PROIECT APUSENI

THEME

THE GROUND WATER AND SURFACE WATER HYDROGEOLOGY AND GEOCHEMISTRY IN THE GÂRDA - GHEȚAR AREA (BIHOR MOUNTAINS)

SUB-THEME

Hydrogeological investigations of the Gârda Seacă - Ordâncuşa water divide territory (Bihor Mountains)

FINAL REPORT FINAL

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CONTENTS

Introduction

The hydrogeological study performed in the framework of this sub-theme has addressed the assessment of the groundwater potential of the Gârda Seacă-Ordâncuşa watershed, in order to establish the possibilities of supplying drinking water to the peasants households located in areas devoid of such sources. It has also aimed at the acquisition and processing of meteorological data required for the completion of the studies concerned with the hydrogeology, the hydrochemistry and the vegetation evolution assessment on the experimental plots with grassland and vegetables, as well at characterizing the climatic conditions over the project completion period within the multi-annual regional climatic framework, relying on data provided by the permanent meteorological stations of the INMH network..

In order to obtain the meteorological data, an observation network has been set up, that consists of Gheţar meteorological station and of the rainfall gauging stations Gârda Seacă and Poiana Călineasa. The meteorological platform is built in the middle of Gheţar village, at 1134 m absolute elevation, and it is provided with a meteorological shelter that inside it has thermometers (for minimum and maximum temperatures, as well as a common one) and a recording thermo-hygrometer, as well as a heliograph, a pluviometer and a

"Centrum" of the Project and the meteorological platform.

rainfall recorder.

The meteorological station provides the following data: air temperature (daily minima, maxima and averages), air humidity, duration of sunshine, amount and type of rainfall. During the winter period, the snow thickness is measured daily, and every five days there are performed densimetry measurements of the snow layer in order to compute the water reserve within it. The station was set up at the end of the month of April 2001 and it started to operate in the month of May 2001.

In the first field phase of the hydrological investigations there have been set up gauging cross section at the springs Coteţul Dobreştilor and Poarta lui Ioanele, outlets that we already knew to be the main sites where the karst aquifers in the watershed discharge. Next, there has been completed the detailed hydrogeological survey of the area at the scales 1:5.000 and 1:10.000 and there have been performed specific hydrogeological works aimed at data acquisition. The survey outlined the occurrence of potential sources for drinking water supply of the area, namely the outlets Iapa and La Izvoare, that subsequently have been also equipped with gauging cross sections. All the cross sections are equipped with staff gages and weekly automatic water-level recorder, while every month the author performed flow rate measurements by means of the current-meter, to finally obtain the values of the outlets daily mean flow rates.

In order to perform the observations and the specific measurements, local people have been hired as observers for the meteorological station, for the rainfall gauging stations and for the gauging cross sections.

There have been performed tests by means of ecological tracers, fluorescein and rhodamine, the corresponding concentration measurements of the collected samples being performed by the Chemistry Laboratory of ISER Bucureşti.

A. Considerations concerning the topography and the hydrography of the area

The Gârda-Gheţar-Poiana Călineasa area is situated in Bihor Mountains and it includes the water divide territory that extends between the streams Gârda Seacă and Ordâncuşa, stretching to the north up to the parallel of Poiana Călineasa. It is situated in the Arieş river catchment area, at the boundary with the Someşul Cald river catchment area, located further to the north. In terms of administrative setting the area belongs to the territory of Gârda village, in Alba county.

Gârda Seacă stream is the most important tributary of Arieşul Mare river in the karst area of Bihor Mountains. It is almost 20 km long and has its headwater under Sesul Gârzii, next to Padiş, its first major source being the spring at Gura Apei (plate 1, no. 12). After a rectilinear course through a narrow valley, along which its flow rate doubles due to the inflows provided by the cave Apa din Piatră (plate 1, no. 13) and by the spring at Coliba Ghiobului (plate 1, no. 14), the entire water discharge of the stream, whose name was down to this point Gârdişoara, sinks in Coiba Mică cave (plate 1, no. 16). Next, from Casa de Piatră hamlet downstream the valley is called Gârda Seacă. It enters a narrow gorge section and receives the left hand tributary Vulturul, then close to Fileşti, by means of Tăuz spring (plate 1, no. 38) the valley gets back its water that had sunk in Coiba Mică. The spring is situated 2650 m away and 110 m below Coiba Mică cave.

The hydrologic connection between Coiba Mică cave and Tăuz spring was outlined by a tracing experiment performed with rhodamine B, the underground transit time of the tracer being 322 hours (ORĂŞEANU et al., 1991). The Tăuz spring has an average flow rate of 529 l/s, and a 68.2 recorded ratio between the extreme average daily flow rates from the observation period X.1984-IX.1985 (ORĂŞEANU, 1996).

At the exit of the gorge section situated downstream of Tăuz spring, the flow rate of Gârda Seacă stream increases due to the inflow provided by the spring Peştera cu Apă de la Tău (plate 1, no. 41), after which the stream follows a long course through sandstone and conglomerate formations, interrupted at the hamlet Coteţul Dobreştilor by the Ladinian-Early Carnian limestone, in which it is excavated the outlet cave bearing the same name (plate 1, no. 46).

Before reaching its junction with Arieşul Mare, Gârda Seacă valley amounts to an annual average flow rate of about 1.5 m^3/s. In Gârda de Sus village, the valley of Gârda Seaca receives on the left side its most important tributary, the valley of Ordâncuşa, whose course strikes roughly parallel to that of Gârda Seacă, being yet shorter. The first 4 km of Ordâncuşa stream, upstream from its junction with Gârda Seacă stream, are excavated in limestone, which resulted in shaping a narrow gorge, with vertical walls, occasionally 200 m high. In this area Ordâncuşa stream receives the inflow from the cave at Poarta lui Ioanele, which actually represents its most important tributary. Downstream from Poarta lui Ioanele, the water of Ordâncuşa stream sinks in a diffuse manner, its entire flow temporarily vanishing in this way through the alluvia in the streambed, to re-emerge in Izvorul Mare at Gîrda de Sus.

The topography of the Gârda-Gheţar-Poiana Călineasa area is elevated by 300-1000m above the streambeds of the adjoining streams, and it consists of isolated ridges separated by saddles and chaotically disposed karst depressions, without displaying a single dominating feature. Immediately northward from the junction of Gârda Seacă and Ordâncuşa streams (730m altitude), the absolute elevations rapidly increase up to Mununa (1100m), then they climb slowly up to Poiana Ursoaia and Stânişoara summit (1375,6m) on the lineament Spurcat brook - the headwaters of Ordâncuşa stream, the topography assuming the appearance of a karst plateau strewn with the entire range of both above ground and below ground karst land-forms that are characteristic to these areas. Northward from the karst plateau the topography is extremely rugged, crossed by deep valleys and marked by high ridges such as Căţânilor hill (1479,9m) and Bătrâna summit (1579,3m).

The karst plateau topography is dominated by the closed drainage basin Ocoale-Gheţar, a karst depression bounded to the west by the ridge that includes Ocoale hill (1325,3m) - Comărnicel (1341,0m) - Bocului hill (1311,9m), to the east by the lineament of the hills Rânjeşti (1301,5m) - Iapa (1261,0m) - Chicera (1267,0 m) - Hănăşeşti (1289,0m), and to the south by Culmea Pârjolii. This closed drainage basin was the object of a multitude of speleological investigations, stimulated by the presence in this area of the Scărişoara cave ice accumulation, the largest in Romania and second largest in Europe.

Ocoale stream has its headwater on the Early Jurassic terrains in the north-western part of the Ocoale-Gheţar depression. The original course, tributary to Gârda Seacă stream, has been concerned in time by a multitude of karst piracy events, marked by the caves network that includes the pothole in Şesuri (plate 2, no. 79)–Gheţarul de la Scărişoara (no. 80)-Pojarul Poliţei, and by the succession of fossil swallets which extends northward up to the present day permanent sinking point, situated at the contact of the limestone with the Early Jurassic sandstone and shales.

Simultaneously with the speleological investigations, there have been also performed observations concerning the groundwater flow directions, fluorescein tracing experiments outlining the hydrologic relationship between the swallet at Vuiagă (no. 76), the pothole in Şesuri and Poliţei spring (no. 44) and the connection between the diffuse seepage in the streambed of Ocoale stream and the sources Coteţul Dobreştilor spring (no. 46) and Morii spring (fig. 1, no. 47) on the border of Gârda Seacă stream (Şerban et al., 1957; Viehman, 1966; Rusu et al., 1970).

B. Geological and structural setting of the area

Within the structural edifice of Bihor Mountains, the lowest position is occupied by the Bihor Unit, frequently designated as the "Bihor Autochtonous". It is built up of metamorphic formations and of a sedimentary stack that includes Mesozoic, ante-Senonian formations, which at its bottom occasionally includes also Permian detritic deposits. From the west to the east, the Bihor Unit formations are overthrust by those belonging to the Codru Nappes System.

The Gârda-Gheţar-Poiana Călineasa area almost entirely consists of sedimentary deposits ascribed to the Bihor Unit. Only in the lower reaches of Gârda Seacă stream, in the south-western part of the area, there are outcrops of Werfenian and Permian sandstone and conglomerate deposits which in structural terms are ascribed to Gârda Nappe of the Codru Nappes System (plate 1).

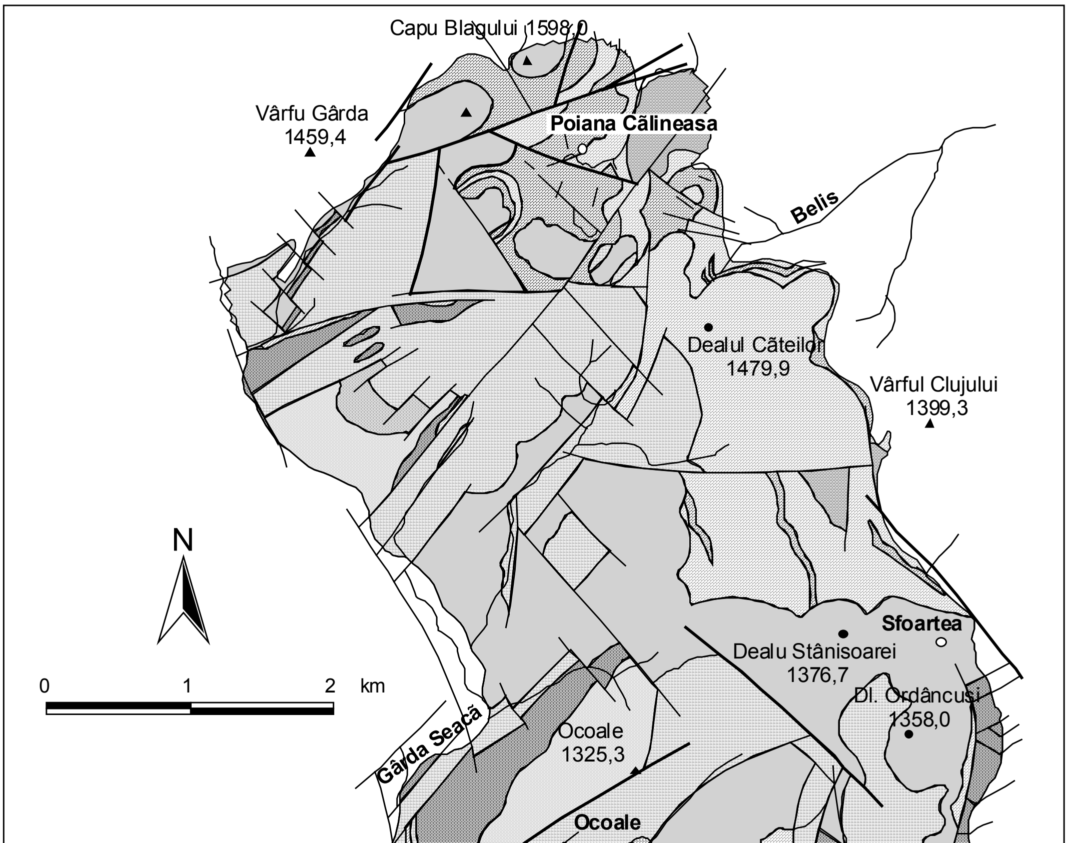
The Bihor Unit formations in the considered area include at their bottom Werfenian detritic deposits, that consist of conglomerates and quartzite sandstones and red shales, which are overlain by a thick series of carbonate deposits with gray Anisian dolomites at their bottom, followed by white Ladinian - Early Carnian reef limestone (the Wetterstein limestone). The carbonate deposits are transgressively overlain by the prevalently detritic Early Jurassic deposits, which consist of quartzite sandstone and conglomerates, shales and black limestones, of 200-300 m overall series thickness (Hettangian - Early Sinemurian), reddish and gray encrinitic limestone, marls and marly limestone (Late Sinemurian - Toarcian, 6-80m thick). The series ends with reef limestone (Oxfordian - Early Tithonic) and black oncholithic Tithonic limestone (Dumitrescu R. et al., 1977, Bleahu M. et al., 1980).

The entire sedimentary series of the Bihor Unit from the Poiana Calineasa-Ocoale-Gârda lineament forms a homoclinal structure, which generally strikes NE–SE. The ensemble dips from NE to SW in the northern half of the structure and from E to W in the southern one. In general, neither a recurrence of the succession due to strike-slip faulting on reverse faults, nor any folding can be identified. The structural continuity of the Triassic deposits along the NW-SE direction is broken by two grabens with Jurassic deposits in their axis, structures that deeply penetrate toward north-east into the homoclinal structure of the Triassic deposits, between Ghiobului stream and Vulturul stream and south of Pârâul Spurcat up to Ocoale area.

In the southern part of the concerned area, the sequence of carbonate deposits is longitudinally dissected by the Hănăşeşti-Mununa fault system, with its western compartments uplifted. In this compartment, along the fault, Anisian dolomites outcrops are frequent.

For the hydrogeological map we completed, the geological background is provided by the sheets Poiana Horia and Avram Iancu of the Geological Map of Romania, scale 1:50.000, devised by Bleahu M., Dumitrescu R., Bordea S., Bordea J., Mantea Gh. (1980) and Dumitrescu R., Bleahu M., Lupu M. (1977).

Geological map (1:50.000) CRUTA



Legende: 1. Alluvium; 2. Kalksteine; 3. bituminöse Kalke; 4. Riffkalke; 5. Mergel und Mergelkalke; 6. Sandsteine, Tone, Konglomerate, bituminöse Kalke; 7. weiße Riffkalke; 8. Riffkalke, Schiefer; 9. Dolomit; 10. Sandsteine, Schiefer, Konglomerate; 11. Sandsteine, Schiefer; 12. geologische Grenze; 13. Überschiebungsdecke; 14. senkrechte oder sehr schrägeinfallende Verwerfung.

C. Meteorological data

Introduction

The meteorological records network, consisting of the meteorological station Gheţar (m.s. Gheţar) and of the rainfall gauging points Gârda Seacă and Poiana Călineasa, was set up in order to provide data necessary as inputs to the hydrogeological and hydrochemical study, as well as for describing the climatic conditions over the period of the project completion within the regional multi-annual climatic framework, relying on the data provided by the permanent meteorological stations of the INMH network, and for assessing the evolution of the vegetation on the experimental plots with grassland and vegetables.

The meteorological platform.

The meteorological platform (photo) is built in the center of Gheţar village, at 1134 m absolute elevation, and is provided with a meteorological shelter that inside it has thermometers (for minimum and maximum temperatures, as well as a common one) and a recording thermo-hygrometer, with heliograph, pluviometer and rainfall recorder. For the maintenance of the equipment and for performing the observations, there have been hired and trained the local people Luminiţa and Lucian Dobra. Observations are performed daily at 8.30 and 20.30. The meteorological station has been installed at the end of the month of April 2001 and its operation started on the month of May 2001.

The station provides the following meteorological data: air temperature (daily minima, maxima and averages), air humidity, duration of sunshine and rainfall data. During the winter period, on the meadow near the platform there are installed three rods for measuring the snow thickness, and every five days there are performed densimetry measurements of the snow layer for computing the water reserve within it.

The present report presents the meteorological data recorded at Gheţar meteorological station up to 31 December 2002. The station will continue to operate, so that data to be obtained subsequently will be sent every month to the interested persons involved in the project. After the station shall stop operating, the meteorological data, including also those recorded after 01 January 2003, shall be used in a unitary report, to be completed as an input for the design of the water supply scheme of the local households.

In the village Gârda de Sus, some 200 m upstream from the junction between Gârda Seacă and Ordâncuşa streams, on the left bank of Gârda Seacă there has been installed a pluviometer for rainfall gauging. Measurements are performed daily at 8:30 and 20:30 by Iulia and Avram Negrea. The equipment is installed at about 745 m elevation.

In order to gauge the rainfall amount in Poiana Călineasa a pluviometer was installed, located some 300 m south-west from the cross on the hill Capul Şanţului, at 1356 m approximate elevation. At this rainfall gauging point observations have covered two distinct periods - May to September of the years 2001 and 2002 - during which herdsmen were temporarily based in that area. Observations are performed by Ana Dobra.

The results of the meteorological observations and measurements performed in the study area are compared with the multi-annual averages recorded until the year 2000 at the INMH stations in the proximity, data that are presented in the final climatologic study completed by Gh. Călinescu and Elena Soare (2001). While preparing the present report, we were not in the possession of climatic data for the years 2001 and 2002 recorded at the INMH meteorological stations close to the investigated area, data that are necessary for correlations and in the end for the multi-annual assessment of the climatic conditions in Gheţar area.

1. AIR TEMPERATURE

Processing of the data provided by daily observations, performed at 8.30 and 20.30 by means of the minimum, the maximum and the common thermometers, corroborated with the continuous temperature records interpretation, resulted in obtaining the following air temperature values (tables 1 of the appendix):

- the instantaneous daily temperature, at the time 8.30, 14.30, 20.30 and 2.30;
- the daily mean temperature, computed as the arithmetic mean of the 4 previously mentioned instantaneous values. We restate that the notion of “day”, according to the meteorological meaning used in the present report, encompasses the time interval between 8.30 of the concerned day until 8.30 of the next day;
- the daily minimum and maximum temperature;
- the monthly mean temperature;
- the minimum and maximum monthly mean temperature;
- the absolute minimum and maximum monthly and annual temperature.

The monthly values of the indicated temperatures are synthetically presented in table 1.

Month	Hourly mean				Monthly mean	Averages				Absolute temperatures				ΔT
	8:30	14:30	20:30	2:30		Max.	Day	Min.	Day	Max.	Day	Min.	Day	(7-9)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
May-01	10.1	14.3	11.1	5.6	10.3	-4.8	18	4.8	12	21.8	27	-1.2	13	9.8
Jun-01	10.1	14.8	10.8	6.9	10.6	15.5	18	4.7	12	21.5	18	0.7	10	10.8
Jul-01	15.7	18.8	15.9	11.4	15.4	19.3	16	12.4	24	23.8	16	8.0	10.15	6.9
Aug-01	15.8	20.6	14.9	11.2	15.6	20.7	5	9.3	31	28.1	6	1.3	29.30	11.4
Sep-01	10.9	13.7	10.4	8.6	10.9	18.1	24	6.0	10, 11	21.1	24	2.0	12.28	12.1
Oct-01	6.4	12.7	10.2	6.2	8.8	13.6	9	1.5	28	21.8	9	-3.6	28	12.1
Nov-01	-1.5	2.1	-0.3	-0.8	-0.1	8.8	9	-9.8	27	12.0	9	-17.8	27	18.6
Dec-01	-10.1	-3.4	-8.6	-9.8	-8.0	-1.9	3	-15.3	17	4.3	2	-21.8	17.18	13.4
Jan-02	-6.6	0.5	-3.7	-5.4	-3.8	6.9	29	-17.5	4	13.1	31	-21.3	3	24.4
Feb-02	-1.1	5.1	1.4	-0.2	1.3	5.5	18	-6.1	16	15.6	3	-10.4	14	11.6
Mar-02	-0.8	6.7	4.1	0.4	2.6	11.1	6	-3.2	28	15.2	15	-7.0	3.4	14.3
Apr-02	2.9	8.3	5.6	1.6	4.6	10.2	31	-6.2	7	16.6	13	-7.9	7	16.4
May-02	11.5	15.4	12.9	7.7	11.9	16.9	26	8.4	1	22.2	26	2.2	1	8.5
Jun-02	13.8	18.0	16.0	9.9	14.4	20.8	24	6.8	2	26.5	22	2.4	2	14.0
Jul-02	16.4	20.9	18.2	12.9	17.1	21.0	20	12.7	1	28.3	11	7.0	1	8.3
Aug-02	13.1	17.6	14.6	11.3	14.1	17.6	4	11.5	30	22.6	4	5.7	30	6.1
Sep-02	8.6	13.0	9.9	8.3	10	15.2	4	4.2	27	22.1	2	1	27	11.0
Oct-02	5.3	9.2	5.8	5.5	6.5	12.6	17	0.3	29	18.0	18	-2.7	19	12.3
Nov-02	1.8	5.8	2.5	2.0	3.0	11.9	17	-3.2	10	18.3	16	-11.7	11	15.1
Dec-02	-5.6	-1.2	-4.7	-5.0	-4.1	3.4	5	-15.6	25	6.3	5	-23.5	25	19.0
2002	4.9	9.9	6.9	4.1	6.5	12.8		-0.7		28.3	11 VII	-23.5	25 XII	13.4

Table 1 The monthly and annual minimum, maximum and mean temperatures recorded at the meteorological station Gheţar over the period May 2001- December 2002

1.1 Monthly and annual maxima and minima

In fig. 1 diagrams of the monthly temperatures fluctuations are shown.

Within the period May-December 2001, the month of August had the highest mean temperature (15.6°C), while the minimum monthly temperature was recorded on the month of December (-8.0°C). The air temperature reached the maximum value on 6 August (28.1°C) and the minimum value on 17 and 18 December (-21.8°C).

The year 2002 had an mean air temperature of 6.5°C, with the extreme monthly mean values occurring on the months of July (21.0°C) and December (-15.6°C). The absolute maximum of the year 2002 was 28.3°C (11 July), while the absolute minimum, -23.5°C, was recorded on 25 December.

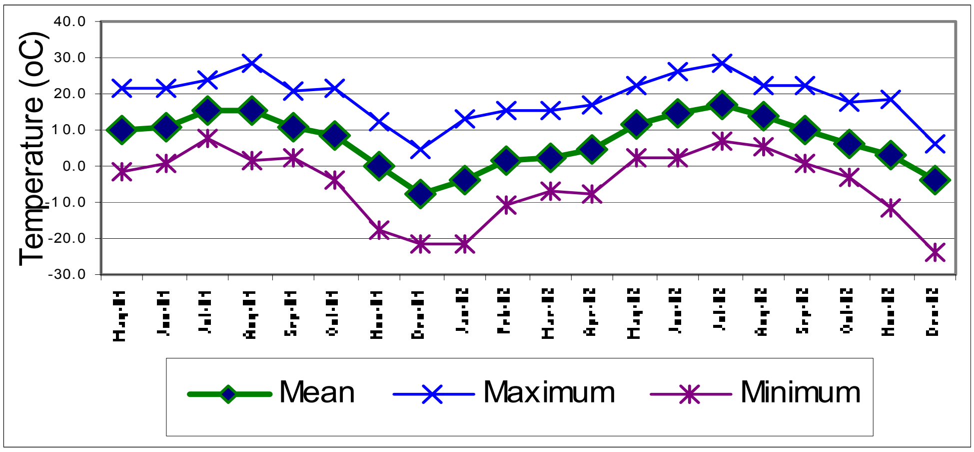


Fig. 1 Monthly variation of the air temperature at Ghețar meteorological station over the period May 2001 - December 2002

In the framework of the multi-annual monthly mean temperatures recorded by the INMH meteorological stations in the proximity of the investigated area (Călinescu, Soare, 2001), temperatures measured at Ghețar range close to the high temperature stations (fig. 2).

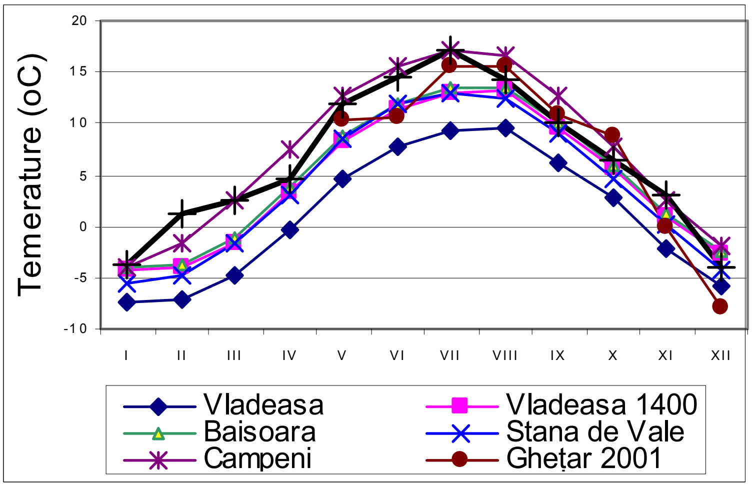


Fig. 2 Variation of the multi-annual (1961-2000) monthly mean temperatures at INMH stations in Apuseni Mountains and their variation at Ghețar Meteorological Station on the year 2002.

The diurnal oscillations of the air temperature have been globally estimated as differences between the maximum and minimum monthly means of the air temperatures. The largest differences between the daily maximum and minimum temperatures occur during the winter months, and the smallest during the summer months (fig. 3). The general trend of these differences has a sinusoidal shape. On the year 2002, the difference between the daily mean temperatures displayed an mean value of 24.4^{o}C on the month of January and of only 6.1^{o}C on the month of August.

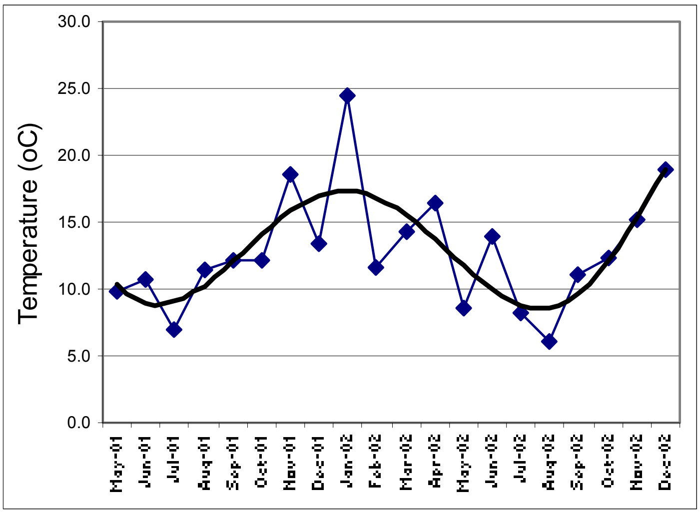


Fig. 3. Variation of the diurnal oscilations of the air temperature (monthly means) at Gheţar meteorological station over the period May 2001 - December 2002

1.2 The number of days with minimum temperature≤ 0°C (freezing days)

The distribution by temperature classes (intervals) of the number of days with mean, maximum and minimum daily temperatures recorded at Gheţar meteorological station is indicated in table 2, and the data of the specified table are displayed in the form of a diagram in the figures 4 and 5.

Temperature classes (°C)	Number of days					
	V-XII. 2001			2002		
	T. mean	T. max	T. min	T. mean	T. max	T. min
30-35						
25-30		6			12	
20-25	1	42		5	46	
15-20	39	77		49	73	4
10-15	85	47	44	89	82	59
5-10	58	22	74	65	66	83
0-5	15	20	69	91	56	75
0-(-5)	21	23	17	40	20	76
(-5)-(-10)	14	8	20	17	8	36
(-10)-(-15)	11		8	6	2	16
(-15)-(-20)	1		11	3		11
(-20)-(-25)			2			5
(-25)-(-30)						

Table 2 The distribution by classes of the mean, minimum and maximum daily temperatures recorded at Gheţar meteorological station over the period V-XII.2001 and over the year 2002

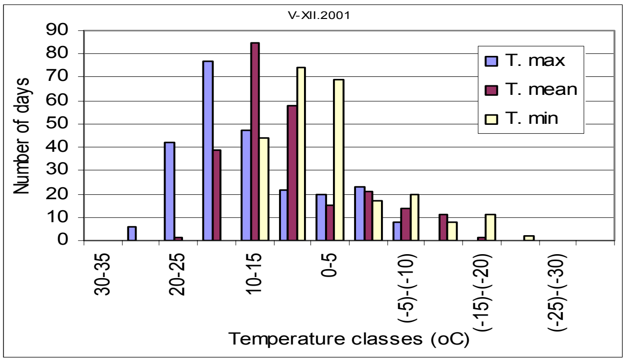


Fig. 4 The distribution by classes of the daily air temperatures recorded over the period May-December 2001 at Gheţar meteorological station.

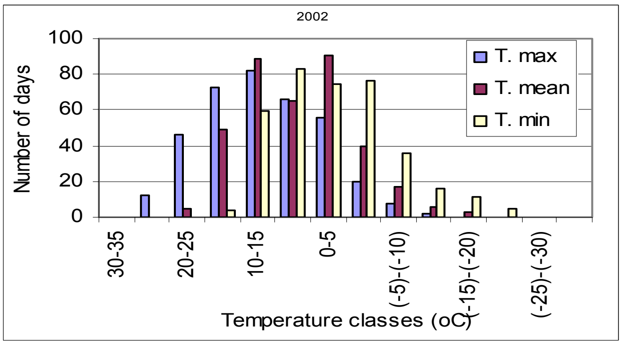


Fig. 5 The distribution by classes of the daily air temperatures recorded over the year 2002 at Gheţar meteorological station.

On the autumn of the year 2001, the first day of frost occurred on 27 October, a number of 59 days with negative minimum temperatures being recorded until the end of the year. The last day of frost of the winter 2001-2002 occurred on 28 April 2002, and the first day of frost of the winter 2002-2003 occurred on 2 October. On the year 2002 there have been a total of 136 days with negative temperatures.

1.3 Number of days with minimum temperature ≤ -10^{o}C (frost nights)

Over the period May-December 2001 there have been 26 days with minimum temperatures lower than -10^{o}C, and on the year 2002, out of the total number of frost days, the number of freezing nights has been 32.

1.4 The number of days with maximum temperature ≤ 0^{o}C (winter days)

The number of days with negative maximum temperature amounted to 51 during the interval May-December 2001, and to much less on the year 2002, only 25 days.

1.5 The number of days with maximum temperature ≥ 25^{o}C (summer days)

The month of August was the warmest month of the year 2001. It is only this month that the maximum air temperature exceeded 25^{o}C (6 times). On the year 2002 the summer days occurred earlier than the preceding year, the 25^{o}C temperature being exceeded 4 times on the month of June and 9 times on the month of July.

Maximum temperatures larger than 30^{o}C (tropical days) or days with minimum temperature larger than 20^{o}C (tropical nights), had not been recorded at Ghețar meteorological station during the period of the years 2001-2002.

2. THE RELATIVE AIR MOISTURE

The relative air moisture was recorded daily by means of a recording hygrometer, the readings on the diagrams being performed for the time moments 8.30, 14.30, 20.30 and 2.30. In the tables 5 of the appendix there are given the values of the 4 instantaneous readings, the daily means for these 4 readings and the monthly means. In table 3 we show the recorded monthly and annual mean values, a diagram illustrating the variation of these values being displayed in figure 6.

Over the period of observations, the relative air moisture had small monthly fluctuations, with variations ranging between 79.0 and 92.8 %. Over the period May–July 2002, the relative air moisture values have been about 10% lower than during the rest of the year. The average value for the year 2002 is 86.4%. The variations of the moisture measured at the time 14.30 (monthly mean values), roughly follow the trends of the monthly mean values, being yet by about 10-20 % smaller.

Month	Instantaneous values				Mean	Monthly averages				Time 14.30			
						Maximum		Minimum		Maximum		Minimum	
	8:30	14.30	20:30	2:30			day		day		day		day
Aug-01	86.1	57.2	82.4	98.3	81.0	94.5	20	66.3	30	100		36	31
Sep-01	85.8	71.2	94.2	94.5	86.4	99.5	7	68.3	14	100		37	14
Oct-01	98.8	71.1	86.2	97.1	88.4	98.3	7	75.5	3	100		27	3
Nov-01	91.8	75.0	88.9	92.2	87.0	99.3	21	60.5	18	100		17	18
Dec-01	93.4	76.1	94.4	97.1	87.4	100	30	80	10	100	30	37	10
Jan-02	94.5	71.5	94.3	94.2	88.6	100	4-6	41.3	29	100	4-6	25	31
Feb-02	94.7	65.1	89.3	94.1	85.8	98.5	10	67.3	4	100		14	15
Mar-02	93.6	54.6	74.5	91.2	78.5	100		59.3	6	100		22	14
Apr-02	96.1	61.3	77.8	97.7	83.2	100	16	70	21	100	16	26	21
May-02	86.7	62.8	79.4	95.9	81.2	97.3	29	55	8	96	12	32	3
Jun-02	83.4	63.5	74.4	95.8	79.3	95.3	6	60.8	24	95	10	37	23
Jul-02	87.3	65.4	83.5	97.2	83.4	96.3	8	57.8	3	96		36	3
Aug-02	98.3	74.5	90.5	98.0	90.3	99	9	76	18	99	14	44	18
Sep-02	95.0	76.9	92.2	96.0	92.8	99	7	82.5	1	97	16	45	1
Oct-02	93.1	73.3	89.9	90.9	89.7	98.5	11	75	17	98		55	17
Nov-02	97.4	77.1	94.6	95.7	91.2	100		74.5	29	100	21	28	18
Dec-02	97.3	83.5	93.9	96.2	92.7	100		74.8	16	100		36	14
2002	93.1	69.1	86.2	95.2	86.4	98.7		66.2		98.4		33.3	

Table 3 Monthly mean values of the relative air moisture (%), measured at Ghețar meteorological station over the period August 2001- December 2002.

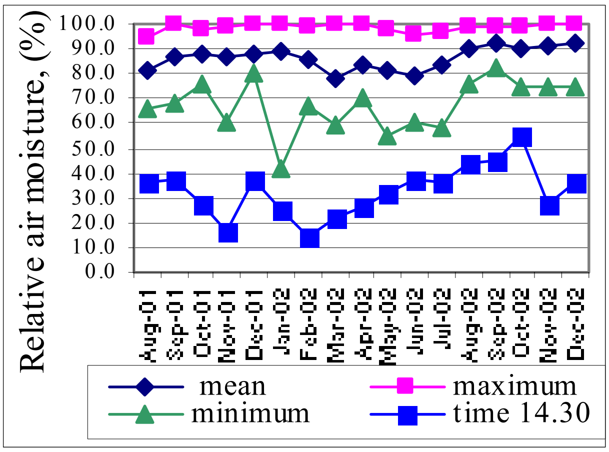


Fig. 6 Variation of the relative air moisture (%), measured at Gheţar meteorological station over the period August 2001-December 2002

Relative air moisture classes, %	Daily means				Time 14.30			
	VIII-XII.2001		2002		VIII-XII.2001		2002	
	Days	%	Days	%	Days	%	Days	%
90-100	55	36.4	145	39.7	30	20.3	89	24.1
80-90	63	41.7	124	34.0	31	20.9	40	11.0
70-80	27	17.9	75	20.5	11	7.4	45	12.3
60-70	6	4.0	17	4.7	21	14.2	62	17.0
50-60	0	0.0	3	0.8	24	16.2	57	15.6
40-50	0	0.0	1	0.3	19	12.8	41	11.2
30-40	0	0.0	0	0.0	7	4.7	18	4.9
20-30	0	0.0	0	0.0	3	2.0	10	2.7
10-20	0	0.0	0	0.0	2	1.4	3	0.8
0-10	0	0.0	0	0.0	0	0.0	0	0

Table 4 Distribution by classes of the relative air moisture (%) measured at Gheţar meteorological station over the period May 2001- December 2002

In order to outline the daily evolution of the relative air moisture we divided the daily mean values and those measured at 14.30 into humidity classes, by a 10 % step. The values thus obtained are shown in table 4 and illustrated by the diagrams in figure 7.

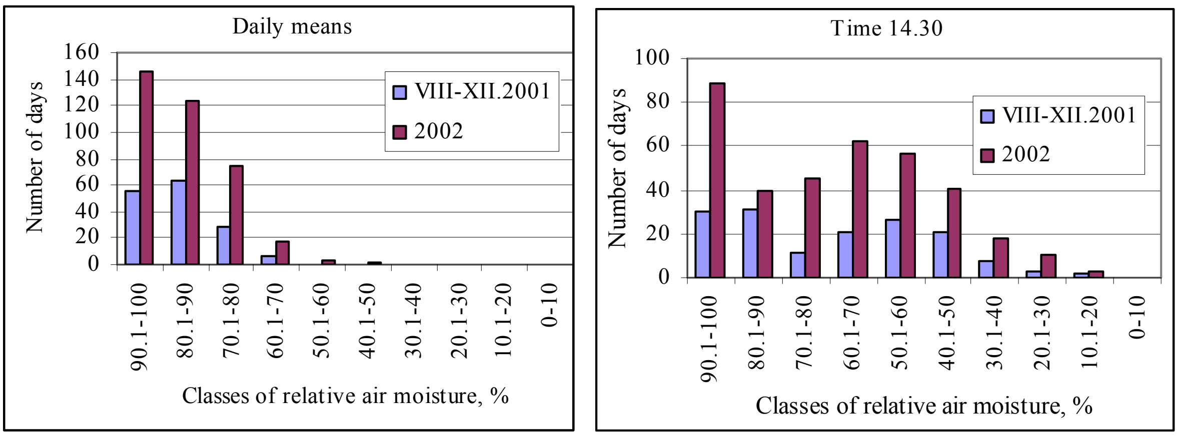


Fig.7 Distribution by classes of the relative air moisture (%),

measured at Gheţar meteorological station. Daily mean values (right) and daily values recorded at the time 14.30 (left).

During the year 2002, the relative air moisture (daily means) had values larger than 80% on 269 days (73.7 %). On 75 days (20.5%) the moisture was 60-80 %, values below 60 % being recorded on the remaining 21 days of the year (5.8 %).

Days with mean relative air moisture of the below 30% indicate severe air dryness conditions. During the period VIII 2001-XII 2002 there have not been such days at Gheţar. The lowest daily average value recorded was 41.3% (29 January 2002).

The series of relative air moisture values recorded at the time 14.30, during the time span of occurrence of the daily maximum temperature, exhibits very large fluctuations, the days with moisture lower than 30 % being sporadically distributed. The number of these days is 12 during the period VIII 2001-XII 2002 and 31 (8.4%) on the year 2002. The lowest values were recorded on days 15.02.2002 (14%), 18.11.2001 (17%) and 14.03.2002 (22%).

3. SUNSHINE DURATION

The duration of sunshine designates the time interval of a day during which the sun shines. It is expressed as hours and tenths of an hour.

In table 5 and in the diagram of figure 9 the sum of the hours during which the sun shone at Gheţar is shown for each month.

The number of sunshine hours has been 917.4 during the period August – December 2001 and 1629.7 over the year 2002. Over the time span of a year, the monthly sums of sunshine hours display significant variations, being at their minimum in December – when the daytime duration is at the minimum and, in many cases, also the cloudiness is the most intense.

Month	Hours
Jun-01	171.5
Jul-01	170.5
Aug-01	245.4
Sep-01	85.4
Oct-01	128.1
Nov-01	61.6
Dec-01	54.9
Jan-02	74.8
Feb-02	88
Mar-02	156.8
Apr-02	135.1
May-02	210.1
Jun-02	246
Jul-02	230.7
Aug-02	198.2
Sep-02	96.8
Oct-02	101.7
Nov-02	56.6
Dec-02	34.9

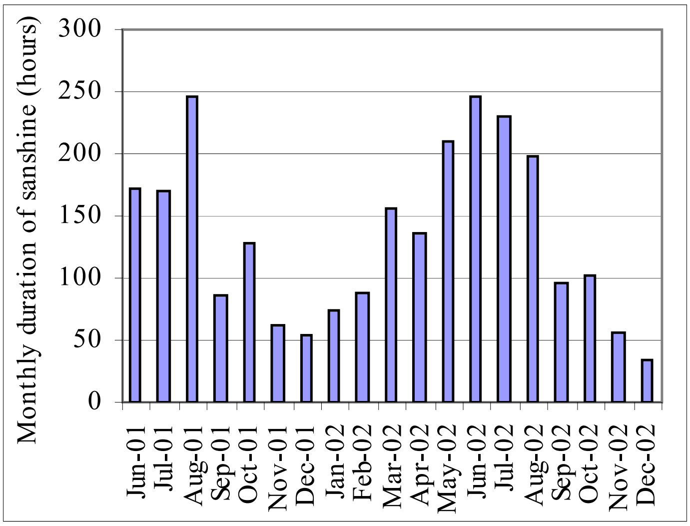


Fig. 9. Monthly duration of sunshine at Gheţar meteorological station

Table 5 Monthly number of sunshine hours at Gheţar meteorological station.

The multi-annual duration of sunshine, measured at the INMH meteorological stations, is 1702.3 hours at Vlădeasa, 1790.2 at Vlădeasa 1400, 1917.1 at Băişoara, 1579 at Stâna de Vale and 1709 hours at Câmpeni.

The distribution of sunshine daily durations over the year 2002 by classes of hours is displayed in figure 10. On that year the sun shone in the sky on 215 days, but on 54 of these the duration of shining was shorter than two hours.

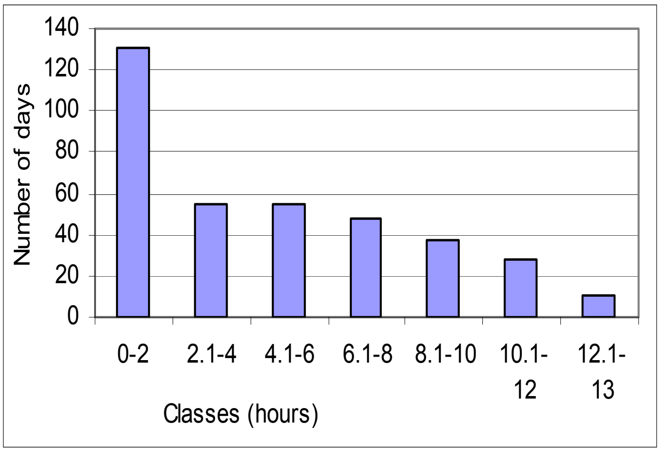


Fig.10 The distribution by classes of the daily durations of sunshine over the year 2002 at Gheţar meteorological station

4. RAINFALL

In order to provide a characterization of the rainfall regime in Gârda Seacă-Ordâncuşa watershed, measurements have been performed on three sites: Gheţar meteorological station (1134 m elevation), Gârda de Sus (745 m elevation) and Poiana Călineasa (1356 m elevation). On the first two sites continuous observations have been performed over the period May 2001- December 2002, while on the third site observations covered two distinct periods, May-September of each of the years 2001 and 2002.

Rainfall daily values measured at the three sites are provided in the monthly tables in the appendix, where there are indicated the values measured at 8.30 and 20.30, the daily and the monthly total amounts and the monthly maximum values (tables 2a-2e, 5a-5e and 6a-6b). Specific signs designate rainfall having occurred as sleet or snow.

Daily rainfall at Gheţar meteorological station is displayed in the diagram of figure 11, where one can notice a constant occurrence of rainfall over the entire period of observations May 2001-December 2002.

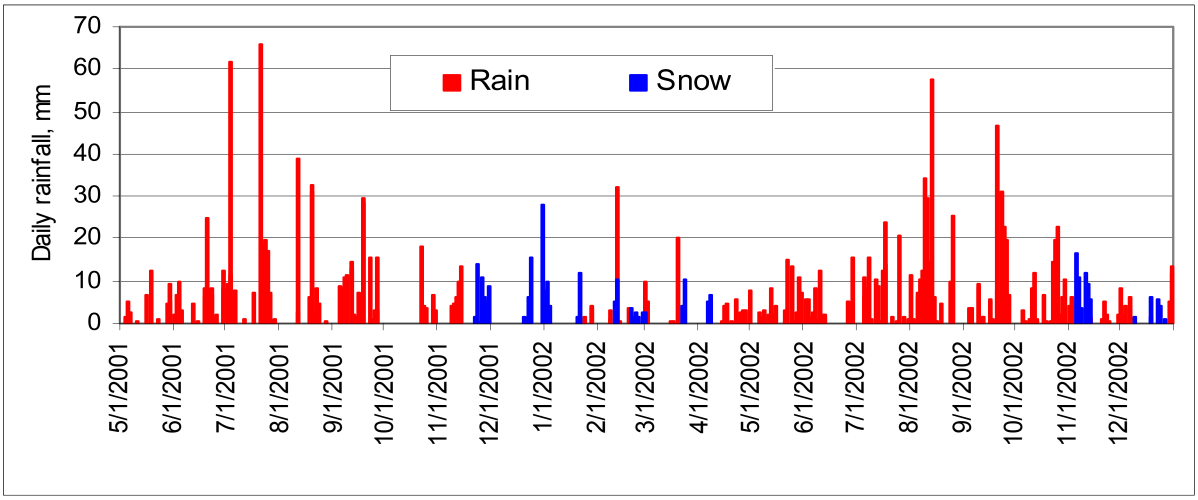


Fig. 11 Daily rainfall amount at Gheţar meteorological station over the period May 2001-December 2002

In the rainfall time distribution, one can notice the occurrence of summer months maxima, separated by a relatively monotonous pattern during the cold period of the year. During the period May-December 2001, there have been 99 rainfall days, yet on 72 of them the fallen amounts have been lower than 10 mm, and on 18 days, between 10 and 20 mm (table 6 and fig. 12). The largest rainfall amounts totaled 66.0 mm on the day of 21 July and 61.6 mm on 3 July.

During the year 2002, the number of rainfall days amounted to 177. On 136 of them, the rainfall amounts totaled less than 10 mm, and in 31 days, between 10 and 20 mm. The largest amounts fell on the days of 13 August - 57.4 mm and 21 September - 46.7 mm.

The rainfall monthly sums measured at Gheţar, Gârda de Sus and Poiana Călineasa are indicated in table 7 and displayed in the diagram of figure 11.

Classes (mm)	Number of days	
	V-XII. 2001	2002
0-10	72	136
10-20	18	31
20-30	4	5
30-40	3	3
40-50	0	1
50-60	0	1
60-70	2	0
Total	99	177

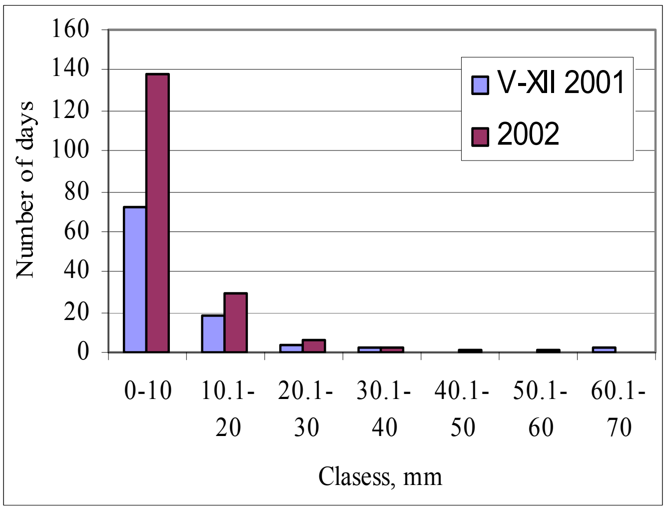


Table 6 and fig. 12. Distribution by classes of the daily rainfall amounts at Gheţar meteorological station

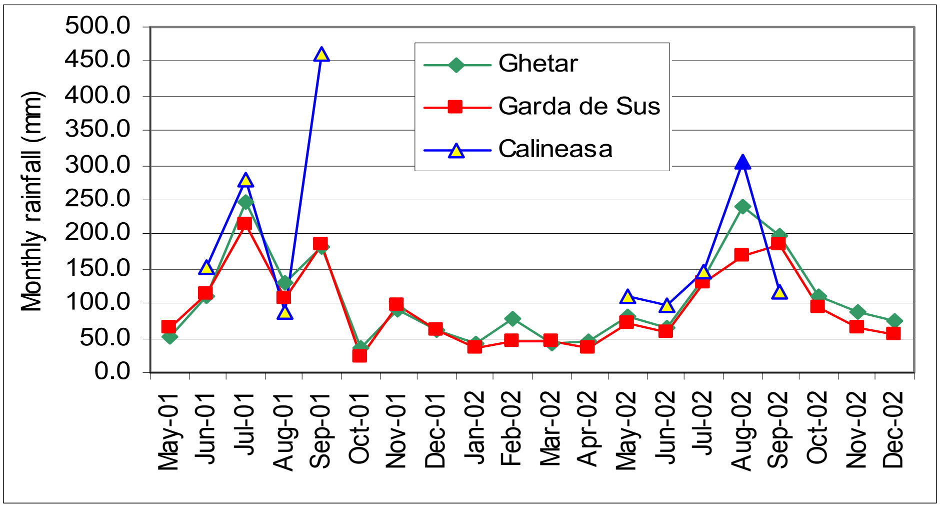


Fig. 11 Monthly rainfall amounts recorded at the stations Gheţar, Gârda de Sus and Poiana Călineasa.

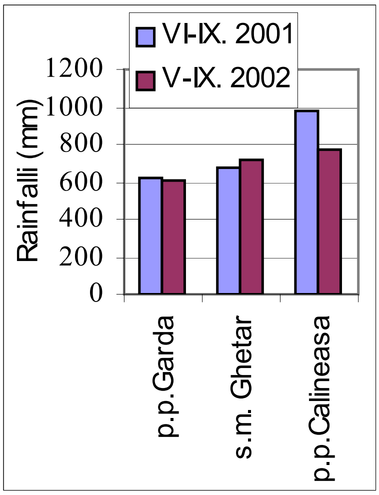
Month	Rainfall gauging point Garda de Sus (745 m)	Ghetar meteorological station (1134 m)	Rainfall gauging point Calineasa (1356 m)
Mav-01	63.6	50.8	
Jun-01	112.9	109.8	154.0
Jul-01	213.0	247.5	280.2
Aug-01	107.0	130.5	88.0
Sep-01	184.6	182.4	461.0
Oct-01	21.7	35.4	
Nov-01	96.7	91.5	
Dec-01	61.5	60.1	
Jan-02	35.3	42.4	
Feb-02	43.9	79.5	
Mar-02	43.9	41.3	
Apr-02	36.3	46.7	
May-02	70.3	81.9	111.6
Jun-02	59.6	64.0	96.8
Jul-02	128.8	137.1	145.1
Aug-02	167.6	239.0	305.3
Sep-02	183.5	196.8	117.5
Oct-02	95.1	109.8	
Nov-02	65.4	86.8	
Dec-02	56.1	75.0	
Total	1846.8	2108.3	
Total (%)	100%	114.20%	
Total 2002	895.8	1200.3	
Total 2002 (%)	100	134	
VI-IX. 2001	617.5	670.2	983.2
VI-IX. 2001 (%)	100.0%	108.5%	159.20%
V-IX. 2002	609.8	718.8	776.3
V-IX. 2002 (%)	100%	117.90%	127.30%

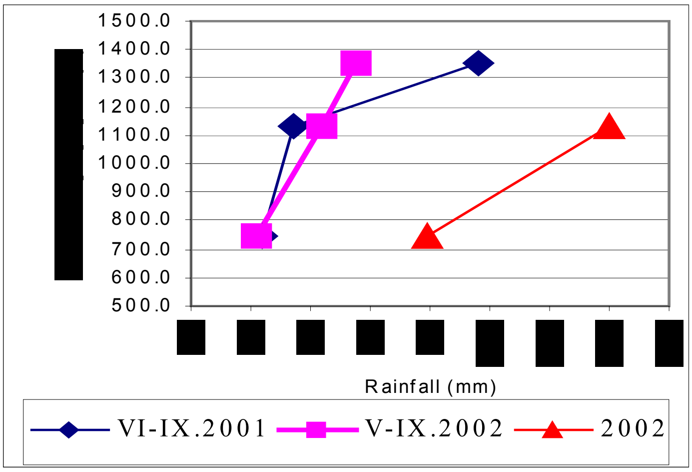
Table 7. Monthy rainfall amounts at Gheţar meteorological station and at Gârda de Sus and Poiana Călineasa rainfall gauging points (mm).

On the 3 sites, rainfall follows resembling increasing or decreasing trends, with high values over the period July-September and low values during the interval October 2001 - June 2002. On the year 2001, the maximum amounts have been measured on the month of July (213.0 mm), and on the year 2002, on the month of August (239.0 mm).

At the rainfall gauging point in Poiana Călineasa, during the time intervals May-September 2001 and 2002, the rainfall amounts exceeded those of the other observation sites, the maximum daily amounts being 80.9 mm (13 August 2002) and 74.2 mm (21 July 2001). The most rainy months have been September 2001 with 461.0 mm and August 2002 with 305.3 mm.

By comparing the total rainfall amounts of the three observation sites, Gârda de Sus, Gheţar and Poiana Călineasa, one can notice that they increase according to the altitude (fig.14 and 15).





Figures 14 (right) and 15 (left). Rainfall-altitude relationships

for the gauging sites Gârda de Sus, Gheţar and Poiana Călineasa.

The snow layer

The time distribution of the snow layer has been recorded at Gheţar meteorological station. Its thickness was measured daily (table 2f) at the time 8.30 and 20.30 by means of three wood rods placed in the form of an equilateral triangle of 10 m side, next to the meteorological platform. The snow density was measured every five days, in several spots located on a lineament meteorological platform - forest (westward). The diagram in fig. 16 displays the variation of the snow layer thickness over the winter 2001-2002.

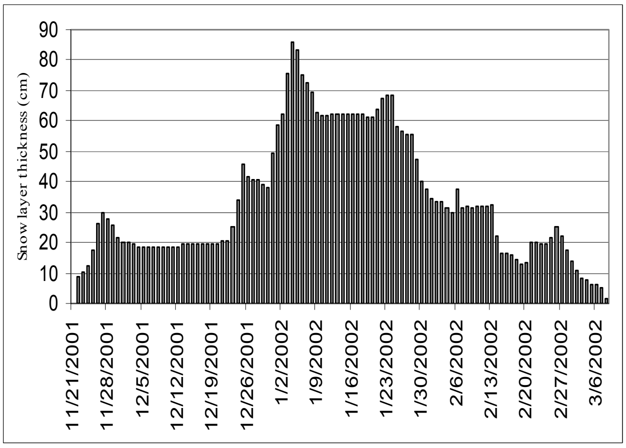


Fig. 16 The variation of the snow layer thickness at Ghețar meteorological station over the winter 2001-2002.

The snow layer has permanently covered the soil for 120 days, during the time span between the first snow (22 November 2001) and its complete melting (8 March 2002). Its thickness was maximum in the second part of the month of December 2001 and on the month of January 2002, at the end of the latter starting to undergo a steady thinning, until it completely disappeared. The layer has reached a maximum thickness of 85.7 cm on 4 January 2002. The monthly average thickness of the snow layer has been 18.2 cm on the month of November 2001, 26.3 cm on December 2002, 62.0 cm on January 2002, 24.3 cm on February 2002 and 5.6 cm on March 2001.

The evolution, in five days steps, of the snow layer water reserve during this time span is indicated in table 8 and in fig. 17.

Date	R (kg)	Date	R (kg)
25-Nov-01	15	20-ian-04	101
1-Dec-01	51	25-ian-05	105
5-Dec-01	48	1-Feb-02	91
10-Dec-01	46.7	5-Feb-02	60
15-Dec-01	45.0	10-Feb-02	35
20-Dec-01	46.7	15-Feb-02	60
25-Dec-01	69.0	20-Feb-02	48
01-ian-02	103	25-Feb-02	52
05-ian-02	124.	1-Mar-02	46
10-ian-02	124	5-Mar-02	33.0
15-ian-03	112	10-Mar-02	0.0

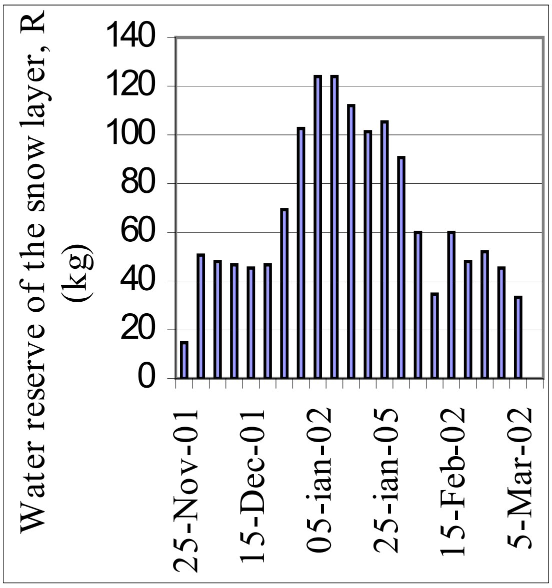


Table 8 and fig. 17. The variation, in five days steps, of the thickness (H, cm) and of the water reserve (R, kg) of the snow layer at Ghețar meteorological station during the winter 2001-2001.

The measurements and the data interpretation for Gheţar meteorological station resulted in computing the daily release of water from the snow layer during the period of its melting. The results that were obtained cannot be extrapolated to the entire study area, they however provide important hydrogeological information, substantiating also the shape of the hydrographs of the springs within the area and at its border. In figure 18 it is provided the diagram of the rainfall amounts at the station, corrected for the winter periods (November 2001-April 2002 and December 2002) by substituting the snowfall amounts (fig. 11) with the moment and the amount of water released from the snow layer during the melt period.

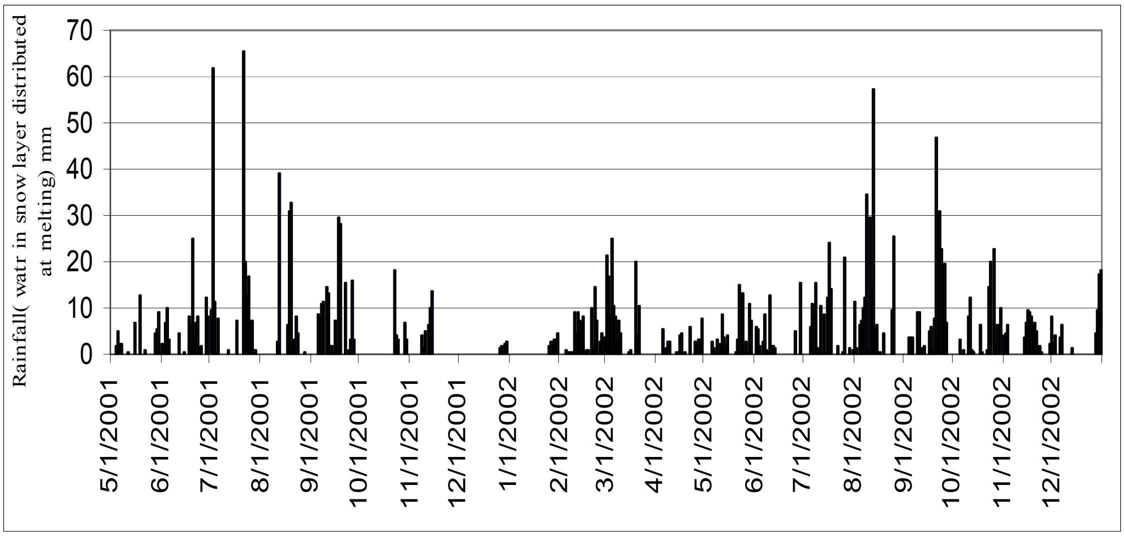


Fig. 18. Rainfall at Gheţar meteorological station.

Amount of water in the snow layer distributed at melting.

D. Hydrogeological issues

1. General issues

The northern half of the area concerned by the present study, from Poiana Călineasa lineament up to the Spurcat stream – Ordâncuşa stream headwaters lineament, is only temporarily inhabited, during the pasturing period, and it has enough water resources for watering the livestock.

The southern half of the concerned area, roughly coincident with the karst plateau, is permanently inhabited, with peasants households that are scattered chaotically or are clustered in villages (hamlets), such as Stânişoara, Dealul Frumos, Gheţar, Hănăşeşti, Mununa, etc. It is hard for the inhabitants of this part of the concerned area to benefit of drinking water supply, since they can resort only to a few low discharge springs, that in general are of temporary character and are located far from the center of the villages or from the isolated households. For watering the livestock local people also use rain water collected from the roofs and stored in pools built of wood, plastic or concrete. For the inhabitants of Ocoale village (photo 1), drinking water is provided by the line of springs on the right side of the homonymous stream, below the ridge Ocoale peak - Comărnicel - Dealul Bocului, springs that discharge the water stored in the Early Jurassic sandstone deposits.

The lack of water sources in the karst plateau is a consequence of the strong karst

Foto 1 Ocoale valley seen from the hill with the same name

processes to which the carbonate deposits had been subject, which resulted in the surface runoff being, to a large extent, disorganized and transferred in the underground. As a result, in the southern part of the watershed between the streams Gârda Seacă and Ordâncuşa, springs are scarce and of low yields, although at depth, in the limestone and dolomite body, there are located significant water accumulations that discharge through high flow rate springs, located at the border of the concerned area, on the banks of the two streams.

Within the area concerned by the present study, the following classes of aquifers occur:

- aquifers in the Early Jurassic deposits;
- aquifers in the alluvial-colluvial deposits.
- karst aquifers:
  - epikarstic aquifers;
  - karst aquifers of local extent;
  - karst aquifers of large extent.

The aquifers are in recharge-discharge permanent relationships, as a general rule the karst aquifers at depth being supplied by the others.

Aquifers in the Early Jurassic deposits. In the northern and the eastern parts of Ocoale village, along the Trei Cărări - Ocoale peak - east of Comărnicel peak - east of Dealul Bocului lineament (plates 2 and 3), the sandstone-conglomerate members of the Early Jurassic stack include water accumulations of local importance that discharge either at the surface, through many springs that are perennial (Fântâna Jimboeşti, nr. 52, photo 2; Fântâna lui Miron, no. 70, Fântâna Ilii Florea, no. 71), or temporary, (Izbucul din Dealul Brăzdeştilor, no. 62, photo 3, etc.), or directly in the underground, to supply the karst aquifers. They are the basic source for the population drinking water supply, playing a crucial role in the settling of the village family homes in the Ocoale area. The water of Fântâna lui Miron and that of Fântâna Ilii Florea have been tapped by the local people for the supply of 12 homesteads. In this area, the hillslope deposits derived from the weathering of the Early Jurassic sandstone deposits exceed
the outcrop area of the latter, by overlying and closely paralleling the limestone basement topography, shaped as small sinkholes.

Foto 2 Fântâna Jimboeşti (up) and
foto 3 Izbucul din Dealul Brăzdeştilor

Foto 4. Izvorul Costenilor (left) and
Foto 5, izvorul Oncheştilor (up),
situated on the right bank of the Ocoale stream.

The discharge of the springs that emerge from limestone in the upstream half of Ocoale stream (Fântâna Oncheştilor, no. 57; Izvorul Costenilor, no. 59, photo 4; Izvorul

Oncheştilor, no. 58, photo 5) is derived from the water accumulations in the Late Jurassic deposits that exist in the immediate proximity.

The water collected on the south-eastern slope of Ocoale peak concentrates in Ocoale stream, a surface water course that has a perennial character down to its junction with Valea Izvoarelor, supplied by the source La Izvoare (plate 3, no. 65). Downstream from this junction, the valley has a temporary character. The water of the springs on the north-western slope of Ocoale peak is collected in Spurcat stream or infiltrates in the depression La Hoape.

Aquifers in the alluvial-colluvial deposits. On the right side of Ocoale stream, there occurs a plain consisting of alluvial-colluvial deposits, built up of debris derived from the disintegration and the weathering of the Early Jurassic sandstone-conglomerate sediments, either carried by Ocoale stream from its head-waters, or fallen from its western slope. These deposits extend over some 2 km length and are 200-300 m wide.

The water accumulations in the alluvial - colluvial deposits flow mainly directly toward the underlying limestone, partly via the underground stream course intercepted in Groapa cu Apă a lui Miron (plate 3, no. 73, 1155 m elevation), a temporary swallet of Ocoale stream. The swallet is about 3 m deep, it is excavated in compact limestone, the underground stream surging from a narrow cavity excavated in the northern wall. The underground stream course, with a minimum flow rate of about 3 l/s, has been explored downstream on 4 November 2001 by Doru Cojocaru from ISER Bucureşti, over a length of about 36 m (-8 m elevation drop), the end of the cave being a sump pool. The cave strikes eastward, perpendicularly to the direction of Ocoale valley. During severe drought due to prolonged winter periods, local people use the water of the underground stream for watering the livestock. The water of the stream reaches the swallet only during high discharge stages, and only during exceptionally high discharge stages runs past it, the last situation occurring on the year 1990, when the water of the stream reached the swallet at Vuiaga Veche.

Foto 6 Fântâna Barâcia

Foto 7 Fântâna din Vuiagă

During low discharge periods, the underground stream in Groapa lui Miron is not supplied by the water that diffusely sinks through the alluvia in the upper reaches of Ocoale stream, the latter getting in contact with it only during very high water stages, when the diffuse infiltration areas and the swallets located upstream have their stream water absorption capacity exceeded. During the tracer test performed on 11 August 2001 by the author, by injecting fluorescein in the water that diffusely sank, in its totality, in the streambed downstream from Izvoarelor brook, the tracer did not emerge in the underground course in Groapa cu Apă a lui Miron within the 10 hours during which observations had been performed.

In its southern limit, the alluvial-colluvial deposits plain has a peaty and wet appearance, the water accumulations within it discharging in the spring Fântâna din Vuiaga Veche (plate 3, no. 76) and in Fântâna din Vuiagă (plate 3, no. 77,photo 6).

The karst aquifers shall be addressed according to the concept of karst system, an elementary drainage unit that is coincident with the karst aquifer, in the case of unitary karst systems (Poarta lui Ioanele, plate 3, no.106), and includes also the non-karst catchment area that contributes to its supply, in the case of binary karst systems (Coteţul Dobreştilor, plate 2, no. 46).

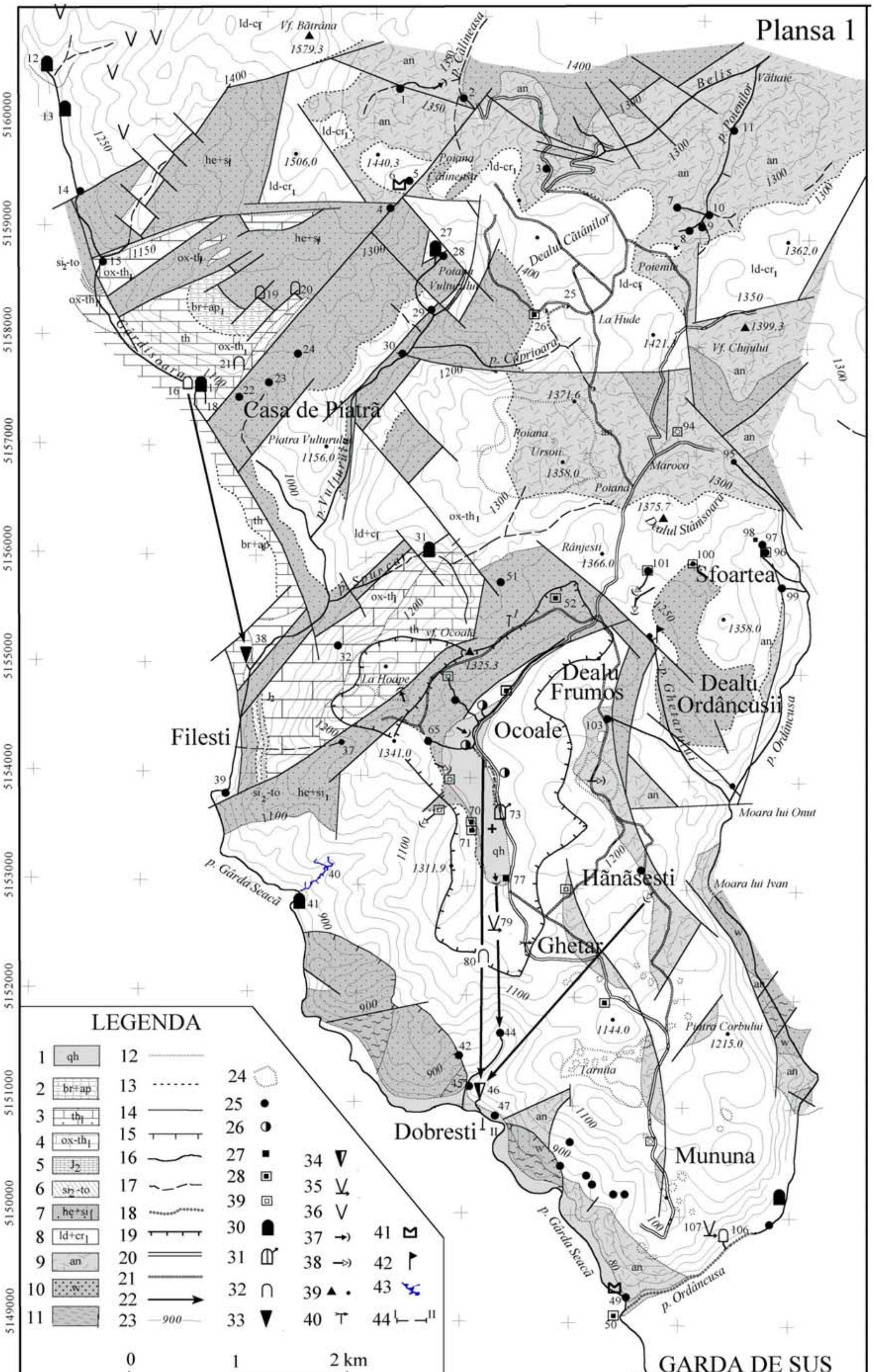
Epi-karstic aquifers. Within the fractured and weathered areas at the surface of the dolomite and limestone deposits, over a few meters depth, water accumulations occur that discharge through springs or that are tapped by fountains dug by local people. The resources of these aquifers are as a general rule poor, and they dry out during long periods of rainfall deficit. The sources emerging from dolomite deposits (Fântâna „Apa din Cale", no. 84, Fântâna Bărâcia, no. 85, photo 7) are a result of the dense fracturing and of the high secondary porosity of the rock, a consequence of the diagenesis processes. The spring Troaca din Hănăşeşti (plate 3, no. 86) is supplied to a large extent by the water accumulations of these areas in the nearby dolomites.

In some areas, generally at the major karst systems limits, the water accumulations in the carbonate deposits have not (yet) been connected to these major systems by means of the karst processes. They build up unitary systems (La Izvoare) or binary ones (Iapa) and they discharge through lithological contact springs. Among the local extent karst systems we also include the binary system discharging through Băii spring (plate 3, no. 32).

In order to benefit of more water, on certain spring sites local people have dug fountains up to 4 m deep, coated with fir tree boards or with concrete walls. During abundant rainfall periods the fountains are subject to overflow of the water, whose level drops, as the drought season advances, beneath the ground elevation, frequently until complete drying. On plate 2 we indicated the hydrological character of the fountains in Ocoale-Gheţar area by means of specific symbols, distinguishing: fountains with permanent water (Vuiaga, no. 77); fountains with permanent water, overflowing temporarily (Fântâna lui Miron, no. 70, Fântâna Ilii Florea, no. 71, La Rădăcini, no. 83, Iapa, no. 103, etc.) and fountains temporarily with water, overflowing temporarily (Izbucul din Dealul Brăzdeştilor, no. 62, Fântâna din Gard de la Dubi, no. 81, Fântâna lui Dobra Traian, no. 82, the fountains at „Apa din Cale", no. 84, Fântâna Bărâcia, no. 85, etc.).

The main karst systems in the southern part of Gârda Seacă-Ordâncuşa watershed are: Coteţul Dobreştilor, Poarta lui Ioanele, Codobana, La Băii, La Izvoare and Iapa, their name being given, as it is customary, according to the name of the spring through which the system water discharges.

The karst systems in the Gârda Seacă-Ordâncuşa watershed, that made the object of specific observations and hydrogeological measurements, are: Coteţul Dobreştilor, Poarta lui Ioanele, Iapa and La Izvoare, their name being given, as it is customary, according to the name of the spring through which the system water discharges.


Plansa 1
Casa de Piatră
Filesti
Ocoale
Dealu Frumos
Dealu Ordâncusii
Sfoartea
Hănăşesti
Ghetar
Dobresti
Mununa
GARDA DE SUS
LEGENDA
0 1 2 km

HYDROGEOLOGICAL MAP OF GÂRDA SEACĂ-ORDÂNCUŞA WATERSHED

Legend

1-Recent alluvia (qh). Bihor Autochthon: 2-Undivided Urgonian limestones (br+ap_1); 3–Black bedded oolithic limestones (th); 4-Reef limestones (ox-th_1); 5-Red oolithic limestones, yellowish spoted limestones, redish and grey encrinitic limestones (J_2); 6-Redish and grey encrinitic limestones, marls (si_2-to); 7-Quartzitic sandstones and conglomerates, argillaceous shales, black limstones (he+si_1); 8-White reef limestones - Wetterstein limestone (ld+cr_1); 9-Grey dolomites (an). Bihor Autochthon and Gârda Nappe: 10- Quartzitic sandstones and conglomerates, red argillaceous shales (w); 11- Crystalline schists; 12-Normal geological boundary; 13-Discordant geological boundary; 14-Fault; 15-Overthrust front; 16-Course of perennial stream; 17-Course of temporary stream; 18- Losses in flow along the riverbed; 19-Limit of endorheic surfaces; 20-Village road; 21-Forest road; 22-Proved groundwater flow direction; 23-Contour line; 24-Karstic depresion, shalow hole; 25-Perennial spring; 26-Temporary spring; 27-Perennial dug well; 28- Perennial dug well, temorary overflowing; 29-Temporary dug well, temporary overflowing; 30-Perennial outflow cave; 31-Temporary inflow cave, tapping an underground stream; 32-Fossil cave; 33-Perennial outflow pothole; 34-Temporary outflow pothole; 35- Pothole tapping an underground stream; 36-Fossil pothole; 37-Perennial swallet; 38-Temporary swallet; 39-Hill; 40-Meteorological station; 41-Pluviometer; 42-Limnigraph; 43-Cave passage; 44-Direction of hydrogeological cross section..

Key of the numbers.

Poiana Călineasa: 1-Călinesei spring; 2-Şanţului spring; 3-Spring under Ţâşlilor hill ; 4-Spring under Piatra Călinesei; 5-„La Dat” spring in Faţa Călinesei; 6-Pluviometer at Poiana Călineasa; 7-Hoanca Seacă (Poieni) spring; 8-Spring at Poieni; 9-Izvorul de sub Brad spring; 10-Spring at Coliba Costii; 11-Spring at Poienilor brook.

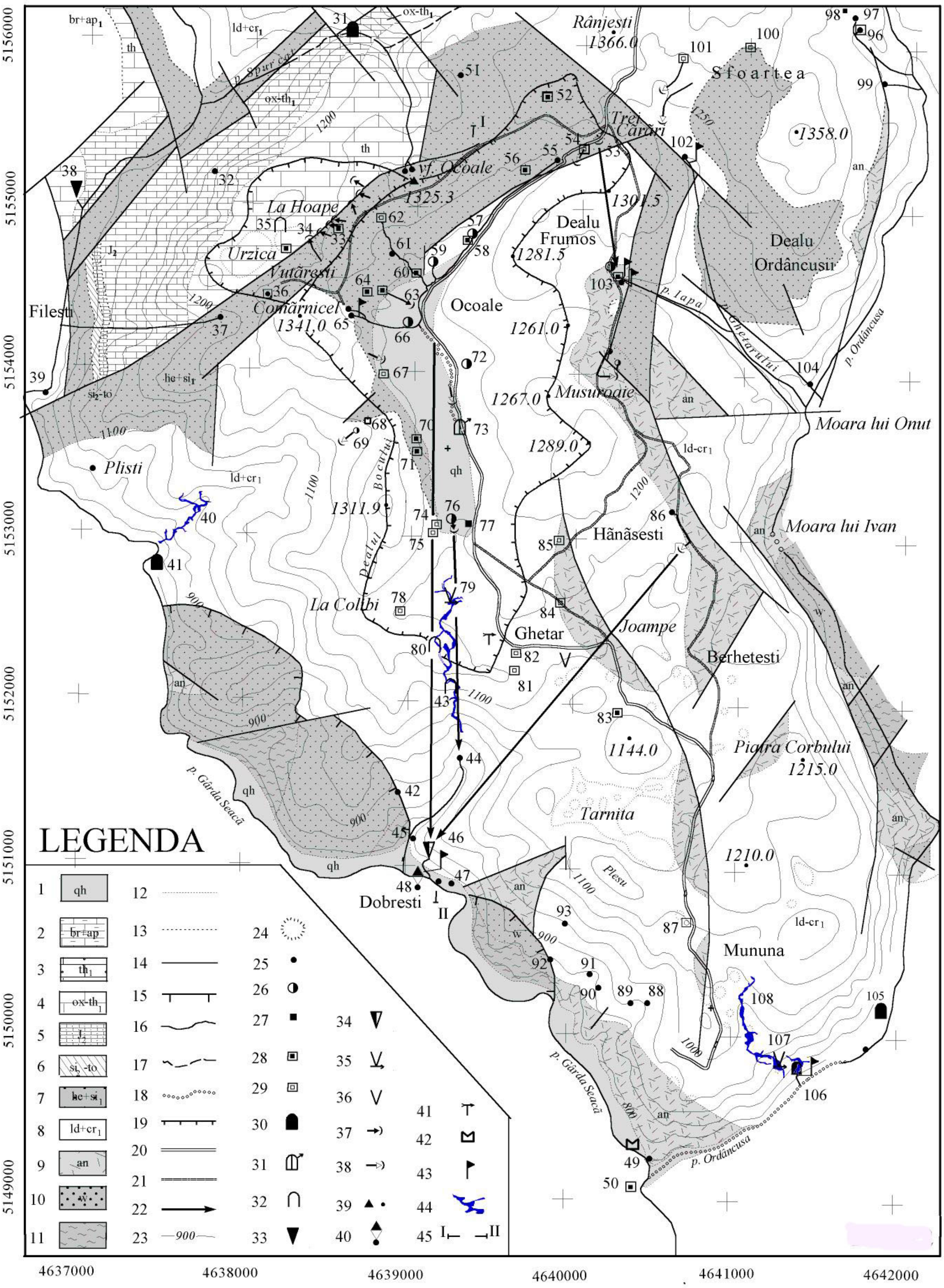
Hydrographic basin of Gârdişoara brook: 12-Gura Apei cave; 13-„Apa din Piatră” spring; 14-Coliba Ghiobului spring; 15-Crişanului spring; 16-Coiba Mică cave; 17-Coibiţa spring; 18- Coiba Mare cave; 19-Peştera de După Deluţ cave; 20- Cave at Orbului brook; 21- Cave at Vârtop; 22- Spring at Casa de Piatră; 23- Spring at Vârtop; 24-Fântâna lui Vasile spring.

Hydrographic basin of Gârda Seacă river: 25- Ciuci spring; 26- In Câmp spring; 27- Cave at Poiana Vulturului; 28- Spring at Poiana Vulturului; 29- Vulturului spring; 30-Izvorul de sub Drum spring; 31-Peştera cu Apă din pârâul Brusturi cave; 32- Spring of Băii brook; 37- Ştiubei spring; 38- Tăuz spring; 39- Spring at Podul Cerbului; 40- Hoanca Apei cave; 41-Peştera cu Apă de la Tău (Codobana) cave; 42- Belenilor spring; 44- Poliţei spring; 45-Dobra’ spring; 46- Coteţul Dobreştilor cave; 47- Morii spring; 49-Izvorul de la Confluenţă spring; 50- Dug well at Casa Speo.

Ocoale basin: 51- Negreştilor; 52- Jimboieşti (la Cârceni) dug well; 65-Sursa „La Izvoare”; 70- Miron’s dug well;71- Ilii Florea dug well’s ; 73-Groapa cu Apă a lui Miron swallet.

Gheţar-Dealul Frumos-Munună area: 77- Vuiagă dug well; 79- Şesuri pothole;

Hydrographic basin Ordâncuşa brook: 94-Fântâna de pe Coastă dug well ; 95-Spring at Ordâncuşa brook origin; 96- Old dug well at Dăgârţeşti; 97- Dăgârţeşti spring; 98-Neag Iosif's dug well; 99- Bolf spring; 100- Stiubei (Sfoartea) dug well; 101- Dug well at Stânişoara; 103- Iapa spring; 106- Poarta lui Ioanele cave; 107- Zgurăşti pothole.



HYDROGEOLOGICAL MAP OF THE OCOALE – MUNUNA AREA

Legend

1-Recent alluvia (qh). Bihor Autochthon: 2-Undivided Urgonian limestones (br+ap$_1$); 3–Black bedded oolithic limestones (th); 4-Reef limestones (ox-th$_1$); 5-Red oolithic limestones, yellowish spoted limestones, redish and grey encrinitic limestones (J $_2$); 6-Redish and grey encrinitic limestones, marls (si$_2$-to); 7-Quartzitic sandstones and conglomerates, argillaceous shales, black limstones (he+si$_1$); 8-White reef limestones - Wetterstein limestone (ld+cr$_1$); 9-Grey dolomites (an). Bihor Autochthon and Gârda Nappe: 10- Quartzitic sandstones and conglomerates, red argillaceous shales (w); 11- Crystalline schists; 12-Normal geological boundary; 13-Discordant geological boundary; 14-Fault; 15-Overthrust front; 16-Course of perennial stream; 17-Course of temporary stream; 18- Losses in flow along the riverbed; 19-Limit of endorheic surfaces; 20-Village road; 21-Forest road; 22-Proved groundwater flow direction; 23-Contour line; 24-Karstic depresion, shalow hole; 25-Perennial spring; 26-Temporary spring; 27-Perennial dug well; 28- Perennial dug well, temorary overflowing; 29-Temporary dug well, temporary overflowing; 30-Perennial outflow cave; 31-Temporary inflow cave, tapping an underground stream; 32-Fossil cave; 33-Perennial outflow pothole; 34-Temporary outflow pothole; 35- Pothole tapping an underground stream; 36-Fossil pothole; 37-Perennial swallet; 38-Temporary swallet; 39-Hill; 40- Gaseous spring; 41-Meteorological station; 42-Pluviometer; 43-Limnigraph; 44-Cave passage; 45-Direction of hydrogeological cross section..

Key of the numbers.

Hydrographic basin of Gârda Seacă river: 31-Peştera cu Apă din pârâul Brusturi cave; 32-Spring of Băii brook; 33-Codruța dug well; 34-Big swallet at La Hoape (Muşuroaie); 35-Biserica lui Iacob cave; 36-Dug well at Vuțăreşti (Puceşti); 37-Ştiubei spring; 38-Tăuz spring; 39-Spring at Podul Cerbului; 40-Hoanca Apei cave; 41-Peştera cu Apă de la Tău (Codobana) cave; 42-Belenilor spring; 43-Pojarul Poliței cave; 44- Poliței spring; 45-Dobra’s spring; 46-Cotețul Dobreştilor cave; 47-Morii spring; 48-Feredeuspring; 49-Izvorul de la Confluență spring; 50-Dug well at Casa Speo.

Ocoale basin: 51-Negreştilor dug well; 52-Jimboieşti (la Cârceni) dug well; 53-Swallet at Trei Cărări (Aprozar); 54-Țuțerilor spring; 55-Spring at Ocoale brook origin; 56-Debii spring; 57-Oncheştilor dug well; 58-Oncheştilor spring; 59-Costenilor spring; 60-Buleştilor dug well; 61-Maciura spring; 62-„Izbucul” din Dealul Brăzdăieştilor spring; 63-Swallet of Gogului brook; 84-Sânt Ion dug well; 65-„La Izvoare” spring; 66- Mii spring; 67-„La Nița” dug well; 68-Fântâna de După Deal de la Bândeşti dug well; 69-Gârjel spring(La Țâraie spring); 70-Fântâna lui Miron dug well;71-Fântâna Ilii Florea dug well; 72-Spring at Hoancă; 73-Groapa cu Apă a lui Miron swallet; 74-„Apa Rece” dug well; 75-Fântâna de După Deal dug well.

Ghețar-Dealul Frumos-Munună area: 76-Fântâna Veche dug well and swallet at Vuiagă; 77-Dug well at Vuiagă; 78-Dug well at Şesuri; 79-Şesuri pothole; 80-Ghețarul de la Scărişoara cave; 81-Fântâna din Gard de la Dubi dug well; 82-Dobra Traian’s dug well; 83-„La Rădăcini” dug well; 84-„Apa din Cale” dug well; 85-Bărâcia dug well; 86-Troaca spring; 87-„La Butură” dug well; 88-Ştiubei spring; 89-Izvorul de la Troacă spring; 90-Troaca Tarniței spring; 91-Hoanca Tarniței spring; 92-Hoanca Fântânii spring; 93- Grosama spring.

Hydrographic basin of Ordâncuşa brook: 96-Old dug well at Dăgârțeşti; 97-Dăgârțeşti spring; 98-Neag Iosif’ dug well; 99-Bolf spring; 100-Stiubei (Sfoartea) dug well; 101-Dug well at Stânişoara; 102-Ghețarului spring; 103-Iapa spring; 104-Spring at Moara lui Ionel; 105-Tunel cave; 106-Poarta lui Ioanele cave; 107-Zgurăşti pothole; 108-Zgurăşti cave.

2. Coteţul Dobreştilor karst system.

In the south-western part of the watershed between the streams Gârda Seacă and Ordâncuşa there is developed one of the largest karst systems in Bihor Mountains, the karst system of the spring at Coteţul Dobreştilor. The northern part of the karst system includes the closed drainage depression Ocoale-Gheţar. The system also encloses the carbonate terrains that extend between Gheţar and Tarniţa, the eastern boundary of the system being probably coincident with the Hănăşeşti - Berheteşti - Piatra Corbului lineament ridge, that continues eastward up to Pleşu hill.

The aquifer system water discharges through several springs, all of which are situated on the left side of Gîrda Seacă stream, within the limits of Coteţul Dobreştilor hamlet, springs that are given the generic name „the outlets at Coteţul Dobreştilor" (fig. 19). In this area, the carbonate deposits of Bihor Unit exhibit a tectonic contact with the Werfenian sandstone of Gârda Nappe, that overthrusts them.

Photo 8. Coteţul Dobreştilor spring

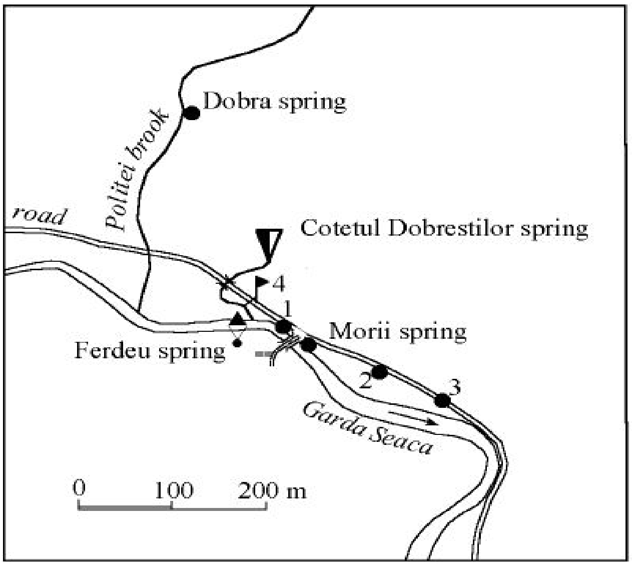


Fig. 19 The outlets at Cotetul Dobrestilor

These springs are:

- The spring at <u>Coteţul Dobreştilor</u> (plates 1 and 2, photo 8), emerges from a sump in a cave, a few meters from the entrance of the latter. The water table in the sump is situated at an average elevation of 770 m. The sump has been explored by divers over a total length of 294 m and down to -67 m depth (Damm et al, 1999), or -75.6 m (Ciubotărescu et al, 1998). Above the cave entrance there is an upper, dry network, that steeply rises up +22 m above the entrance. The total length of the cave is 511 m, out of which 294 m are flooded, and its passages extend over a total elevation range of 89 m (-67; +22). During the drought periods the spring dries out, which designates it as being an overflow outlet of the karst system.

- <u>Izbucul Morii</u> (plate 1, no. 47), situated some 5 m downstream from the bridge over Gârda Seacă stream, at about +2 m relative elevation with respect to its average level. The spring emerges from a limestone boulders accumulation. Its average flow rate is estimated to 30 l/s;

- <u>The source situated some 20 m upstream from the bridge over the stream</u>(fig. 19, no. 1). It emerges from beneath the solid boulders of limestone of the road embankment and it can be noticed only during the low stream discharge periods, being, conversely, flooded during high and average water stages;

- The source in the glade between the road and the stream (fig. 19, no. 2). It emerges from and area densely covered with grass, some 2 m from the road and 50 m downstream from the bridge. Its average flow rate is estimated to about 5 l/s.

On the right side of Gârda Seacă stream, opposite to its junction with the streamlet flowing out of Cotetul Dobrestilor spring, a sub-thermal spring Feredeu (plate 2, no. 48) emerges from the flood plain alluvia. Its temperature is 15,8 - 16,2^0 C and it is accompanied by strong outflows of free gas. Its occurrence is related to a deep circulation of the karst waters along the overthrust plane of Arieseni Nappe. The gas consists of the atmospheric air dissolved in water and subsequently released as a result of the increase in temperature.

The investigation of the groundwater circulation in the Gârda Seacă-Ordâncuşa watershed was initiated by the fluorescein tracer test performed in the underground stream course of the pothole in Şesuri, in the year 1957, by Serban, Coman and Viehman. Those investigators thus outlined the flow of the stream toward Poliţei spring (plate 2, no.44), the straight line distance between the final lake in the pothole and the spring being 450 m, over an elevation drop of about 40 m. The authors claim that Izbucul Dobreştilor outlet belongs to „a different, still unknown, closed system of caves, of considerable extent".

In a classic morpho-hydrologic study addressing the area of „Scărişoara karst complex", Rusu, Racoviță and Coman (1970) mention the tracer test performed by Rusu and Racoviță in the month of April 1964 by means of 1,5 kg of fluorescein in the Ocoale stream sinking point, during a high discharge period associated to snow melting. The fluorescein emerged in two temporary springs downstream, that occur on the bank of Ocoale stream, to subsequently sink in another swallet located even further downstream. The tracer reached the spring at Cotețul Dobreştilor (2.8 km straight line distance and 375.5 m elevation drop) after 38 hours, „a time span that appears to be too long and suggests the existence of sumps and lakes". Fluorescein also emerged „ in two karst springs located downstream, roughly at the Cotețul Dobreştilor spring level, on the lower terrace of Gârda valley" (probably in Izvorul Morii and in spring 3 of fig. 19- author's note). By considering also the result of the 1957 tracer test, the authors infer that three hydrologically independent underground flow floors exist across Ocoale – Cotețul Dobreştilor lineament:

- a shallow one, located between the sinking points in the upper section of Ocoale stream and the overflow springs that occur further downstream, on the valley axis;
- a second floor, extending between the swamp area to the north of the pothole (Vuiaga - author's note), the pothole in Şesuri and Poliței spring;
- a third floor, extending between the sinking points of Ocoale stream, at the contact between the Jurassic sandstone-shales terrain's with the Triassic limestone, and the outlets in Cotețul Dobreştilor area.

In the year 1992, Rusu and Cocean reiterated the statements above, the last two underground flow paths being highlighted as more important.

On 11 August 2001, I performed a tracer test by means of 750 g of fluorescein injected in the swallet where Ocoale stream was sinking entirely, downstream from the junction with Izvoarelor valley, simultaneously setting up a continuous monitoring of Poliţei spring of the spring at Cotețul Dobreştilor and of Morii spring. Unfortunately, during the subsequent night there was a heavy rainstorm in Ghețar area (54 l/m^2), the sprig discharges strongly increased, so that the fluorescein underwent a very strong dilution, and as a result it was not detected in the monitored springs. In the underground stream course in Groapa lui Miron (plate 2, no. 73, photo 9), the tracer was not detected within the observation period of 10 hours.

On 12 August 2001, I performed a tracer test by means of 1 kg of rhodamine B injected in the streamlet sinking in the swallet at Fântâna Veche de la Vuiagă (plate 2, no. 76). The tracer emerged after 10 hours in Poliței spring, yet it was not detected in the waters of the spring at Cotețul Dobreştilor or in that of Morii spring.

Photo 9. Groapa cu Apa a lui Miron swallet

We infer that in Ocoale-Ghețar-Cotețul Dobreştilor area a unitary karst system is developed, so that there are not three superimposed karst aquifers, the hydrological behaviours noticed by the previous investigators being in fact specific ways in which different parts of the karst system behave (figure 20). The tracer injected by Serban et al. (1957) emerged only in Poliței spring, by following a preferential displacement along the upper part of the karst aquifer, or even along fractures and karst holes in the infiltration area. Small amounts of tracer, even carried in a deep circulation, reached the outlets at Cotețul Dobreştilor in very small concentrations, that the equipment available by that time was not able to detect.

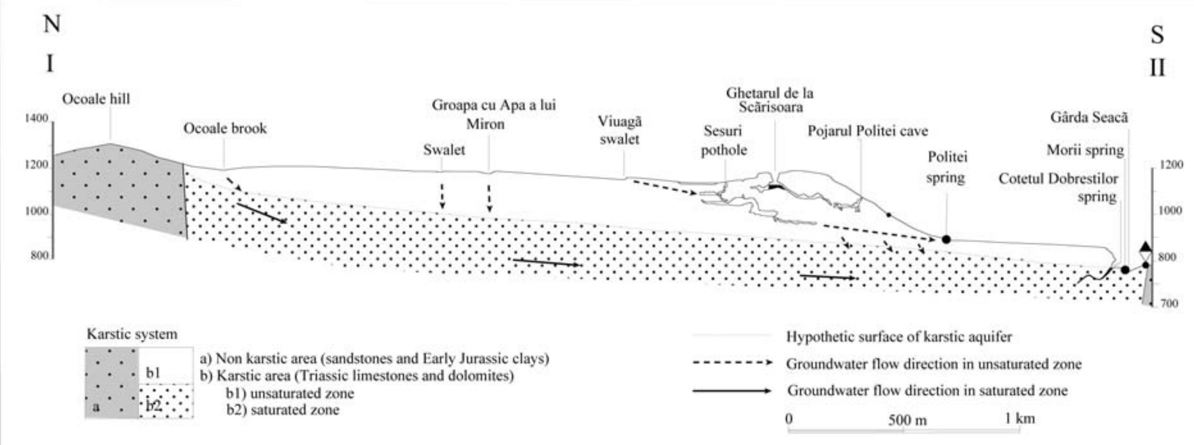


Figure 20. Cross section Ocoale hill - Cotetul Dobrestilor spring

(Karstic network in Ghetar area after Serban M., Coman D. and Viehman I. , 1957.
Izbucului de la Cotetul Dobrestilor pothole after Ciubotarescu et al., 1998)

On 29 October 2002, at 14,40 time, I performed a tracer test by means of 1 kg of fluorescein injected in the sinking point of the surface stream that during high discharge periods emerges from Troaca de la Hănăşeşti spring (plates 1 and 2, no. 86, photo 10). When injection was performed, the spring had a flow rate of about 2 l/s, its water flowed down the timber trucks road over a distance of about 200m, after which it diffusely sank through the alluvia accumulated on the bottom of the sinkhole on the right side of the road, in the forest.

The tracer was detected in the water of the spring at Coteţul Dobreştilor 42 hours after its injection, the maximum concentration being recorded after 161.5 hours. Troaca spring is situated at 1025m elevation, while the swallet elevation is about 15 m lower. The elevation drop down to the spring at Coteţul Dobreştilor, situated at a straight line distance of 2430 m, is 330 m.

Photo 10. Troaca spring at Hanasesti

The line between Troaca and Coteţul Dobreştilor has as a landform mark the sinkhole valley that extends between Troaca, Joampe and the escarpment above Poliţei valley, this sinkhole lineament presumably outlining a fossil course of Ordâncuşa stream, that predated the incision of the alternative pathway through the present-day gorge, when Ordâncuşa stream abandoned the flow direction from the area of Moara lui Ivan toward Gârda Seacă at Dobreşti.

By the present time, Ordâncuşa stream is diffusely sinking in the dolomite substratum along its section next to Moara lui Ivan. 50 years ago, the stream used to sink completely in the underground in this area through a swallet in its left bank, opposite to the mill that formerly existed. The tracer tests that we have planned to perform in this area in the year 2003 shall also take into consideration the possible hydrological connections with the outlets at Coteţul Dobreştilor.

The average flow rate of Coteţul Dobreştilor spring recorded over the hydrological year X.1984-IX.1985 was 280 l/s, while the maximum monthly flow rate was 1.06 m^3/s (Orăşeanu, 2000). In drought periods the flow rate of the spring progressively diminished, until completely drying out, the outlet actually being an overflow to the system. The permanent outlet of the system is Izbucul Morii and the springs that emerge along the left bank of Gârda Seaca valley, at water level or beneath it, along the previously indicated section (figure 19). The cummulated discharge of these springs and of Izbucul Morii has been occasionally gauged during field trips when Dobrestilor spring was dry, the average of these measurements being 85 l/s.

The average temperature of the water of the spring at Coteţul Dobreştilor is 7.65 ^oC, with fluctuations ranging between 7.2 and 8.0 ^oC.

Starting from the month of May 2001, the flow rate of the spring at Coteţul Dobreştilor is subject to systematic monitoring. Daily observations and device maintenance are performed by Lenuţa Dobra, a local woman that lives in the neighbourhood. Flow rate measurements performed at the gauge flow section records into daily mean flow rates (tables 7a and 7b).

Over the period May 2001-December 2002, the spring at Coteţul Dobreştilor exhibited very large fluctuations of the daily mean records, from 2 to 8000 l/s (fig. 21).

The monthly mean flow rate fluctuated from 35.1 l/s in the month of December 2001 to 771.8 l/s in the month of September 2002. The average flow rate recorded over the year 2002 was 351.3 l/s, while the most frequent flow rates fall within the 51-250 l/s range (215 days, table 8 and fig. 21).

In order to obtain additional information concerning the degree of structuring of the main karst systems, the electric conductivity of the water of the springs Coteţul Dobreştilor, Poarta lui Ioanele, La Izvoare and Iapa was measured every two days.

The electric conductivity is a global geochemical parameter, that is quite easily obtained in the field, with good accuracy and excellent reproducibility, its distribution diagrams outlining both the differences in the behaviour of the different aquifer types, and the degree of structuring of the karst aquifers (Bakalowicz, 1975). Specifically, the development of a main flow axis within the flooded zone brings about in this zone a particular condition, the easy, unaltered transmission of the information derived from the storage occurring as an appendix to the duct, along the flow direction. The distribution diagrams hence provide a more or less distorted image concerning the ways in which the flooded zone is recharged, image transmitted by the latter. If the underground flow in this zone is not organized, the geochemical characters of the infiltration waters will become homogenized. The fractured carbonate aquifers behave, within the flooded zone, similarly to the granular aquifers.

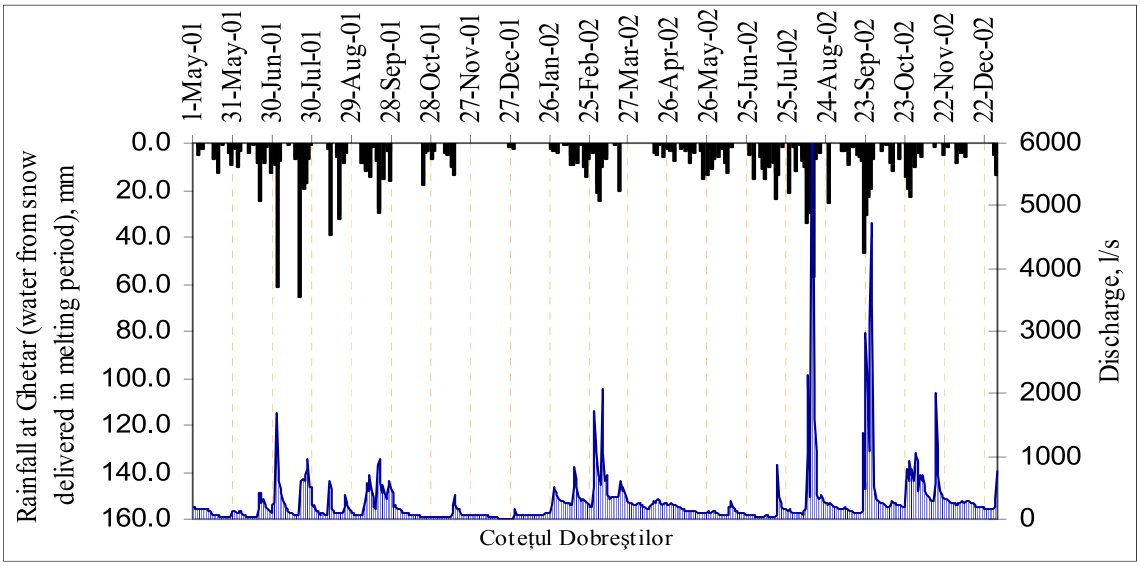


Fig. 21. Variation of the flow rate of the spring at Coteţul Dobreştilor and distribution of rainfall at Gheţar M.S., over the period May 2001-December 2002.

The distribution diagrams of the water conductivity values for a carbonate aquifer, distributed over a hydrological cycle, hence offer the capacity of defining with certitude the development degree of the functional karst in this aquifer. The influence of the particular constitution of the karst aquifer on the heterogeneity of the different water bodies that flow without mixing, provides the parameters to be used in issuing a diagnosis for the karst development status. Theses methods lead to the satisfactory identification of the degree of structuring of the karst aquifer.

Classes, l/s	Number of days		
	days	%	Σ%
0-50	14	3.8	3.8
51-100	64	17.5	21.3
101-150	48	13.2	34.5
151-200	40	11.0	45.4
201-250	63	17.3	62.7
251-300	35	9.6	72.3
301-350	25	6.8	79.1
351-400	15	4.1	83.3
401-450	6	1.6	84.9
451-500	8	2.2	87.1
501-550	1	0.3	87.4
551-600	4	1.1	88.5
601-650	5	1.4	89.8
651-700	7	1.9	91.7
701-750	0	0.0	91.7
751-800	1	0.3	92.0
801-850	3	0.8	92.8
851-900	1	0.3	93.1
901-950	2	0.5	93.7
951-1000	0	0.0	93.7

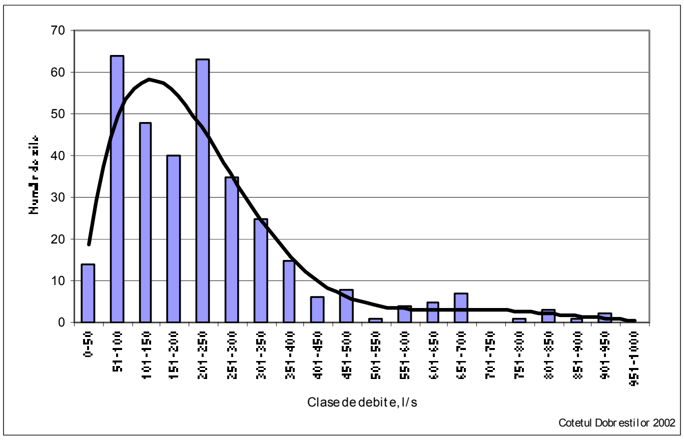


Table 8 and fig. 22. Distribution by classes of the flow rates of the spring at Coteţul Dobreştilor, recorded over the year 2002.

The water of the analyzed karst outlets in the Gârda Seacă-Ordâncuşa watershed (fig. 23) is derived from at least two distinct populations, each one having its own geochemical evolution and own hydrogeological history. The populations of the water conductivity diagrams are related to different manners of recharge of the flooded zone: slow or fast infiltration, distinguished or not by way of a shallow-karst storage and with possible evolutions in the flooded zone.

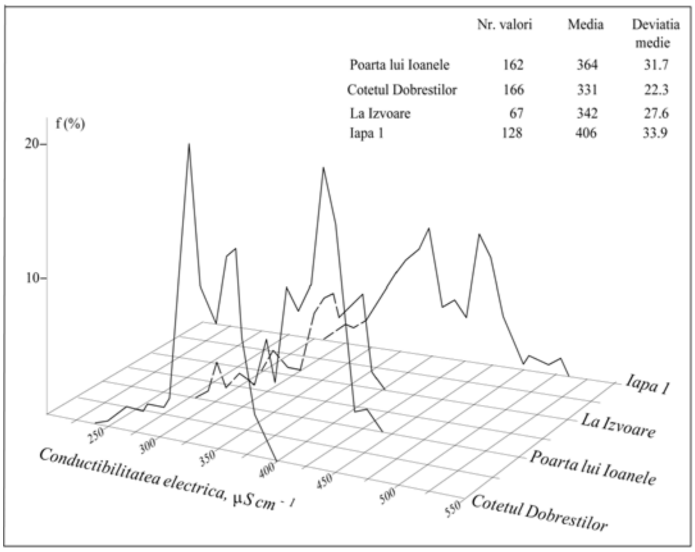


Fig. 23 The distribution diagrams of the water conductivity values for a karsic springs.

The aquifer discharging through the outlets at Coteţul Dobreştilor is well structured and organized, with a functional main flow axis that facilitates to the water sunk in Ocoale area a fast arrival to the springs, without significantly mixing with water stored in the appendix systems of the karst aquifer. The important weight assumed by the low conductivity water (infiltration water) in the group of conductivities of the water discharging through the spring indicates that the water originating from the non-karst catchment area has a significant influence in terms of aquifer recharge (the springs by which the aquifer located in Late Jurassic deposits discharges have water electrical conductivities ranging between 200-250 μS cm^{-1}, while the water of the surface streams running over these deposits falls in the 100-150 μS cm^{-1} range)

The water electrical conductivity measurements results for the outlets analyzed during the period May 2001-December 2002 are displayed in a synthetic way in the diagram of fig. 24. A seasonal variation is visible for all the outlets, the water mineral content decreasing during the first part of the year, as a consequence of the fact that karst aquifers are supplied by infiltration water derived from snow melting and from the spring rainy season. During the second part of the year, the outlets water mineral content constantly increases due to the diminishing of the infiltration and to the increasing underground residence time of the water. The electrical conductivity variation is opposite to that of the outlets discharge.

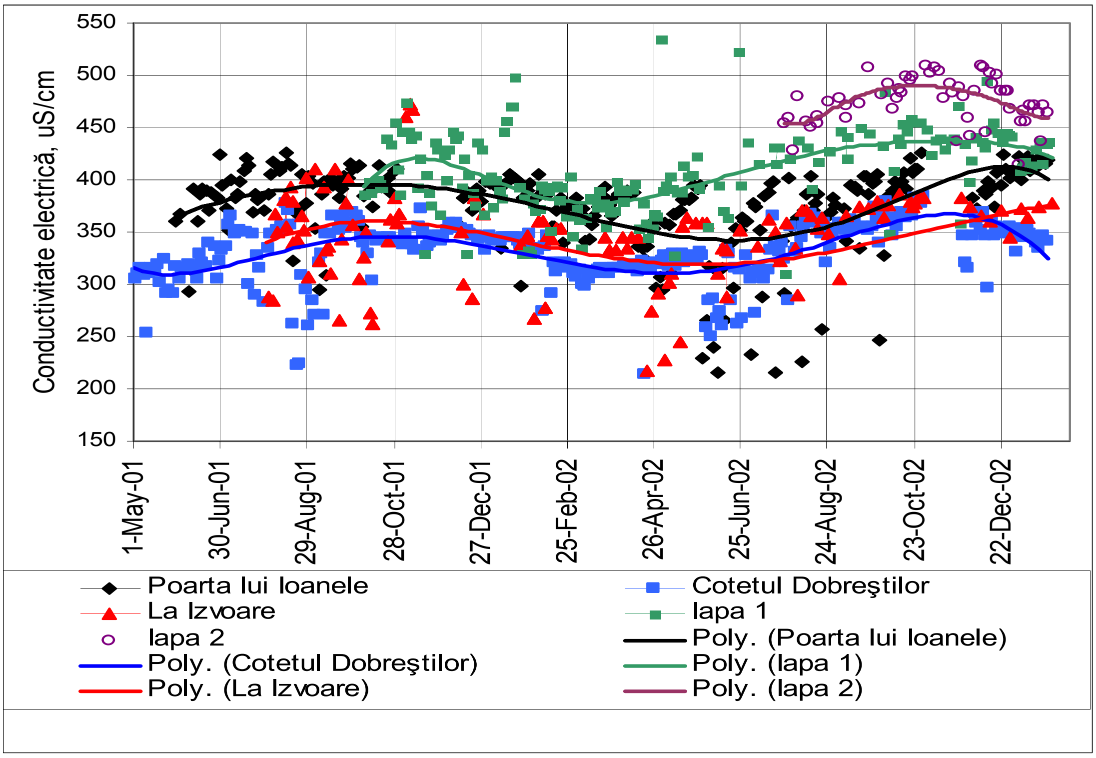


Fig. 24 Distribution of water electrical conductivity of sme carstic systems of the water divide territory during the period mai 2001-decembre 2002.

3. Poarta lui Ioanele karst system

The spring at Poarta lui Ioanele (Poarta lui Ionel) is the second largest source in terms of flow rate on the boundary of the Gârda Seacă-Ordâncuşa watershed. The spring has a permanent character and diffusely emerges through the limestone boulders that build the floor of the impressive entrance of the cave that bears the same name (photos 11 and 12). From the cave downstream, there occurs a succession of small waterfalls, built by the travertine deposited from the spring water.

Poarta lui Ioanele cave.
Photo 11. Entrance of the cave (left).
Foto 12. Spring and water level recorder (above).

The cave Poarta lui Ioanele (810m elevation) is situated on the left side of Ordâncuşa stream, about 30m above the streambed. It is 324.4m long, extending over 35m elevation range above the entrance, and over a horizontal straight line distance of 102 m. A temporary stream runs on its floor (Ciubotărescu et al., 1998).

Sideways from the cave Poarta lui Ioanele, at 880m elevation, it is gaping the impressing entrance of Peştera de sub Zgurăşti (Gheţarul de sub Zgurăşti, Zgurăşti pothole), that has a total length of 5210m, extending across a total elevation range of 75m (-45;+30 m, with respect to the entrance) and over 640m horizontal straight line distance (Damm et al., 1999). The cave includes two virtually horizontal floors, and in terms of hydrology its main characteristic is provided by 4 lakes that store impressive amounts of water: The Entrance Chamber Lake, temporary, 65/38/14m, The Great Lake, 65/20/10m, Velenţa Lake, 25/10/5m, and The Long Lake, 75/5/2-5m. The lakes are interconnected via an underground stream, that in the section between the two lakes at the entrance has a temporary character. In the Entrance Chamber the underground stream sinks through collapsed boulders, to further emerge in Poarta lui Ioanele spring. During high water stages, the lake in the Entrance Chamber overflows through the Spillway Tunnel passage, to form an impressive waterfall on the right side of Ordâncuşa stream. Low stage water flows to Poarta lui Ioanele directly from the Great Lake (Damm et al, 1999). The lakes altogether represent a reservoir of about 50.000m^3 storage capacity, with a water level occurring at 860-865m elevation, some 100m above the streambed of the nearby Ordâncuşa stream. The flow rate of Poarta lui Ioanele spring is monitored since the month of May 2001 by means of a gauge level section equipped with a limnograph, placed at the cave entrance, some 4 m downstream from the outlet. Hydrometric observations and device exploitation and maintenance works are performed by Iulia and Avram Negrea from Gârda de Sus. The spring daily flow rates are listed in tables 8a and 8b, in the appendix, and the diagram illustrating the flow rate variation is displayed in fig. 25.

Over the year 2000, the spring at Poarta lui Ioanele had an average flow rate of 48.3 l/s, with daily fluctuations between 14 and 615 l/s. In the hydrologic year X.2001-IX.2002, the most frequent flow rates fell within the 10-20 l/s range, which occurred over almost half of the total number of days of the indicated year. During the observation period the spring water temperature displayed minor oscillations, in the range 7.4-7.8 ^{o}C.

The hydrogeological catchment area of the spring is extended to the north, over the terrains subject to strong karst processes in Mununa area. The remarkably constant flow rate is a result of the slow release of the stored water amounts from the lakes in Peştera de sub Zgurăşti, yet an additional supply, due to diffuse sinking of a part of Ordâncuşa stream cannot be ruled out, if one takes into account the occurrence of quartzite gravel in the above-mentioned cave (Damm et al, 1999).

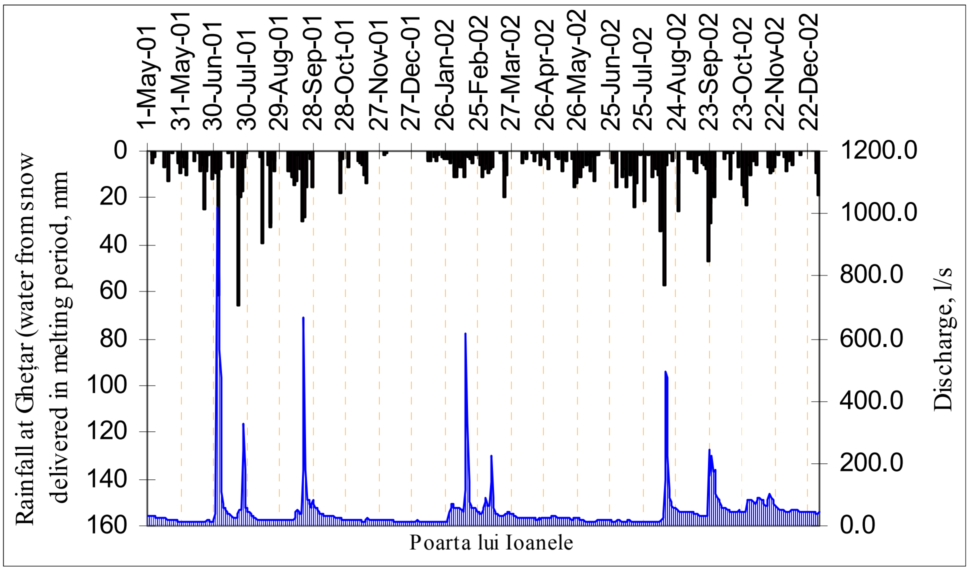


Fig. 25. Distribution of the daily average flow rates of the spring at Poarta lui Ioanele and of rainfall recorded at Gheţar M.S., over the period May 2001-December 2002

Clase de debit, l/s	Număr de zile
0-10	0
11-20	103
21-30	64
31-40	18
41-50	72
51-60	45
61-70	17
71-80	7
81-90	15
91-100	6

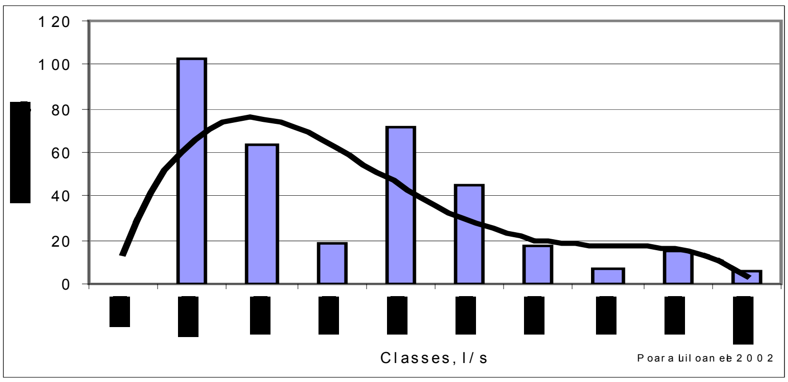


Table 9 and fig. 22. Distribution by classes of flow rate of the number of days of thr year 2002

The water electric... 23) has a wide, pluri-modal configuration, indicating the existence of a structured flow, with a small weight of courses inflows with low mineral content waters. The diagram also displays a strong narrow peak, which is characteristic for un-structured aquifer systems, yet this may be an outcome of the very large water amounts stored in the underground lakes, a storage that leads to a certain homogenization of the geochemical characters of the infiltration waters.

4. Iapa karst system

Iapa spring is situated in the catchment area of Gheţarului stream, a right hand tributary of Ordâncuşa stream (plates 1 and 2, photos 13 and 14). It emerges from highly fractured and weathered Triassic dolomites, at the contact with the Early Jurassic sandstones and shales (Iapa fault). The binary type karst system includes the Early Jurassic terrains in the Trei Cărări (Aprozar) area, situated southward from Rânjeşti peak and the Ladinian - Early Carnian limestone in Dealul Frumos area, the boundary between them being traced by the eastern half of the Ocoale stream fault.

Photo 13. Iapa springs at Dealu Frumos

Foto 14. Iapa 1 spring in April 2001

The system is supplied by rainfall infiltrated on the limestone surface and from the water accumulations in the Early Jurassic deposits. During periods of strong rainfall and snow melting, the system is additionally supplied by runoff on the Jurassic terrains, that sinks via the swallet near the pub at Trei Cărări (plate 2, no. 53) and by the water of Tuţerilor spring (no. 34), that sinks into the swallet situated in its immediate proximity.

On 23 March 2002, at the time 10,30, I injected fluorescein in the surface stream that sank in the swallet at Trei Cărări (1300 m approximate elevation), which was flowing as a result of snow melting. 10,5 hours after being injected, the tracer appeared in the water of Iapa spring. By considering the insalubrious conditions around the pub at Trei Cărări, this hydrologic connection provided a huge and unpleasant surprise to the local people who drink water from the spring.

Iapa spring discharges through two outlets (photo 13 and fig. 27):

- the domestic use spring, that we call Iapa 1;
- the permanent spring, called Iapa 2, situated some 20 m downstream and about 1 m below in terms of elevation;

Some 60 m upstream from Iapa 1 spring, a temporary spring that flows only during high discharge periods emerges from the carbonate substratum.

Iapa 1 spring is situated at about 1230 m elevation. It is inappropriately tapped in a concrete pool (3,5x1,5 m), with water flowing beneath it, so that animals coming to drink and rain water can easily contaminate it. During heavy rainfall and fast snow melting periods the spring water is slightly opalescent. The depth of the water in the pool is 1 m on the average. Local people say that during very long drought periods the water stops flowing from the spring, yet never was the pool completely dry.

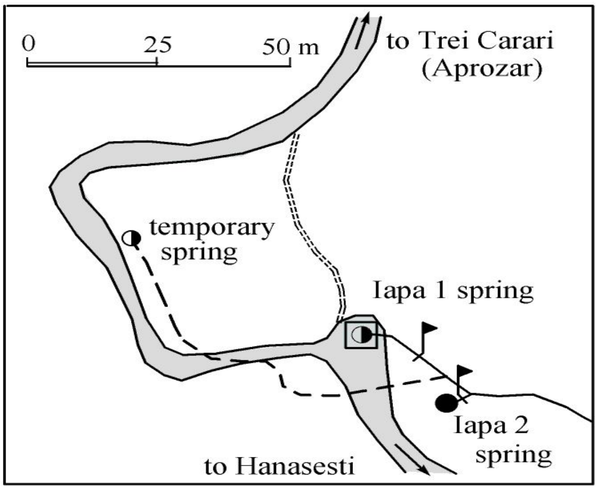


Fig. 27 Location of Iapa springs

Iapa 2 spring emerges under pressure from the alluvial deposits of the valley, in a wet, grass covered area. It is not used by the local people.

Iapa spring is the outlet with the largest flow rate in the karst plateau, and it has an outstanding importance for the local people. In order to assess its flow rate, there have been installed right angle weirs (ά=90) and limnographs at both outlets, Iapa 1 (October 2001), and Iapa 2 (October 2002). Hydrometric observations and limnographs exploitation and maintenance are performed by Gheorghe Belei, who resides in the neighbourhood. The daily average flow rates computed for the two springs are listed in tables 10a, 10b and 11 in the appendix, and they are displayed in a graphic form in the diagram in figure 28.

Over the year 2002, Iapa 1 spring had an average flow rate of 5.77 l/s, with daily average extremes ranging between 0.3 l/s (1-8 January) and 38 l/s (13 February), the spring quickly reacting to the rainfall induced impulse.

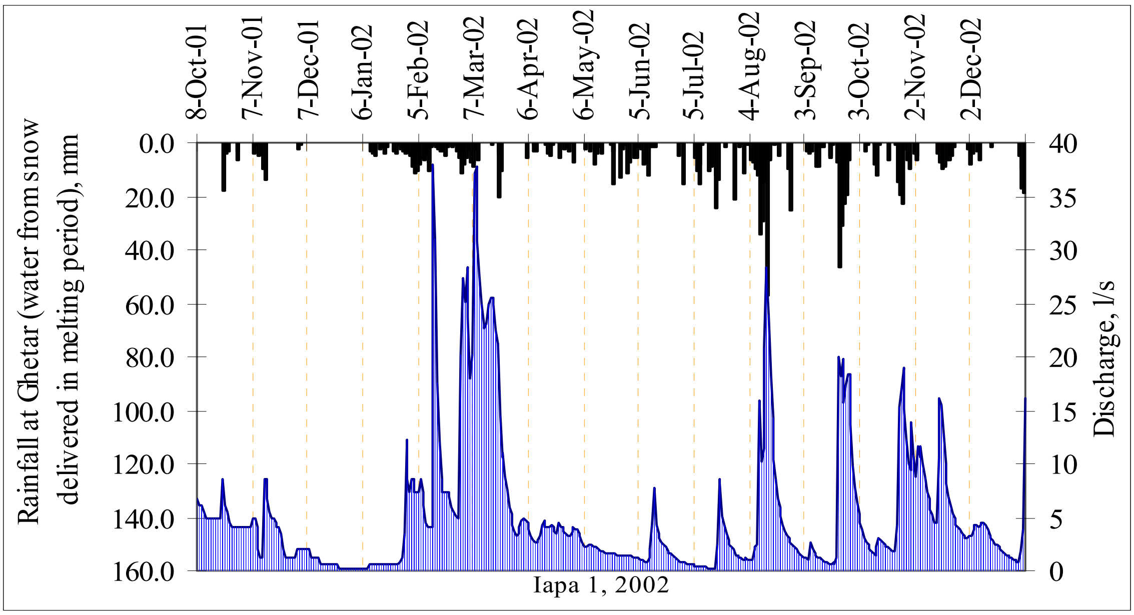


Fig. 28. Variation of the Iapa 1 spring flow rates and distribution of the rainfall at Ghețar M.S., over the period May 2001 - December 2002.

The most frequent daily mean flow rates recorded over the year 2002 range in the 0.51-1.0 l/s interval (9.9 % days per year). In 66 % of the days of the year the spring had flow rates ranging in the 1,01-6,0 l/s interval. Only in 1.1 % of the days the flow rates dropped below 0.5 l/s. Over our period of observations, the spring has been flowing continuously.

Clase de debit, l/s	Număr de zile		
	Zile	%	Σ%
0-0.5	17	4.658	4.658
0.51-1	47	12.9	17.5
1.01-1.5	38	10.4	27.9
1.51-2	31	8.5	36.4
2.01-2.5	28	7.7	44.1
2.51-3	14	3.8	47.9
3.01-3.5	25	6.8	54.8
3.51-4	18	4.9	59.7
4.01-4.5	27	7.4	67.1
4.51-5	10	2.7	69.9
5.01-5.5	7	1.9	71.8
5.51-6	5	1.4	73.2
6.01-6.5	3	0.8	74.0
6.51-7	4	1.1	75.1
7.01-7.5	10	2.7	77.8
7.51-8	3	0.8	78.6
8.01-8.5	2	0.5	79.2
8.51-9	10	2.7	81.9
9.01-9.5	1	0.3	82.2
9.51-10	2	0.5	82.7

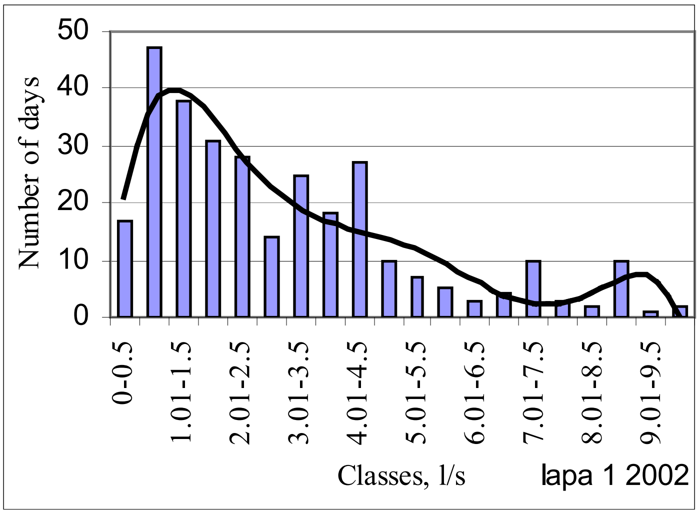


Table 10 and fig. 29 Distribution by classes of the flow rates recorded during the year 2002 at Iapa 1 spring

Over the time interval August-December 2002, the flow rate of Iapa 2 spring fluctuated between 0.3 and 5.2 l/s, with variations analogous to that of Iapa 1 spring (table 11 in the appendix and fig. 30). The relationship between the flow rates of the two outlets, gauged over the time interval August-December 2002, is displayed in figure 31, while in figure 32 there is displayed the same relationship for Iapa 1 spring flow rates lower than 2 l/s and Iapa 2 spring flow rates lower than 1 l/s. When Iapa 1 spring stops flowing, Iapa 2 spring has an estimated flow rate of 0.16 l/s.

Relying on the relationship in fig.31, we estimate that during the year 2002 Iapa 2 spring had a daily average flow rate of 1.58 l/s, while the springs Iapa 1 and Iapa 2 cumulated daily average

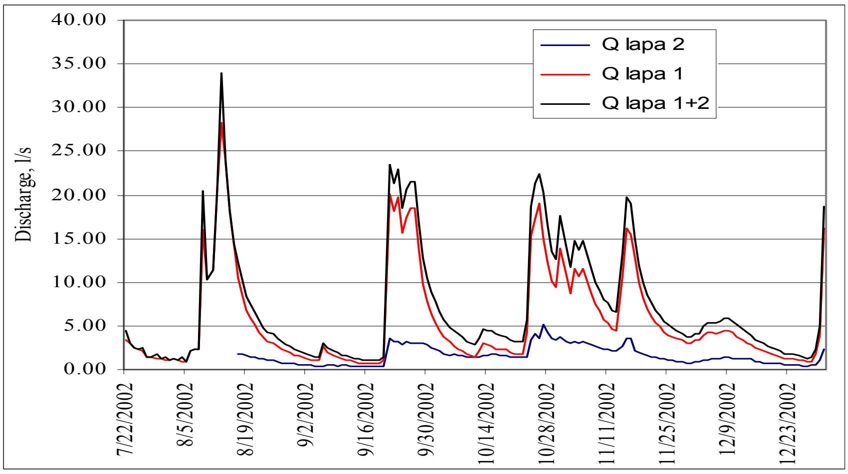


Fig. 30 Discharges fluctuate of Iapa springs in second part of 2002 year

flow rate was 7.3 l/s. As further data will be collected, while gauging the outlets flow rate is still being continued, computations shall be repeated and their confidence level shall increase.

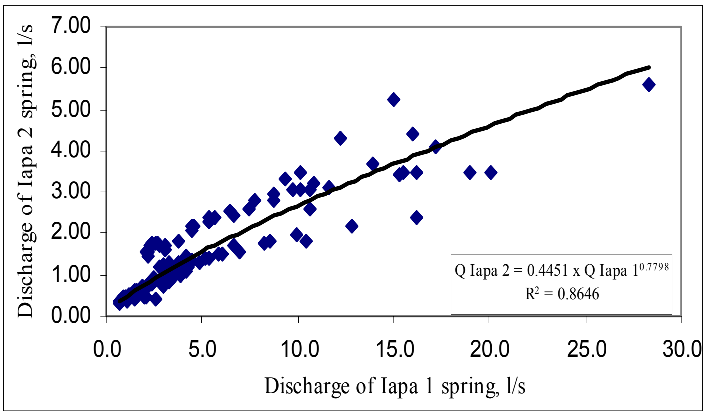


Fig. 31. The relationship between the flow rates of Iapa 1 (below 2 l/s) and Iapa 2 (below 1 l/s) outlets

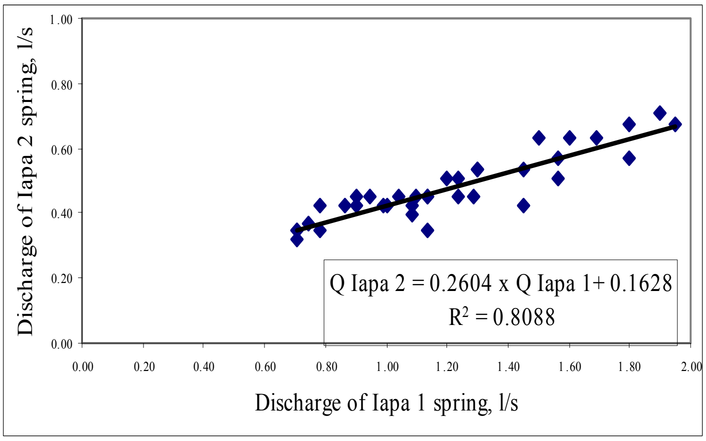
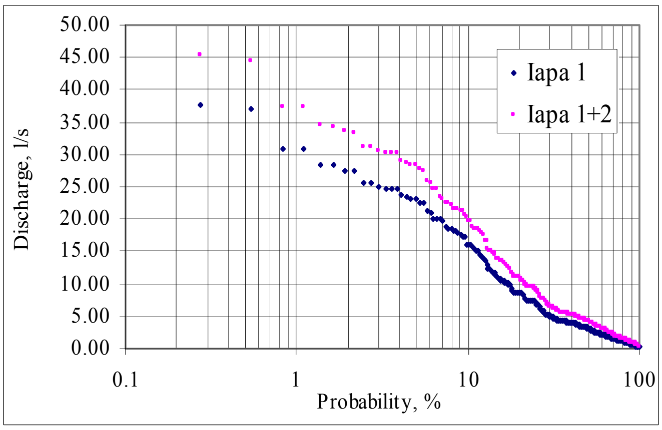


Fig. 32. The relationship between the flow rates of Iapa 1 and Iapa 2 outlets, gauged over the time interval August-December 2002

The safety diagrams for Iapa 1 spring flow rate and for Iapa 1 and Iapa 2 springs cumulated flow rate are displayed in fig. 33, while table 11 provides the flow rates for the most frequently used safety ranges.



%	Iapa 1	Iapa 1+2
80	1.1	1.6
85	0.87	1.3
90	0.6	0.9
95	0.51	0.8
97	0.3	0.5

Fig. 33 The safety diagrams for Iapa springs.

Table 11. Flow rates of Iapa springs for used safety ranges

Over the observation period, Iapa 1 spring had an ... ith fluctuations in the 6.4 - 7,4 ^{o}C range. Iapa 2 spring had an average temperature of 8.1 ^{o}C, while the overall temperature of the temporary spring was 7.7 ^{o}C. The monthly variations of Iapa outlets water temperature follow the monthly average temperature oscilations trend at Ghețar meteorological station, a fact which indicates the existence of a shallow and not very extended karst system (fig. 34).

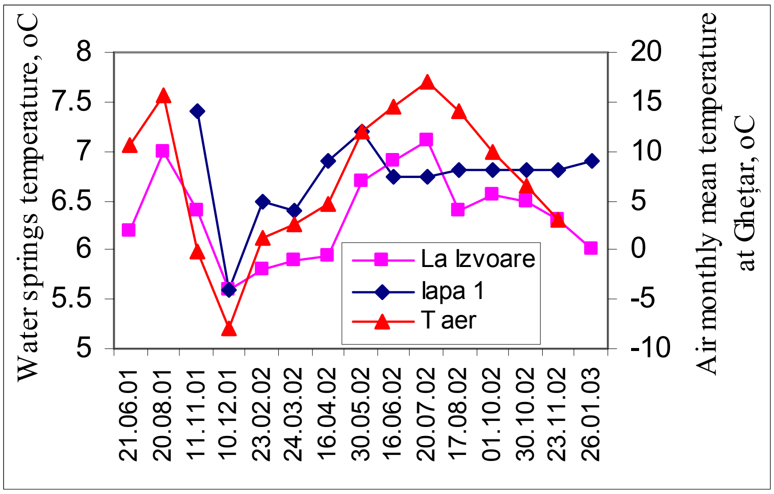


Fig. 34. The monthly variations of Iapa and La Izvoare outlets water temperature and air temperature at Gheţar meteorological station.

The distribution diagram of the Iapa 1 outlet water electrical conductivity (fig. 23), indicates the existence of a very well organized and functional karst aquifer. The impulse transmitted by the water infiltrated locally in the northern part of the system is transmitted without being altered through the flooded zone toward the outlet. The system has been subject to strong karst development, during high water stages the infiltration water supplies the appendix systems, without mixing with them in the main flow axis.

Photo 15. Temporary swallet at Trei Carari (Aprozar)

The data provided by the interpretation of the Iapa 1 spring water electrical conductivity are substantiated by the tracer test performed in the swallet at Trei Cărări (Aprozar). The water sunk into it, derived from runoff over the northern hill slope that consists of Early Jurassic shales and sandstones, flows toward Iapa outlets with high velocities, without being filtered. This critical situation is subject to even more severe deterioration, due to the utterly insalubrious conditions around the pub at Trei Cărări (photo 15), where waste, as well as dirty water, WC effluents included, are dumped into the swallets.

5. "La Izvoare" karst system

Photo 16. La Izvoare spring.

La Izvoare spring is situated on the right side of Ocoale stream, below the ridge of Comărnicel peak (plate 2, no. 65, photo 16). The outlet is tapped in a primitive way, by means of a wood pipe, the water emerging from the hill slope deposits with limestone blocks placed in a clay matrix. Esatward from the spring, some 15 m away and about +1 m above there occurs another spring, probably the overflow of the main spring La Izvoare, outlet that we called "Izvorul Interzis" ("The Forbidden Spring"), because of the permanent obstructions that the land owner opposed to our observations program.

The flow rate of La Izvoare outlet is permanently monitored with a rectangular weir ($\alpha=90^o$), provided with limnograph. Hydrometric observations have been peformed by Creț Mariana until the month of february 2002, and further on by Belei Gheorghe. The daily average flow rates of the spring are indicated in tables 9a and 9b, in the appendix, their variation being illustrated in the diagram in fig. 35.

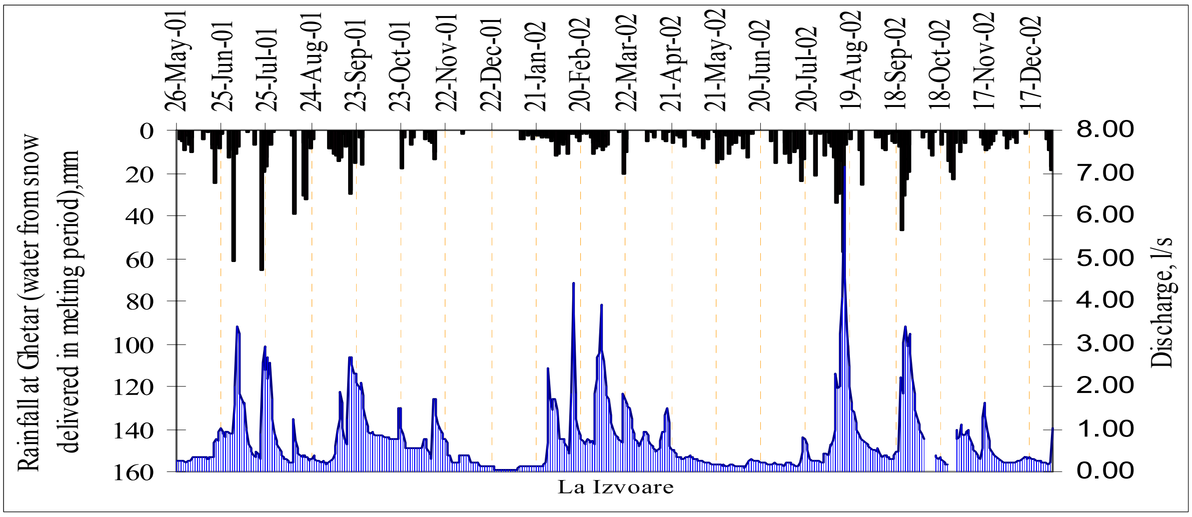


Fig. 35. Distribution of the daily average flow rates of the spring La Izvoare and of rainfall recorded at Ghețar M.S., over the period May 2001-December 2002

During the observations period, the daily average flow rate of the spring La Izvoare fluctuated between 0.1 and 5.6 l/s, the annual mean value being 0.75 l/s for the year 2002. The most frequent flow rates range in the classes 0.21-0.3 l/s (22,2 % of the days of the year) and 0.11-0.22 % (17.3 %). Flow rates smaller than 0.1 l/s amount to a weight of 2.5 % (table 12 and fig. 36).

During the same period, the average water temperature of the spring La Izvoare has been 6.4 ^{o}C, with fluctuations ranging between 5.8 and 7.1 ^{o}C.

The flow rate of the Forbidden Spring was volumetrically gauged monthly, its value being about 25 % larger than that of La Izvoare spring. Its temperature is by 0.3 ^{o}C higher on the average, while the electrical conductivities of the two springs are roughly the same.

Clase debit,	Număr de zile		
	Zile	%	Σ%
0.01-0.1	9	2.5	2.5
0.11-0.2	63	17.3	19.8
0.21-0.3	81	22.2	42.0
0.31-0.4	30	8.2	50.2
0.41-0.5	15	4.1	54.3
0.51-0.6	15	4.1	58.4
0.61-0.7	21	5.8	64.1
0.71-0.8	26	7.1	71.3
0.81-0.9	9	2.5	73.7
0.91-1.0	18	4.9	78.7
1.01-1.1	4	1.1	79.8

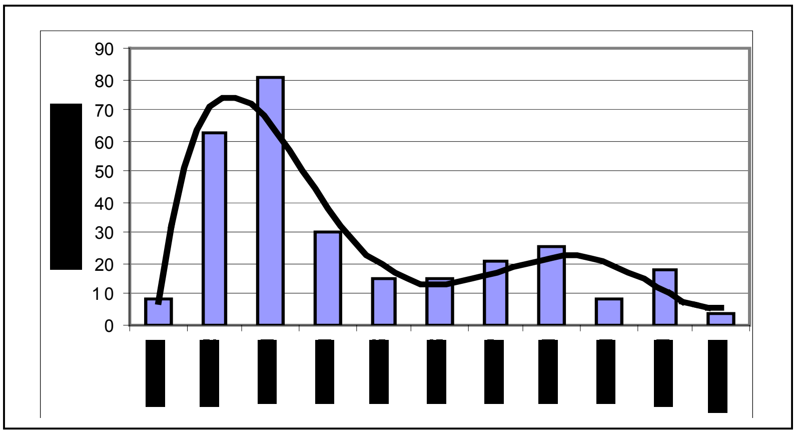
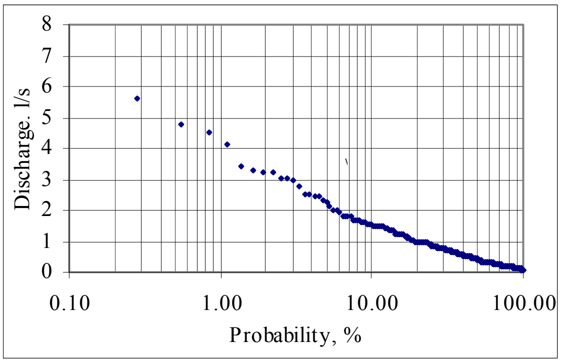


Table 12 and fig. 36 Distribution by classes of the flow rates recorded during the year 2002 at La Izvoare spring

The flow rate safety diagram of La Izvoare outlet is displayed in fig. 37, while table 13 provides the flow rates computed for the most frequently used safety ranges.



%	Q, l/s
80	0.18
85	0.17
90	0.14
95	0.11
97	0.1

Fig. 37 The safety diagrams for La Izvoare springs.

Table 13. Flow rates of La Izvoare springs for used safety ranges

E. Considerations concerning the drinking water supply of the settlements in Gârda Seacă-Ordâncuşa watershed

The villages Gheţar, Mununa, Hănăşeşti and Dealu Frumos, located within the Gârda Seacă-Ordâncuşa watershed, are facing a severe water shortage, due to the fast infiltration of the rainfall derived water into the carbonate substratum that is subject to a strong karst development. Due to the same reason, the surface stream courses are absent within the territories of these villages. A few fountains (Vuiaga, Rădăcini, Apa din Cale, Barâcia, Troaca), some of them dry during long periods of rainfall deficiency, are the only drinking water supply source for the inhabitants. In order to get drinking water, the latter are obliged to perform long trips to the springs on the territory of Ocoale village, or to Iapa spring. For other needs of their households, village people regularly use rainfall water collected in concrete pools, or in wood and plastic barrels. This water is not fit for drinking, because it is subject to severe bacteriological contamination.

In the year 1994, at the request of the Village Council of Gârda, a proposal has been devised by S.C. Peoex SRL Alba Iulia for supplying drinking water to Gheţar and Ocoale villages by tapping Oncheştilor, Costenilor and La Izvoare springs. The proposal consists in building two tanks and a pipeline for supplying the villages streets, by use of taps to be installed about 200 m away from one another. The proposal does not specify either the flow rate of the springs that are considered for being tapped, or the flow rate required for the villages supply, while the solutions proposed for tapping, by means of manually excavated, 4 m vertical shafts and radial collecting drains extending from these shafts (solutions specific for tapping aquifers in detrital deposits), are inappropriate for tapping springs that emerge from limestone.

Local people in Ocoale village have tapped the water of Fântâna lui Miron and Fântâna Ilii Florea, permanent springs actually, in a concrete pool, from which water is conveyed through PVC pipelines toward the households in the neighborhood, thus the supply of drinking water, distributed by taps, being secured for about 12 families.

The springs considered for the drinking water supply of the indicated villages are:

<u>Iapa spring.</u>

The spring is located on the territory of Dealu Frumos village, at about 1230m elevation. It emerges from limestone dolomite through two distinct outlets, the currently tapped spring (Iapa 1) and the basic source (Iapa 2), that is situated some 20 m downstream.

In the year 2002, Iapa 1 spring had an average flow rate of 5.77 l/s, with daily average extremes ranging between 0.3 l/s (1-8 January) and 38 l/s (13 February), the spring rapidly responding to the rainfall induced impulse. The most frequently recorded daily average flow rates of the year 2002 (table 10 and fig. 29) range in the class 0.51-1.0 l/s (9.9 % of the days of a year). On 66 % of the days of the year, the spring had flow rates ranging in the 1.01-6.0 l/s interval. Only on 1.1 % of the days dropped flow rates values below 0.5 l/s. Over our observations period the spring has flown permanently.

Over the year 2002, the combined sources Iapa 1 + Iapa 2 had a calculated annual average flow rate of 7.3 l/s, the flow rates calculated correspondingly to different safety ranges being 1.6 l/s (80 %), 1.3 l/s (85 %), 0.9 l/s (90 %), 0.8 l/s (95 %) and 0.5 l/s (97 %).

Iapa karst system is supplied by rainfall that reaches the limestone surface, and via the underground, from water accumulations in the Early Jurassic deposits. During heavy rainfall and snow melting periods the system is also supplied by runoff over the Early Jurassic terrains, that sinks in the underground through the swallet next to the Trei Cărări (Aprozar) pub, as it was proven by the fluorescein tracer test we performed. Water sunk in this swallet reaches Iapa outlets with high velocities, without being filtered and purified. This critical situation is subject to even more severe deterioration, due to the utterly insalubrious conditions around the pub at Trei Cărări (photo 15), where waste, as well as dirty water, WC effluents included, are dumped into the swallets. Using this source for supplying drinking water to the population is subject to strict compliance to the conditions stipulated by the legislation in force concerning groundwater intakes sanitary and hydrogeological protection.

La Izvoare spring.

La Izvoare spring is located on the right side of Ocoale stream, below the ridge of Comărnicel peak. Over the year 2002, the daily average flow rate of the outlet La Izvoare fluctuated between 0.1 and 5.6 l/s, the annual mean value being 0.75 l/s. The most frequent flow rates range in the classes 0.21-0.3 l/s (22,2 % of the days of the year) and 0.11-0.22 % (17,3 %). Flow rates below 0.1 l/s amount to a weight of 2.5 %.

The flow rates calculated for the most frequently used safety ranges are: 0.18 l/s (80 %), 0.17 l/s (85 %), 0.14 l/s (90 %), 0.11 l/s (95 %) and 0.10 l/s (97 %).

Eastward from the spring, some 15 m away and about +1 m above there occurs another spring, probably the overflow of La Izvoare outlet, that we called “The Forbidden Spring”. The flow rate of the Forbidden Spring was volumetrically gauged monthly, its value being about 25 % larger than that of La Izvoare spring. Globally, we estimate that the cumulated flow rate of the two springs is double than that which has been specified for La Izvoare spring.

Groapa cu Apă a lui Miron

Groapa cu Apă a lui Miron is a temporary swallet of Ocoale stream, and at the same it provides access to the underground stream course running through the cave that bears the same name. During medium and small water stages, the stream in the cave is supplied only by the aquifer located in the alluvial-colluvial deposits that coat Ocoale valley and its right side hill slope. During these periods, water sunk in the upper course of Ocoale stream does not contribute to its recharge. The underground stream has a minimum flow rate of about 3 l/s and during periods of severe drought due to prolonged winter, it is used by local people for watering the livestock.

The water of the underground stream may be tapped by building in the upstream passage a watertight dam in concrete, provided with a pipeline for the actual water intake, as well as with an outlet slide for cases of high discharge. Through the pipeline water shall be carried to a storage tank, then, after being treated, it shall be pumped into the distribution network.

Water accumulations in the colluvial deposits

Around the sources Fântâna Ilii Flore-Fîntăna lui Miron and for about another 100 m to the north, colluvial deposits beneath Dealul Bocului include water accumulations outlined both by the above-indicated sources and by the permanently wet soil condition of that area. These resources are partly exploited by local people by means of strainers placed in the two fountains (springs), water flowing gravitationally toward a tank located immediately downstream.

The water accumulations may be exploited by building a collecting drain placed longitudinally at the foot of the hill-slope, with water being collected in an intake chamber, from which it shall be carried toward a storage and distribution tank.

The Norms for designing and completing water supply and sewage works for rural settlements (code P66-2000), issued by the Ministry of Public Works and Territorial Planning, stipulate the following:

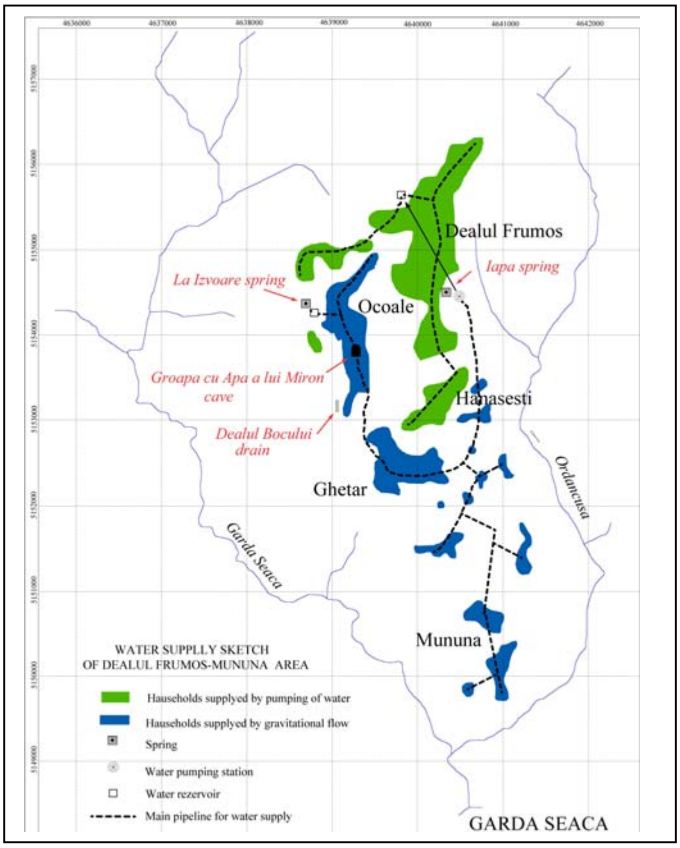
- the domestic consumers water supply in rural areas is performed by means of taps installed on the streets, while supply of economic, social-cultural objectives is performed by means of the distribution network offtake pits (art. 2.1);

- The domestic water requirements are evaluated by considering the specific yield q_s = 50 l/man, day, with K_{day} = 1.3, under the assumption that the water supply is provided exclusively by street taps (art. 3.2.1);

- The water requirements for livestock are: cows-60 l/day head; horses-50 l/day head; pigs – 30 l/day head.

The distribution of the water consumers within the villages of the Gârda Seacă-Ordâncuşa watershed is as follows:

Index	Village	Number of inhabitants	Cattle	Pigs	Horses	Water requirements m^3/day
1	Gheţar	106	65	34	36	12.02
2	Dealu Frumos	102	44	22	28	9.8
3	Hănăşeşti	104	58	26	36	11.26
4	Mununa	94	52	20	22	9.52
5	Ocoale	301	144	38	84	29,03
	TOTAL	406	219	102	122	71,63 m3/zi = 0,83 l/s



The potential water supply source for the area is Iapa spring. By tapping the springs Iapa 1 and Iapa 2, the yield required for supplying the households in Dealul Frumos, Hănăşeşti, Gheţar, Mununa and Ocoale by means of street taps shall be secured.

Households in the northern part of the area are situated by up to 100 m above Iapa spring elevation, hence in order to supply them a fraction of the total water amount shall be pumped in a tank, to be built in the area of Rânjeşti hill, and distributed by gravitational flow.

From Iapa spring a main conduit shall be built that will carry water gravitationally, with branchings toward Gheţar - Ocoale and southward down to Mununa. From this conduit, branch pipes shall be built toward the clusters of households in the area. In Ocoale area, water tapped from La Izvoare spring shall be also fed into the conduit, and provided that the further development of the area would require larger water amounts, there shall be also built the drain at the foot of Dealul Bocului, or there shall be tapped the underground stream in Groapa cu Apă a lui Miron.

The decision about the spring (or springs) to be tapped, and about the drinking water distribution networks extent is to be taken by the local authorities of Gârda village, by considering the hydrogeological proposal we devised. Hydrogeological studies will still continue to a limited extent during the year 2003, and their completion shall include the devising of the hydrogeological proposal that will provide the background for the proposal concerning the drinking water supply of the area.

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