3.7. SEBEȘ MOUNTAINS

by **Gheorghe BANDRABUR, Rădița BANDRABUR**
Prospectiuni Company, gheorghe.bandrabur@prospectiuni.ro, radita.bandrabur@prospectiuni.ro

Introduction

The Sebeş Mountains, also designated as Şureanu Mountains, belong to the major unit of the Southern Carpathians, specifically to the group that extends between the rivers Olt and Jiu-Strei (the Central Southern Carpathians group). They are bordered by Cindrel Mountains to the east, by the lower Strei valley depression to the west, by the Mureş valley to the north, by the Haţeg and Petroşani depressions and by Caprei Mountains (an extension of Parâng mountains) to the south.

The main ridge, whose course exhibits a SSE facing concavity, is 49 km long and it is dominated by several peaks, namely: Sălanele (1709 m), Vârful lui Pătru (2059 m), Pârva (1901 m), Comărnicel (1894 m), Ştevia (1763 m), Jiguru Mare (1497 m), as well as by the saddles Gura Potecului (1600 m), Şureanu (1760 m), Prislop (1260 m) etc.

Both the main and the secondary ridges display fragments of old erosion surfaces that belong to the various evolution stages underwent by that mountains body. On the whole, they correspond to the three erosion surfaces that the French geographer Emm. De Martonne has identified in the Southern Carpathians. Distorted by tectonic movements and dissected by erosion, occurrences of the three erosion surfaces (Auşel, Păltinei and Luncani) can be tracked from the basin center toward its margin.

The stream courses belong to two main catchment areas: that of Mureş river (the streams Grădiştea and Strei) and that of the river Jiu (the Eastern Jiu, with its tributaries Răscoala, Taia and Băniţa streams). The streams network density of Sebeş Mountains ranges between 0.7 and 0.9 km/km^2, while in the Petroşani and Haţeg depressions that density increases to 0.9-1.0 km/km^2 (Pascu, 1983).

In Şureanu Mountains, the multi-annual rainfall amount ranges from 550-600 mm in the border areas, to more than 1000 mm in the central areas, where elevations exceed 1800 m. The time distribution of rainfall has a discontinuous and non-uniform character (Trufaş, 1986).

1. Current status of the geological and hydrogeological investigation

The earliest papers addressing the geological investigation of the formations occurring in that area are those of L. Mrazec and G. Murgoci (1897).

Geological investigations addressing Sebeş Mountains have been performed, among others, by H. Savu and co-workers (1957-1958), by H. Savu and C. Micu (1959).

Al. Stilla (1965-1972) has conducted, alone or in co-operation with O. Dragastan and I. Dumitru (1968, 1972), detailed investigations that concerned the sedimentary formations of the Pui zone.

In the year 1968 the G.I.R. has edited the sheet Orăştie of the geological map at the scale 1:200,000, then in the year 1986 there has been edited the sheet Lupeni of the geological map at the scale 1:50,000, within which there were included the south-eastern part of the Haţeg basin and the south-western prolongation of Sebeş Mountains.

In order to delineate the groundwater flow directions in areas of extensive carbonate deposits occurrences, several tracer tests have been conducted (V. Trufaş,1965; I. Orăşeanu, R. Venţel, E. Gaşpar, 1986 and 1987).

There have been also carried out a multitude of speleological, morphological, geological, hydrogeological, a.s.o. studies addressing that area. Among their authors we mention: Margareta Dumitrescu, Tr. Orghidan, N. Orghidan, V. Puşcariu, Jana Tanasachi, Ştefania Avram (1967), H. Mitrofan (1978, 1972), G. Ponta (1978, 1984), I. Giurgiu (1983), H. Mitrofan and G. Ponta (1985), I. Giurgiu (1999), S. Roată and Liliana Roată (2002) etc.

During the period 2002-2003, Gh. Bandrabur and co-workers have investigated the carbonate formations in Sebeş Mountains in terms of hydrogeology.

2. Geological setting

Geological formations occurring in the south-western part of Sebeş Mountains belong to the Getic domain.

The lower structural level of this domain consists of crystalline schists of the Sebeş-Lotru mezometamorphic series, whose age is Late Precambrian, overlain by sedimentary deposits of Paleozoic, Mesozoic and Neozoic age (Fig. 1).

At the bottom of the Alpine sedimentary series, formations of Late Paleozoic age have been identified.

The first term of that series, of Permian age, consists of a stack of red-violet conglomerates and sandstones, that are about 60 m thick.

For most part of the south-western part of Sebeş Mountains, the crystalline schists of the Getic domain are overlain by Mesozoic sedimentary deposits (Early Jurassic - Early Maastrichtian) belonging to the Pui zone, and by Neozoic (Miocene) deposits belonging to the basins Haţeg and Petroşani.

Above the Early Jurassic sandstone, there occurs a gradual transition toward carbonate sandstone and arenitic spatic limestone, limestone with chert inter-beddings, marly limestone and limestone, a stack whose overall thickness reaches about 120 m (Aalenian - Early Oxfordian).

The previously mentioned stack is conformably overlain by another, up to 125 m thick stack of pink-white, reddish limestone, with stained appearance or including at its top insertions of nodulous-shaly limestone (of Late Oxfordian - Tithonic age).

Subsequently, during the Late Jurassic – Aptian time interval there has been deposited the white, gritty, organogenic, massive limestone (in reef facies), whose thickness reached up to 400 m and whose maximum development was recorded in the region extending between the settlements of Cioclovina (to the NW) and Merişor (to the SE).

Within the hydrogeological map, the two above-indicated carbonate sequences have not been considered separately and they have been hence represented as a single complex of Late Jurassic - Aptian age.

After the reef limestone deposition, the Austric tectonic movements made the considered region emerge from the sea and thus previously

Figure 1. Hydrogeological map of the South-Western area of the Sebeș Mountains.

Legend

A Hydrogeological caracterisation:

I Mesozoic carbonate series, fractured and karstified, characterised by an intensive groundwater flow. Springs flow rate up to 500 l/s; 1 Limestones (J_3-ap);

II Quaternary detritic deposits with reduced thickness and extension, hosting groundwater pores-flow. Local importance aquifers; 1, a Alluvial deposits (qh), b Holocene proluvial deposits, c Holocene screes;

III Detritic deposits with permeability of fissures and pores with reduced thikness and extension; 1 Paleogene sandstones and conglomerates (Pg_3); 2 Permian conglomerates and sandstones (P);

IV Marly and shaly deposits including rock-complexes of variable permeability. Aquifers are discontinous; 1 Holocene lanslides; 2 Cretaceous flysch (al-ma_1); 3 Jurassic conglomerates, shales, marls (J_1-ox_1);

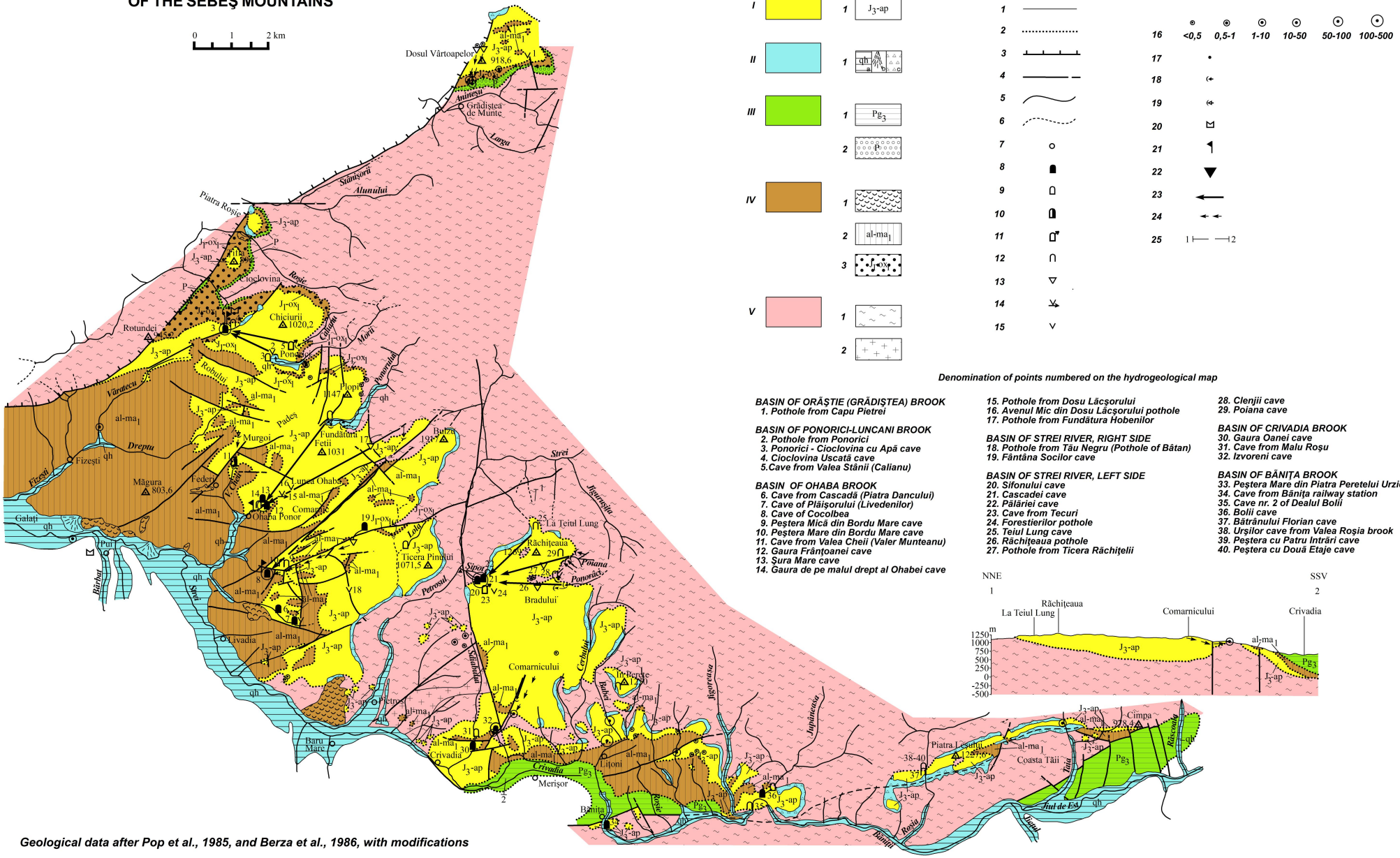
V Precambrian metamorphites and magmatites with large thickness and extension. The permeability of fissures has a discontinous distribution and intensity; 1 Shists; 2 Granites;

B Signs and symbols:

1 Geological boundary;
2 Unconformity boundary;
3 Overthrust plane;
4 Fault;
5 Perennial surface course;
6 Temporary surface course;
7 Locality;
8 Perennial outflow cave;
9 Perennial inflow cave;
10 Temporary outflow cave;
11 Cave tapping a underground stream;
12 Fossil cave;
13 Perennial inflow pothole;
14 Pothole tapping a underground stream;
15 Fossil pothole;
16 Sources discharge (l/s);
17 Perennial impenetrable source;
18 Perennial impenetrable ponor;
19 Temporary impenetrable ponor;
20 Precipitation gauge;
21 Hydrometric gauging section;
22 Temporary hydrometric gauging section;
23 Underground flow direction established by tracer experiments;
24 Presumptive underground flow direction;
25 Hydrogeological cross-section line.

Figure 1

HYDROGEOLOGICAL MAP OF THE SOUTH-WESTERN AREA OF THE SEBEŞ MOUNTAINS



deposited formations became subject to intense erosion, with a karst topography taking shape in the areas where Late Jurassic - Early Cretaceous limestone outcropped. During the Albian period, in the cavities of that Late Aptian paleo-karst there have been accumulated detritic and chemical precipitation sediments that generated lens-shaped detritic-chemical formations, with bauxitic rocks.

Within the Late Cretaceous formations, widely developed in the south-western part of Şureanu Mountains northward of the stream Strei, there have been separated several groups of sedimentary terms (Early Cenomanian - Early Maastrichtian), whose deposits displayed a prevalently flyschoid character.

A subsequent thick stack of gravel, sands, conglomerates etc. has been ascribed to the Paleogene-Neogene interval of deposition.

The most important fracture detected in the south-western part of Sebeş Mountains is the Pui zone border line, a segment of the overthrusting contact between two major units of the Southern Carpathians: the Getic nappe and the Supra-Getic units, their sedimentary formations zones also included.

Fracture-type tectonic elements, consisting of a series of typically transverse fractures, concern the Mesozoic stacks of that region and they have a reverse fault character, with westward dip, so that their western compartment is thrust over their eastern one.

The fold-type tectonic elements occurring in that area generally strike NE-SW, transversally with respect to the main orogenic stress.

The geological background used for constructing the hydrogeological map of that area has included the sheets Lupeni (Berza et al.,1986) and Pui - draft (Pop et al., 1985) of the geological map at the scale 1:50,000, and the Geological Map of the region Haţeg-Cioclovina-Pui-Băniţa (Stilla, 1985), with adjustments.

3. Investigation approach

The investigation of the carbonate deposits in the south-western part of Sebeş Mountains has included the following types of works: hydrogeological surveys, systematic measurements of the physical parameters (temperature, turbidity, etc.) and of the hydrodynamic parameters (flow rates), mapping of the sinking points and assessing the water amounts that are lost by the surface streams network, tracer tests, groundwater sampling for complete chemical analyses and for establishing the microelements concentrations (by means of the I.C.P method).

The hydro-meteorological observations network (hydrometric rods, limnigraphs, pluviometers) has been operating for one year (01.10.2002-30.09.2003).

The investigation of the hydrodynamic behavior of the concerned karst systems has resorted to methods that are specific to the systems analysis.

4. The karst in Sebeș Mountains

In the south-western part of Sebeş Mountains, limestone occurs in four distinct bodies with dissimilar extents. The first one is located next to Grădiştea de Munte, in Vârtoapele Hill (1.96 km^2); the second one extends between the settlements Cioclovina and Baru (35.27 km^2); the third one occurs in the area Crivadia-Băniţa-Peştera Bolii (20.51 km^2); the last one occurs in the north-eastern part of the Petroşani Depression, in Piatra Leşului ridge (1.55 km^2). The limestone bodies located on the right and on the left sides of Petros stream (namely in the areas Cioclovina-Baru, and Crivadia-Băniţa respectively), display an abundance of karst landforms, a direct result of their larger extent and thickness.

When considering the surface topography of the limestone body, one may notice not only the variety of the included landforms, but also the differences between their stages of evolution, as well as the various conditions under which they were generated.

Grikes. Extended fields of grikes occur on the peaks: Vârtoapele, Chiciurii, Plopi, Feţii, Curmătura, Răchiţeaua and Comarnicului, as well as in the neighborhood of the depressions: Ponorici, Fundătura, Luncile Hobenilor (Lunca Ohaba), Fântâna Socilor.

Sinkholes may have extremely variable dimensions (ranging from 2 to more than 100 m in diameter and up to 20 m in depth), the most frequent shape being that of a cone. They occur as fields (to the west and south of Fundătura, to the north of Murgoi), or along tectonic fractures, or as

perched valleys (in Vârtoapele Hill, to the north-west and north of Ponorici, in Lola valley, to the north-west and south of Bradului Hill).

Ouvalas, large extent depression-shaped landforms, are met to the north of the hills Robului and Padeş, as well as to the south-west of Vârful Feţii .

To the west of Ohaba-Ponor plateau, *karst contact depressions* occur. The valleys Morii and Ponorului (Ohaba), whose headwaters are located on crystalline terrains, carry permanent and rather large flow rates until reaching the limestone substratum. At the boundary between those two types of rocks, there is a lineament of swallets which occur at the bottom of very steep escarpments.

The Strei corridor is the most illustrative among the *karst valleys* in that area. Over a length of about 10 km, the valley displays large limestone escarpments whose absolute elevation is 700 m. There has been presumed (Roată and Roată, 2002) that at a certain stage of its evolution, the river Strei might have followed, along this section, an underground course.

There occur also *gorges* (along the valleys Cheii, Cerbului, Roşia and Taia), *temporary flow valleys* (Şipoţel brook, the streamlet discharging from Fântâna Socilor and the brooks located to the east of Bradului Hill), *blind valleys*, namely valleys whose discharge sinks completely in swallets located along the lithologic boundary line (Morii valley, Ponorului valley and Calianu valley), *«cul de sac» valleys* (along the streams which discharge from the caves Şura Mare and Cocolbea).

The sinkhole valleys, quite abundant in that area, occur along old flow-paths of the surface streams network. They are visible on the western slopes of Padeş Hill, on the western and southern slopes of Vârful Feţii, above the escarpment of the stream Strei and on Vârtoapele Hill.

Other karst topography landforms occurring in the carbonate section of Sebeş Mountains are the *residual erosion bodies* and the *limestone escarpments.*

The underground karst landforms (caves, potholes) are also abundant. Table 1 indicates the main underground karst phenomena in that area.

In that area there occur *dry caves* (Cioclovina Uscată Cave, The Small Cave in Bordu Mare, The Large Cave in Bordu Mare, Fundătura Cave, The Cave in Dealul Mătuşanului, the caves in Roşia Valley); *swallet caves* (on the Lola valley tributary, The Cave at Teiul Lung, The Cave in Valea Clenjii); *outlet caves* (Cioclovina cu Apă Cave, Şura Mare Cave, Cocolbea Cave, The Cave at Fântâna Socilor, The Cave at the Waterfall, Plăişorului Cave, Izvoreni Cave).

Gaura Oanei Cave and Bolii Cave are categorized as through-flow caves.

Some dry entrances lead to a network of stream passages, with perennial or temporary character (The Cave in Valea Stânii, Tecuri Cave).

In that same area, there occur also potholes which are vertical or sub-vertical and of various diameters and depths. Among them we mention: *dry potholes* (The Pothole at Capu Pietrei, The Pothole at Tău Negru, The Pothole Forestierilor de la Cabana Tecuri); *swallet potholes* (The Pothole at Fundătura Hobenilor, Răchiţeaua Pothole), *potholes intercepting an underground stream course* (The Pothole in Dosu Lăcşorului).

5. The karst terrains Hydrogeology

Carbonate rocks of Late Oxfordian - Early Aptian age are the main reservoir formation in the south-western Şureanu Mountains area. As a result of their large extent and because they are subject to intense fracturing and karst processes, the indicated deposits favor the through-flow and storage of important groundwater resources.

Groundwater accumulations in carbonate deposits are highlighted by the amount of springs occurring within the considered terrains and by the discharge of those springs. There have been identified a total of 101 springs, whose average flow rates range between 0.01 l/s and 380 l/s. As previously mentioned, the discharge of certain karst springs has been monitored during the time interval 01.10.2002-30.09.2003, when the total amount at rainfall recorded at the rain gauging stations in that area amounted to 764.8 mm at Cioclovina (650 m elevation) and 589.0 mm at Pui (420 m elevation).

The performed investigations contributed to delineating the way in which the carbonate aquifer was structured. That structure shall be analyzed by considering the karst systems and the catchment areas for which hydrometric observations and measurements have been performed.

Ponorici - Cioclovina cu Apă karst flow system

Within the largest extent limestone body, between the settlements Cioclovina and Baru, there occurs the most evolved karst flow system, whose name has been given after that of the main through-flow cave, *Ponorici - Cioclovina cu Apă System*. The karst plateau, strewn with a multitude of sinkholes, is crossed by the stream Ponorici (Morii valley).

A few hundred meters after reaching the limestone substratum, the valley abruptly ends against a limestone wall. At the bottom of that cliff the stream sinks, then it flows across **Ponorici - Cioclovina cu Apă Cave**, to finally emerge through Cioclovina cu Apă Cave entrance and to continue its course as a surface stream called Luncanilor brook (Morii valley). Within the western slope of Ponorici valley, some 10 m above the streambed, there occurs Ponorici Cave entrance – the upstream access into Ponorici - Cioclovina cu Apă Cave.

The groundwater catchment area has expanded its extent both on the vertical and by means of lateral stream piracies, one of its present-day main tributaries being the stream Calianu (~Valea Stânii, which generated the cave bearing the same name).

In order to establish the groundwater flow directions, as well as the transit velocities, two

No.	No. on the map	Name	Length (m)	Depth (m)	Abs. elev. (m)	Hydrology A - stream F - dry
Orăştie (Grădiştea) catchment area						
1	1	The Pothole at Capu Pietrei	-	-	-	F
Ponorici (Valea Morii) – Luncani catchment area						
2	2	The Pothole at Ponorici	150.0	-20	-	F
3	3	Ponorici - Cioclovina cu Apă Cave	7890.0	-174.0	-	A
4	4	Cioclovina Uscată Cave	763.0	-	-	F
5	5	The Cave in Valea Stânii (Calianu Cave)	-	-	-	A
Ohaba catchment area						
6	7	Plăişorului Cave (Livedenilor Cave)	239.0	+28.0	-	A
7	8	Cocolbea Cave	125.0	-	450.0	A
8	11	The Cave in Valea Cheii (Valer Munteanu Cave)	230.0	+16.,0	550.0	A
9	13	Şura Mare Cave	3143.0	+50.0	460.0	A
10	15	The Pothole in Dosu Lăcşorului	796.0	-268.0	-	A
11	17	The Pothole at Fundătura Hobenilor	295.0	-78.0	920.0	A
Strei catchment area, right side						
12	18	The Pothole at Tău Negru (Bâtan Pothole)	150.0	-101.0	-	F
Strei, catchment area, left side						
13	22	Pălăriei Cave	121.0	-15.0	-	F
14	23	Tecuri Cave	458.0	-49.0	926.0	A
15	28	The Cave in Valea Clenjii	1467.0	-103.0; +2.0	1150.0	A
Crivadia catchment area						
16	30	Gaura Oanei Cave	557.0	-	728.0	A
17	31	The Cave at Malul Roşu	343.0	-	760.0	A
18	32	Izvoreni Cave	100.0	-5.0	-	A
Băniţa catchment area						
19	33	The Large Cave in Piatra Peretelui Urzicari	427.0	+15.0; -4.0	-	F
20	36	Bolii Cave	455.0	+2.0	720.0	A
21	38	Urşilor Cave in Valea Roşia brook	189.0	+8.0; -5.5	-	F
22	39	The Four Entrances Cave next to Urşilor Cave	145.0	+6.5; -5.5	-	F

Tabel 1. Main underground karst phenomena in the south-western section of Sebeș Mountains (after Goran, 1982).

α = 0.0203 day^{-1} - e corect? E alfa? La copy/paste a aparut μ !

fluorescein tracer tests have been performed in the area Valea Morii (Ponorici) - Cioclovina, the tests results being indicated in Table 2.

The characteristics of the stream discharged by Cioclovina Cave are indicated in Table 3. Over that period, the stream water temperature has ranged between 4.9 and 11.3°C.

The distribution of the discharge values by classes and frequencies indicates that during 74 % of the entire period when the outlet was monitored, its flow rates were smaller than 155.0 l/s.

From the flow rates recession diagram (Fig. 2) constructed for the time interval 19.04.2003 (Q = 551.4 l/s) - 02.07.2003 (Q = 36.0 l/s) the following coefficients values were derived: α = 0.0203 day^{-1} and $V_{dyn.}$ = 367.0 m^3. The outstandingly low value of $V_{dyn.}$ made us assume that the flooded karst is poorly developed and that water transit is fast. The latter inference is also substantiated by the tracer tests results.

The overall characterization of Ponorici - Cioclovina cu Apă karst flow system is that of a poor storage system, with fast drainage rate and small groundwater reserves.

Fundătura - Şura Mare karst flow system

In the northern part of Ohaba Ponor village, after progressing for about 500 m upstream the gorge of Ohaba brook, there occurs a crosswise-positioned wall which appears to close the valley completely.

That wall is however pierced by a huge (37 m tall by 8-12 m wide) crack, which provides access to **Şura Mare Cave** (Table 1), that is the outlet of a stream sunk about 3 km further to the north, at Fundătura Ponorului.

The karst flow system Fundătura - Şura Mare is mainly developed along Ohaba brook. The latter sinks into several swallets in Fundătura area, to re-emerge at ground surface through the entrance of Şura Mare Cave.

Northeastward of Ohaba Ponor village there occurs also **The Pothole in Dosu Lăcşorului** (-262 m), whose eastern passage leads to an underground stream which finally reaches Şura Mare Cave main passage, not very far from the cave entrance area.

The large groundwater flow velocities (232-467 m/hour) indicated by tracer tests (Table 2) provide an evidence for fast-flowing, well-structured drainage systems.

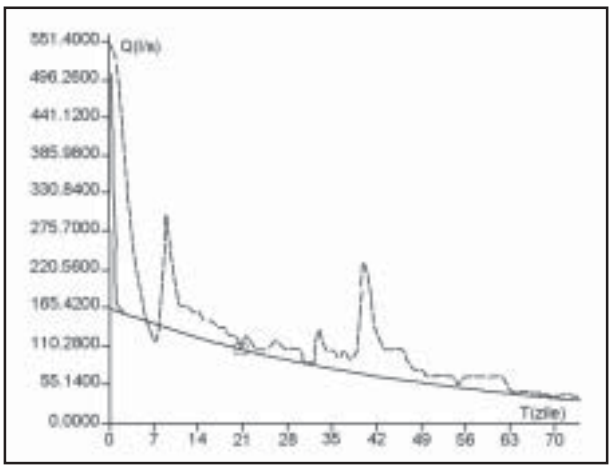


Figure 2. Recession diagram – Cioclovina Cave.

Şura Mare outlet discharge records are given in Table 3 (T° = 5.7-12.4°C).

By processing the recession diagram (Fig. 3) constructed for the time interval 16.04.2003 - 01.07.2003 there was assessed an amount of water (available to be released during an idealized zero-infiltration episode) of 2130 m^3 and a recession coefficient of 0.0087 day^{-1}. Those figures suggest a relatively important storage and a slow drainage rate.

The memory-effect derived from the correlogram amounts to 24 days, thus indicating a slow release of the system water, in accordance with the recession diagram.

The spectrum function diagram is strongly controlled by the 31, 21, 17 days periodicities, some of which are also discernible in the rainfall values spectra recorded at Cioclovina and Pui. The computed regulation time is 24 days.

We presume that the memory effect (24 days) and the regulation time (24 days) mirror mainly the characteristics of the catchment area that provides the recharge and which is developed on impervious terrains, the latter possessing their own memory effect which is transferred, via the swallets, to the karst system.

Compared to the previously discussed system, this one is subject to a slower drainage rate, it has a larger storage and a higher memory effect. Those features are not a direct consequence of the storage properties of the system itself, but they are more likely a characteristic of the associated surface flow catchment area that is developed on non-karst rocks.

No.	Sinking point (elevation - m)	Resurgenc (elevation - m)	L (m)	H (m)	The used tracer	T (hours)	V (m/hour)	Date
1	Calianu brook (905)	Cioclovina Cave (650)	1900	255	fluorescein	48	39.6	21.06.2003
2	Valea Morii (830)	Cioclovina Cave (650)	1550	180	fluorescein	8	194.0	15.09.2003
3	Fundătura Pothole (900)	Şura Mare Cave (460)	3250	440	fluorescein	14	232.0	17.08.1964
4	Fundătura (880)	Şura Mare Cave (460)	2800	420	fluorescein	6	467.0	1968
5	Fundătura (880)	Şura Mare Cave (460)	2800	420	fluorescein	12	233.0	10.09.2003
6	Luncile Hobenilor (910)	Cocolbea Cave (450)	4600	460	fluorescein	126	37.0	08.10.2003
7	Poiana brook –	Şipot brook spring –	–	–	–	–	–	1965
8	Ponorâci brook –	The Sump Cave –	–	–	–	–	–	1965
9	Ponorâci brook (900)	The Sump Cave (560)	1800	340	In - EDTA	144	12.5	05.10.1986
10	The Cave in valea Clenjii (906)	The Sump Cave (560)	1909	346	rhodamine B	132	14.5	05.10.1986
11	Teiul Lung cave (868)	Şipot brook spring (560)	1850	308	Dy - EDTA	96	19.3	13.09.1987
12	Poiana brook swallet (1230)	Şipot brook spring (560)	2400	670	rhodamine B	72	33.3	13.09.1987
13	Poiana brook swallet (1230)	Şipot brook spring (560)	2400	670	fluorescein	40	60.0	16.08.2003

Table 2. Results of certain tracer test experiments conducted in the south-western part of Sebeș Mountains.
L = Horizontal distance between the sinking point and the resurgence
H = Elevation drop from the sinking point to the resurgence
T = Time of the tracer first arrival
V = Velocity
1, 2, 5, 6, 13 - Bandrabur et al., 2003.
3 - Dumitrescu et al., 1967.
4 - The Joint British Universities Speleological Expedition, 1968.
7, 8 - Trufaș, 1986. The only available information is that the tracer has reached the resurgence.
9, 10, 11, 12 - Orășeanu et al., 1991.

No.	Outlet	Qmax. l/s	Qmin. l/s	Qmax./ Qmin.	Qmed. l/s	α	V.dyn. m	E.M. days	F.T.	T.R. days
1	Cioclovina Cave	1173.0	36.0	32.6	140.9	0.0203	367.0	8	0.012	–
2	Şura Mare Cave	1442.0	108.5	13.3	377.6	0.0087	2130.0	24	0.08	24
3	Cocolbea Cave	315.0	28.0	11.2	80.3	0.0116	370.0	17	0.200	12
4	Şipot brook	1178.0	71.0	16.6	267.0	–	–	–	–	–
5	Spring in Morii valley	82.0	15.0	5.4	30.7	–	–	–	–	–

Table 3. Hydrodynamic parameters of the springs monitored over the time interval 01.10.2002-30.09.2003 in the south-western part of Sebeș Mountains.
α - recession coefficient;
E.M. - memory effect;
F.T. - cutting frequency;
T.R. - regulation time

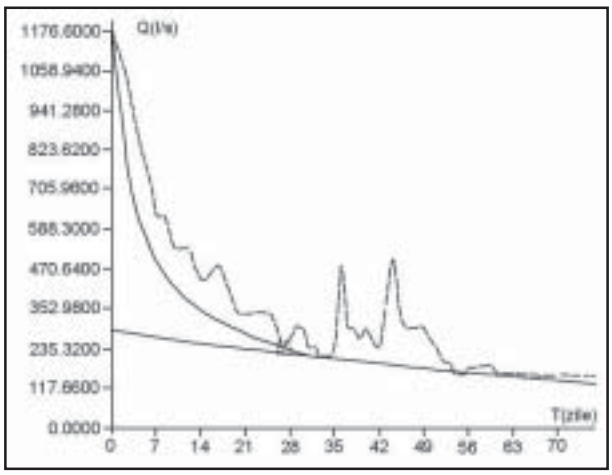


Figure 3. Recession diagram – Şura Mare Cave.

Cocolbea Cave karst flow system

Cocolbea Cave is located about 2 km northeast of Ponor village, at the end of a *«cul de sac»* valley.

Significant in hydrogeological terms is also the **Cave Fântâna Socilor**. It is located in Lunca Priporului, about 5 km northeastward of Ponor village. It is an outlet cave, whose discharged water (Q ~ 0.4 l/s, T°= 9°C – 22.07.2002) sinks once more after flowing for a few hundred meters south-southeastward above the ground.

The recharge area of the stream which flows across Cocolbea Cave extends between Lunca Ohaba (Luncile Hobenilor) and Chicera Hill.

The latter inference has been in a certain extent proven by tracer tests. Tracer injected on 08.10.2003 in the spot where the stream in Luncile Hobenilor sank entirely (Q_{sink}~ 0.3 l/s), has been detected 126 hours afterwards in the water sam"ples collected (Table 2) from Cocolbea Cave (Q = 70 l/s).

Flow rates recorded at Cocolbea Cave outlet are indicated in Table 3 (T° = 8.4-9.6°C).

The discharge classes analysis indicates a karst system with a unitary behavior, devoid of flow delays ascribable to the annex systems.

For analyzing the recession diagram, there has been s-a been considered the time interval 14.04.2003-25.06.2003, during which the discharge declined from 315.0 l/s to 35.0 l/s (Fig. 4). The recession coefficient and the dynamic volume values derived as a result of that procedure indicate a small discharge rate and a poor storage.

The flow rates correlogram indicates a 17 days "memory effect", thus suggesting a rather slow transit of groundwater.

The spectrum function diagram illustrates the existence of periodicities larger than the observation window (seasonal and/or annual trends), as well as periodicities of 31, 16, 12 and 7 days, some of which are also noticeable within the rainfall values spectrum recorded at Pui. The regulation time (the duration of the rain phenomenon influence) amounts to 12 days. The cutting frequency f = 0.200 (5 days) indicates a system without major inertia.

Characteristic to Cocolbea Cave karst system are the poor storage capacity and the fast discharge rate.

Lola karst area

Lola, a tributary of the stream Strei in the major gorge section of the latter, is essentially a dry valley. Along the two main branches of Lola valley, there have been identified several sites (swallet, pothole, cave) where water sinks, to emerge again in springs occurring close to Petros streambed.

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Within the carbonate rocks area Crivadia - Băniţa - Peştera Bolii, in the the Tecuri - Comarnic Hill plateau, there can be separated two distinct domains where the underground flows follow diverging directions, namely westward - in the area which lies between Poiana valley and Şipot brook - and respectively southward for the area Comarnic Hill - Izvoreni.

Toward the east, the limestone outcrop area becomes increasingly narrow, to eventually disappear completely.

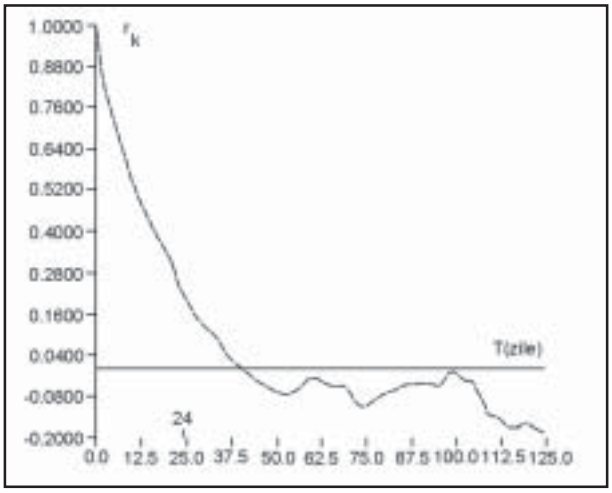

Figure 4. Recession diagram – Cocolbea Cave.

Poiana - Șipot karst flow system

The system is located in the northernmost section of the Crivadia - Băniţa - Peştera Bolii area and it represents the main groundwater flow system in that region.

The best known cave is the one at **Tecuri** (Table 1). The cave is located on the left side of the upper section of Strei valley, close to the crystalline/limestone boundary, at 926 m absolute elevation. One of the two passages of that cave leads to a permanent lake, that is subject to frequent oscillations of its level. The perennial character of the lake, as well as its level oscillations are a result of the fact that by the present time the cave is connected to an underlying network of submerged flowpaths.

Karst terrains in that area are devoid of surface streams, since the latter become organized on the adjoining domains built up of crystalline formations, then the surface flows sink entirely when reaching the limestone substratum.

Groundwater stored within the limestone discharges via three main outlets, namely: the right branch of Şipot stream, the Waterfall Cave outlet and the Sump Cave outlet. The three outlets become united to form a stream whose characteristic discharge values are indicated in Table 3 (T° = 3.2-12.9°C).

Rainfall collected on the carbonate plateau located straight to the east, where it quickly infiltrates, as well as sinking surface streams, provide the recharge to the previously mentioned outlets.

The above indicated sinking areas (with flow rates ranging as a general rule between 0.1 and 0.5 l/s, except for Ponorâci valley, where sinking flow rates range between 1 and 10 l/s) occur along Poiana stream, on the valley located to the north-west of Teiul Lung Peak, along Răchiţeaua stream, along Clenjii valley, at the pothole at "Tăul fără fund" and at the swallet at "Stâna Trăsnită".

An essential part in establishing the groundwater flow directions and velocities was played by the tracer tests conducted in that area in various epochs (Table 2). The results provided by those experiments led to two major conclusions, namely (Orăşeanu et al., 1991):

- The overall groundwater flow velocities are relatively slow, a circumstance suggesting a rather fast infiltration of the surface water along essentially vertical pathways, subsequently followed by a slow discharge toward the outlet, along very gently dipping pathways.
- The Sump Cave outlet on the one hand, and the spring on the right branch of Şipot stream on the other, possess, each one, distinct groundwater catchment areas. There is no connection between those two groundwater catchment areas, at least during draught and moderate discharge periods. This situation is the result of the elevated position assumed by the crystalline basement, which to the north of the Cave in Valea Clenjii forms an E-W striking bulge. For groundwater flowing through the limestone body, this uplifted crystalline basement acts as a water divide that isolates the two groundwater catchment areas from each other.

During periods of rainfall or snowmelt, as a result of the rising of the underground water level, the above indicated position of the water divide may be altered, so that eventually no water divide occurs anymore close to the two outlets. In that case, the two groundwater catchment areas merge into a single one, with two discharge points.

Comarnic – Izvoreni karst area

The carbonate plateau of Comarnic Hill acts as a supply area to the springs occurring further to the SSW.

The water outlet by Izvoreni Cave is located on the right side of Izvoreni valley. Two underground streams unite just next to the cave entrance (Q = 6.0 l/s, T° = 8.7°C – 19.10.2003).

About 650 m north-east of Izvoreni Cave, on the left side of the same valley, there occurs another karst spring displaying the following characteristics: Q = 8.0 l/s, T° = 7.4°C (19.10.2002).

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Eastward of Izvoreni area, in the village Liţoni (north of Băniţa village), there occurs another major outlet, the spring in Valea Morii (Table 3).

A fraction of the discharge of this outlet has its origin in Valea Babei, where several water sinking areas have been identified.

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The last limestone body, located between the streams Roşia and Răscoala, occurs as a narrow strip that reaches its maximum width – 500 m – in Piatra Leşului. In accordance with its small areal extent, also karst phenomena are scarce and of modest size. A few springs occur, with flow rates ranging between 0.1 and 0.5 l/s.

7. Hydrochemistry issues

Water samples have been collected from karst springs and groups of springs, in order to be analyzed in terms of their general chemical composition and of microelements content (by means of the I.C.P. method). The water sampling has been mainly performed during the drought periods of the years 2002 and 2003.

The water of the sampled outlets is of calcium-bicarbonate type, with total mineralizations ranging between 174.66 - 469.4 mg/l.

For water of outlets discharging from carbonate deposits, the concentrations variation range is rather narrow, the corresponding chemical composition including low contents of Na^+ (0.4 - 4.6 mg/l), K^+ (0.2 - 5.0 mg/l), Cl^- (0.0 - 7.1 mg/l), SO_4^{2-} (0.0-21.0 mg/l) and HCO_3^- (121.9 - 280.6 mg/l). Similar values were recorded also for the content of Mg^{2+} (0.0-5.9 mg/l).

In situ measurements of the pH values normally fall within the range 7.25-9.14.

The microelements content is less than 1 mg/l.

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