) and the mean altitude of catchment area. Significance of numbers as in tabel 1.

($F=24.4$ km^2, H med=1450 m), there is available for runoff and infiltration a water amount of 440 l/s, out of which 40 l/s flow down the stream Brusturet, 320 l/s are discharged by the springs Gâlgoaie, while the remaining 80 l/s assumedly flow underground, underneath Gâlgoaie springs, further downstream.

There are 24.7 km^2 of additional catchment area which belong to the segment of Dâmbovicioara stream that extends 7 km downstream the springs-group Gâlgoaie, down to the junction with the river Dâmboviţa. That stream section is subject to opposing actions, induced by two distinct factors: (a) water inflows provided by spring discharges (e.g. Izvoarele din Plai) and by precipitations falling on the catchment area, the overall result being an increase in the flow-rate of the surface stream, and (b) diffuse infiltrations of surface waters into the carbonate deposits and/or the conglomerates, occurring both through the streambeds of the main course and of its tributaries, as well as through the entire surface of the catchment area, the overall result being a reduction of the flow-rate of the surface stream. The rainfall regime controls the positive or negative balance between those two factors.

During the years 1979 and 1980, along the river Dâmboviţa and along its main tributaries, flow gauging has been conducted both permanently and occasionally (during field trips), that undertaking resulting in a large amount of significant information concerning the karst flow regime. Specifically, along the "Cheile de Sus" gorge section, streambed seepage results in a reduction of the Dâmboviţa river flow-rate. Apart from contributions provided by the Dâmbovicioara and Chei tributaries, the same flow-rate reduction regime is noticeable also along the "Cheile de Jos" gorge section; it is only about 300 downstream the junction with Cheia stream that the river flow starts increasing, due to inflows which extend down to the gorge termination and which provide a total of 800 l/s (supplied by a springs lineament and by groundwater discharges located beneath the river water-level).

Groundwater discharged by the outlets in the "Cheile de Jos" gorge section of Dâmboviţa river is derived not only from infiltration occurring in the catchment area of Dâmbovicioara stream, but also from infiltration occurring within the limestone area of the western mountain-slopes of Piatra Craiului ridge, southward of the peak La Om (5.5 km^2), and within the areas covered by sedimentary deposits in the catchment areas of the streams Cheia (19 km^2), Ghimbav (5 km^2) and of the river Dâmboviţa (10 km^2 in Podu Dâmboviţei-Rucăr area). Additionally, the indicated outlets are also supplied by seepage occurring in the streambeds of the brooks Cheia and Ghimbav, which are for most part supplied by runoff occurring on the crystalline terrains which provide the substratum of their upper catchment areas.

For the karst domain of the Dâmboviţa river catchment area there has been plotted a variation diagram of the effective infiltration values, which indicated springtime maxima, followed by summertime minima; however, since the surfaces bounded by positive, and respectively negative infiltration values were similar (175.6 mm against -169 mm), a good accuracy has resulted for the water budget of that catchment area.

None of our observations appears to substantiate the occurrence of any significant hydrogeological connection between the karst aquifers in the northern part of Dâmbovicioara Passage and the groundwater accumulations in the Braşov depression. We assume that such connections are largely prevented by the occurrences of Vraconian-Cenomanian sandstones and of Turonian-Senonian shales, which transgressively overlie the limestones.

5. Hydrogeology of Dâmbovicioara Passage

5.1. Hydrogeological characteristics

The deposits building up the lithological assemblage of Dâmbovicioara Passage exhibit a wide lithological diversity and they were subject to various degrees of tectonic deformations impact, circumstances which in terms of hydrogeology resulted in various kinds of groundwater recharge, storage, and discharge, consequently leading to the identification of 5 formation types with distinct geological-structural and hydrogeological characteristics (Fig.1).

A. Thick series of Mesozoic carbonate deposits, highly fractured and moderately karstified, displaying very high effective infiltration values and being subject to intensive groundwater flows. Groundwater accumulations occurring in this type of deposits discharge through a multitude of large flow-rate springs. This class includes carbonate deposits occurring in the lower half of the sedimentary stack of Dâmbovicioara Passage, Hauterivian age limestone included. Crystalline schists occurring within the basement provide the impervious bed for the karst groundwater accumulations.

B. Coarse, prevalently carbonate molasse deposits of Late Aptian age (carbonate conglomerates and breccia), subject to groundwater flows through fissured, porous and karst media. Surface flows occur only temporarily, as rainfall water is subject to fast seepage, the latter process also supplying groundwater to karst aquifers hosted by the underlying Kimmeridgian-Tithonic limestones.

C. Vraconian-Cenomanian molasse deposits (compact sandstones, polymictic conglomerates, shales) subject to groundwater flows through porous-fissured media. The groundwater accumulations supply permanent surface flows by means of low-yield springs. In the underground, the corresponding aquifers are drained through karst flows occurring in the Kimmeridgian-Tithonic limestone.

D. Quaternary unconsolidated detritic deposits (sands, gravel, occasionally clays) of reduced thickness and extent, subject to intensive groundwater flows and hosting groundwater accumulations of local importance. Such deposits occupy extensive areas along the main streamcourses.

E. Crystalline schists and prevalently marly deposits, within which groundwater accumulations are minor, or just missing. Surface flows derived from crystalline terrains adjoining the passage-region provide limited supplies to karst aquifers, by sinking either completely (Fundăţica, Crovului, Cheia, Raţei), or just partially (Ghimbavul, Rudăriţa). The same role is played by the crystalline schists outcrops in the central part of the passage-region (Coacăzei valley).

Piatra Craiului syncline incorporates a complex hydrogeologic structure, with groundwater discharging both to the north, in the Prăpastia valley catchment area, and to the south, in the catchment area of the river Dâmboviţa. The underground water-divide between the two indicated groundwater reservoirs is provided by the crystalline basement uplift area that occurs along the lineament Sbârcioarei valley-Coacăzei peak-La Table-La Om peak.

5.2. Groundwater outlets in Prăpastia valley

The northern section of the aquifer hosted by the Piatra Craiului syncline is discharging mainly through the groundwater outlets of Prăpastia valley. Those outlets occur both in Kimmeridgian-Tithonic limestones, as well as in Late Aptian conglomerates, the latter deposits building up the matrix of the same aquifer, which had been subject to a complex folding and fracturing tectonic regime.

Along Prăpastia stream, two distinct groups of springs occur. The first group, also known as "The 6th of March" springs, is located within the median section of the streamcourse, to the northwest of Măgura village (Fig. 1, no. 2). The entire groundwater discharge is tapped in closed water-intake chambers and conveyed to the town Zărneşti, where it is used for industrial purposes. Fluoresceine tracer tests performed by T. CONSTANTINESCU in 1976 have indicated that the recharge of those springs was partly derived from infiltration occurring in the catchment area of Vlăduşca brook.

The second group, known as Fântânile Domnilor, is located at the downstream end of the gorge excavated by Prăpăstia stream (Fig.1, no.3) and it consists of 3 outlets having their entire flow-rate tapped for the water supply of Zărneşti town. One outlet discharges from a small cave passage occurring on the left side of the stream, while a second one is located on the opposite bank and it consits of several upflows surging from the floor of the water intake chamber, 3 m below the ground level. The third outlet, of temporary character, is located downstream the second one.

Over the water-year X. 1979-IX. 1980, the tapped average flow-rate of the Prăpastia valley springs amounted to 576 l/s, while contemporarily, the average flow-rate of the actual Prăpastia stream was 239 l/s. Over the water-year X. 1989-IX. 1990, the springs discharge has dropped to half the above-indicated value, while Prăpastia stream flowed only sporadically.

5.3. Topliţa water intake

At the bottom of the northern slopes of Piatra Craiului, in the prolongation of Topliţa fault, there occurs the water intake that bears the same name, which consists of a 300 m long draining gallery, striking N45°W and being excavated in slope debris, at 5-8 m depth (Fig. 1, no. 1). Water enters the gallery through the weep holes located in its northwestern wall. The average annual flow-rate amounts to 100 l/s, while the average water temperature is 7.8°C.

5.4. Gâlgoaie groundwater discharge

Groundwater accumulations within the southern section of Piatra Craiului syncline discharge mainly through the outlets designated as "La Gâlgoaie" and "Izvoarele din Plai", located within the Dâmbovicioara stream catchment area. The same groundwater accumulations also contribute to the recharge of the springs located in the "Cheile de Jos" gorge section of the river Dâmboviţa.

Gâlgoaie groundwater discharge (Fig. 1, no. 6) is located in the central section of the Dâmbovicioara catchment area, at the bottom of the right side slope of Dâmbovicioara stream, just upstream the junction of the latter with the brook Izvorul Uliului (950 m elevation). Groundwater discharges from deposits consisting of intensely fractured and karstified Tithonic limestones, overlain by sub-lithographic limestones with glauconite and by Hauterivian marls, covered at their turn by a thick stack of Barremian marls (Figure 4). Groundwater up-flows along the fault-gauge filling of the "Gâlgoaie" fracture zone, discharging via several outlets distributed over 5 m length, and being also accompanied by gas exhalations whose composition resembles that of atmospheric gas. Several additional springs occur further upstream, the most significant being the one "La Bile" (Fig.1, no. 5).

Over the time-interval X.1979-XI.1980, the average discharge of Gâlgoaie amounted to 317.8 l/s, the corresponding minimum and maximum values being 180 and 430 l/s respectively. Over the period April 2003 - March 2005, the groundwater discharge ranged between 151 and 463 l/s, the associated average flow rate amounting to 221 l/s, while the corresponding base flow index value (Bf=0.738) indicated that spring as being one of the most stable among the major karst outlets of Romania.

Parameters obtained through the processing of the discharge recession curves are indicated in Table 2. The very low values (0.0016-0.0063) of the α recession coefficient are characteristic to fracture permeability karst systems, which only to a small degree undergo the karst processes impact. The period ti during which the discharge is subject to fast recession extends over a rather long time-interval (23-49 days), this feature additionally emphasizing the gentle, gradual character of the flow rate reduction process. The groundwater volumes flowing across the aquifer (Vdyn) are very large, amounting to more than 10 million m^3. The groundwater volumes that the spring discharges during the fast recession period (v inf) amount to only a very small fraction (0.18-1.68 %) of the total groundwater volumes (V).

Gâlgoaie spring discharges a fraction of the total amount of groundwater supplied by aquifers located in the Piatra Craiului syncline extending within the Dâmbovicioara stream catchment area. In 1980, the author together with E. Gaşpar have conducted a tracer test by injecting Br-82 tracer into stream-losses located in the upper reaches of

Recession no.	1	2	3	4
Time period	02.01.1980-11.03.1980	15.05.2003-10.10.2003	13.12.2003-03.03.2004	19.04.2004-20.07.2004
α	0.0063	0.0016	0.0046	0.0052
QO, l/s	300	232	242	463
Q'O, l/s	240	179	194	275
ti, days	23	49	27	30
Recession period, days	69	148	80	92
V dyn., mc	3 830 000	10 500 000	4 090 000	5 330 000
v inf., mc	6900	61 000	12 000	91 000
V, mc	3 836 900	10 561 000	4 102 000	5 421 000
v inf. (% din V)	0.18	0.58	0.29	1.68

Table 2. Results of the recession curves processing.

Seaca Pietrelor valley, consequently outlining an underground flow directed toward Gâlgoaie springs, which were located 4.4 km downstream and 325 m below the sinking point.

In 1990, another tracer test has been performed in cooperation with members of the caving club "Hades" of Ploieşti, by releasing 80 g of In-EDTA in the underground stream that flowed across the pothole in Grind (Fig.1, no. 4), a cavity of 540 m total depth (POPESCU G. 1988). For the next 30 days, water samples have been collected from the springs Fântâna Domnilor of Zărneşti, Gâlgoaie, as well as from the river Dâmboviţa, at the downstream end of the "Cheile de Jos" gorge section, in the town Rucăr. According to analyses performed by E. Gaşpar in the IFIN laboratories, no detectable concentrations of tracer have been recorded in the collected samples.

5.5. Izvoarele din Plai

Izvoarele din Plai are groundwater outlets located on the right side of Dâmbovicioara stream, downstream the junction of the latter with Peştera brook (Fig.1, no.7). The supply of those springs is partly derived from flows sinking in the upper reaches of the brook Peştera, and of two tributaries of the latter brook, the valleys Vopselelor and Ulucelor (T. CONSTANTINESCU, 1985). The groundwater outlets, one permanent, amounting to 60 l/s flow rate, and a temporary, over-flow one, that is located some 10 m away, discharge from the Late Jurassic limestone bedding planes. During the drought period of the 1990 fall season, the flow rate of the permanent spring had dropped to 10 l/s.

5.6. The springs in the "Cheile de Jos" gorge section of Dâmboviţa river

The springs are located at the southern extremity of the sedimentary deposits of Dâmbovicioara Passage, close to the boundary with the crystalline terrains, in an area which displays noticeable traces of intense tectonic deformation, where the crystalline basement together with the Late Jurassic limestones are uplifted in a stepwise manner along a system of transverse-faults. Those springs occur downstream the junction with Cheia stream, being spread over about 2 km, on both banks of the river Dâmboviţa, both above the water level and in the streambed.

On 28.07.1980, in cooperation with E. GAŞPAR and T. TĂNASE from IFIN, a tracer test has been performed by injecting I-131 radioactive tracer in the region where Izvorului brook, a tributary of Dâmbovicioara (Fig. 1, no. 8) underwent diffuse total sinking (at 975 m elevation). For tracer detection, filters provided with Vionit ion-exchangers have been placed in three locations - in the upstream, median and downstream sections of the spring lineament. The tracer has been detected in the groundwater discharges of the "Cheile de Jos" gorge section, which were located, on the average, 4250 m away and 250 m below the injection point. The tracer reached the springs 60-70 hours after being injected and it remained in de-

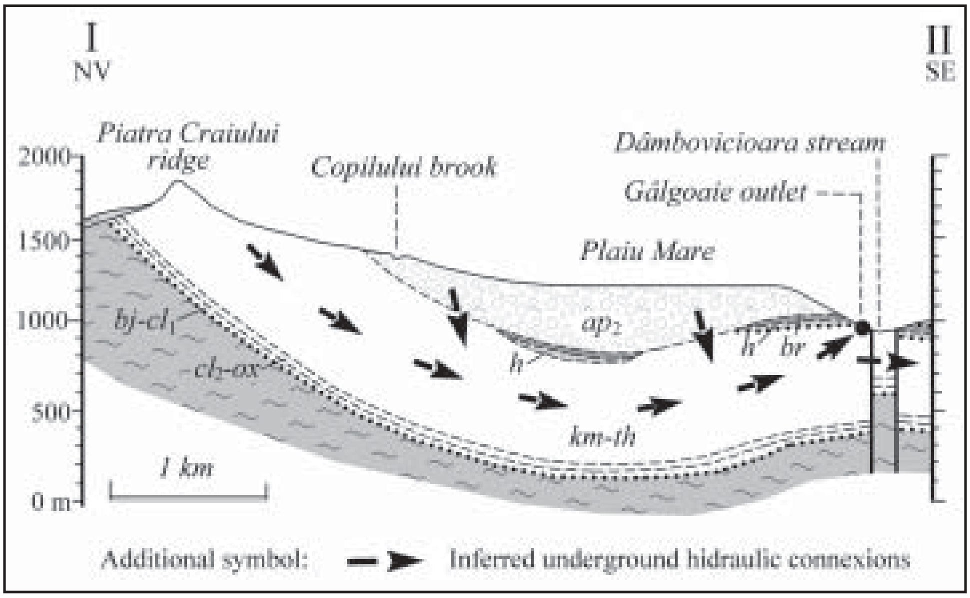


Figure 4. Hydrogeological cross section across Piatra Craiului syncline. Legend as in Figure 1. Section line indicated in Figure 1.

tectable concentrations for about 160 hours afterwards, the largest amount of tracer being identified in the middle section of the spring lineament.

The groundwater discharge of the springs in the "Cheile de Jos" gorge section of the river Dâmboviţa has been assessed by processing the flow gauging data recorded by the stations Podu Dâmboviţei and Rucăr during periods when the hydropower retention facilities were not operating, and by conducting spinner measurements at the upstream, and respectively downstream extremities of the springs lineament. Groundwater inflows have been thus assessed to range between 0.8 and 1.75 m^3/s.

The karst system associated to the spring occurrences in the "Cheile de Jos" gorge section of the river Dâmboviţa probably extends as far as the upper reaches of the catchment area of Ulmului stream, and it might also discharge flows that are sinking into the swallet of Şirnea (Fig.1, no.9).

5.7. Fântâna Ulmului (Fig. 1, no. 10)

On the right side of Ulmului stream, out of a limestone cliff which displays noticeable traces of intense tectonic deformation, a spring lineament discharges under drought conditions a total of about 15 l/s. The corresponding outlets are likely supplied by diffuse infiltration occurring in the upper catchment area of Grădiştea valley, within the grounds of Fundata village.

5.8. The springs in Sbârciorii valley

Several springs discharge from alluvia located in Sbârciorii valley, close to the junction of the latter with Coacăzei valley, in an area consisting of a 150 m long and 40-50 m wide alluvial plain, that occurs at the bottom of a Late Jurassic limestone pinnacle (Fig.1, no.11). Among those springs, those designated by the letters b and d discharge the highest flow-rates (40-50 l/s), while each of the outlets designated by the letters a and c discharges only about 10 l/s. The above-mentioned alluvial plain is bounded by a gorge section: further downstream there occurs a line of springs which are perched about 1 m above the streambed and discharge about 5 l/s.

On 19.09.1990, the cumulated discharge of all those springs amounted to 125 l/s. Their recharge is probably derived from infiltrations into the Vraconian-Cenomanian sandstone outcrops of the Peştera settlement area, as well as from water infiltrated in the catchment area of Coacăzei stream (which downstream the crystalline schists outcrops is subject to a temporary flow), and from seepage occurring in the streambed of Ulmului brook, upstream its junction with Coacăzei stream. Those outlets occurrences are controlled by the crystalline basement uplift which is situated downstream the springs, the same structural setting being also responsible for the spring occurrence (Fig.1, no.12, 10 l/s) on the lower course of Nenu stream.

5.9. The spring of Uluce Cave

Uluce Cave is located on the left side of Cheia stream, about 300 upstream the junction of the latter with Fundăţica stream (Fig. 1, no. 13). The cave provides the outlet for flows sinking into the Rudăriţa stream swallet (Fig.1, no.14), as well as farther beyond that swallet, just into the streambed (I. Orăşeanu et al., 1984, Al. Bulgăr et al., 1984). The discharge of that outlet amounts to about 70 l/s.

Opposite to Uluce cave, a group of springs occurring in the same Late Jurassic limestone deposits discharge a cumulated flow-rate of 30 l/s. Unlike the flow discharged by Uluce cave, those springs water is constantly clear and probably originates in the catchment area of Crovului brook.

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