3.15. CUCIULAT-PURCĂREȚ-BOIU MARE KARST AREA, NORTHERN PART OF THE SOMEȘ PLATEAU

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Introduction

The Someş Plateau (ca. 5100 km^2) is a geomorphic unit bordering the northwestern part of the Transylvanian Basin (Fig. 1). The plateau forms a morpho-tectonic link between the western and eastern Carpathian Mountains, with several crystalline massifs outcropping from thick Paleogene-Miocene clastic (locally evaporitic and pyroclastic) deposits. Karst deposits, including limestones and calcareous sandstones outcrop mainly north of the Someş River Valley on a WSW-ENE direction for about 50 km, between the towns of Jibou and Târgu Lăpuş (Istvan, 1995). The most representative part in terms of karst phenomena is the Purcăreţ-Boiu Mare area (105 km^2) located in the north-eastern part of the plateau (Fig. 2). Because of the N-S monocline dip of strata, the northern part of this area has been modeled by regressive erosion of Lăpuş River tributaries as structural escarpments. The limestone outcrops are preserved mainly as erosive structural surfaces. The southern part, leaning towards the Someş Valley is characterized by long slopes along the monocline orientation. Locally, the limestones are overlain by thin cap rocks con-

Figure 1. Map of the major karst regions of Romania (after Onac & Constantin, 2004), showing the location of Someș Plateau.

sisting of shales/clays and sandstones (Fig. 2). The hydrographic network has been highly disorganized by many minor faults; dry valley beds, gorges, karstic springs and caves are common karstic features.

The geology of this region was thoroughly investigated by Răileanu & Saulea (1956), Mészáros & Ghiurcă (1965), and Rusu (1977). Over the last 30 years several caving clubs (e.g., Cepromin Cluj, CSER Bucureşti, Montana Baia Mare, CSER Cluj, Politehnica Cluj etc.) carried out extensive speleological exploration and research. Most of these activities were oriented towards discovery and inventory of new cavities (Baboş, 1981; Baboş & Mureşan, 1981; Giurgiu et al., 1983; Istvan & Zachan, 1983; Istvan et al., 1992; Rist & Diaconescu, 1992; Istvan, 1995; Minghiraş & C.S. Montana, 2008), karst springs diving (Constantinescu et al., 1992, 1995; Rist, 1992, 1996), as well as investigating various aspects related to karst geomorphology (Istvan, 1983; Todoran & Onac, 1987; Onac et al., 1989) and cave mineralogy (Onac & Todoran, 1987; Onac, 1991; Vereş, 2000; Onac & Vereş, 2003).

Although there is limited information on the karst hydrogeology of the Someş Plateau, the geological and speleological studies have provided a fundamental framework for characterizing the karst of this region. Here we present a synthesis of this data and new results of several pilot studies on the tracing and hydrogeochemical characterization of the main karst springs. Physical parameters (temperature, pH, total dissolved solids (TDS), electrical conductivity (EC), and occasionally the discharge) were recorded at 37 locations for 3 to 5 months between May 2000 and February 2002 (Table 1). Our measurements were conducted with a multi-parameter IP67 Waterproof CyberScan Series PC 300 meter with a built-in auto-temperature compensation that guarantees high levels of accuracy even under varying temperature conditions.

Four dye tracing experiments (using fluorescein and rhodamine) have been performed to establish the main underground flow directions and characterize the hydrogeological parameters. Because we suspected short distance drainages and therefore easy and direct observation of color in springs, monitoring/collection of water samples was set up at only one site, the Bulbuc Spring in Purcăreţ Valley (Fig. 2).

Geology of the area

Thick Neogene sedimentary deposits consisting of conglomerates, sandstones, sands and clays, marls and limestones (typical associations of shallow-water depositional settings) with frequent lateral and vertical faciesal variation cover most of the Someş Plateau (Răileanu & Saulea 1956; Mészáros & Ghiurcă 1965; Rusu 1977). On the basis of biostratigraphic criteria, the sedimentary megasequences have been separated into several main units (Rusu, 1977), and among these, the *Cozla Limestone* (Upper Eocene - Lower Oligocene) hosts the most extensive karst phenomena (Onac et al., 1989) (Fig. 2). The *Cozla Limestone* unit consists of recurrent successions of coralgal-bioclastic "parasequences" developed on a marly substrate (Prică, 2001). The unit is circa 60 m thick, and raised chronological difficulties when the age of the host rock (Eocene vs Oligocene) in which karst cavities developed had to be precisely documented. However, a biostratigraphical study by Todoran & Onac (1989) identified the Eocene-Oligocene boundary immediately above a thin horizon with *Numulites fabianii* (Rusu, 1977). As this horizon is clearly visible in most of the caves, it is now possible to assign the correct age of the bedrock that hosts the cavity. The *Cozla Limestone* outcrops mainly in the northern part of the plateau and along river valley walls/beds in the southern part. The limestone rests unconformably over thick (~1000 m) clastic deposits (mainly clays) of the *Jibou-Racoţi-Valea Nadăşului Formations* of Paleocene-Eocene age.

The Oligocene *Cuciulat* (30-50 m thick) and (partly) *Bizuşa* (calcareous marls) formations also host significant karst phenomena such as karren fields, dolines, springs, and caves, although in these formations the limestone horizons are only a few meters thick and repeatedly intercalated within clays and calcareous marls. These units are overlain by the non-karst deposits of *Ileanda* (Oligocene) and *Buzaş* (Oligocene-Miocene) formations and locally also by thin Quaternary alluvial sediments.

Lithological, structural and tectonic control on karst development

Although more than 90% of lithologies outcropping in the Someş Plateau are non-karstic,

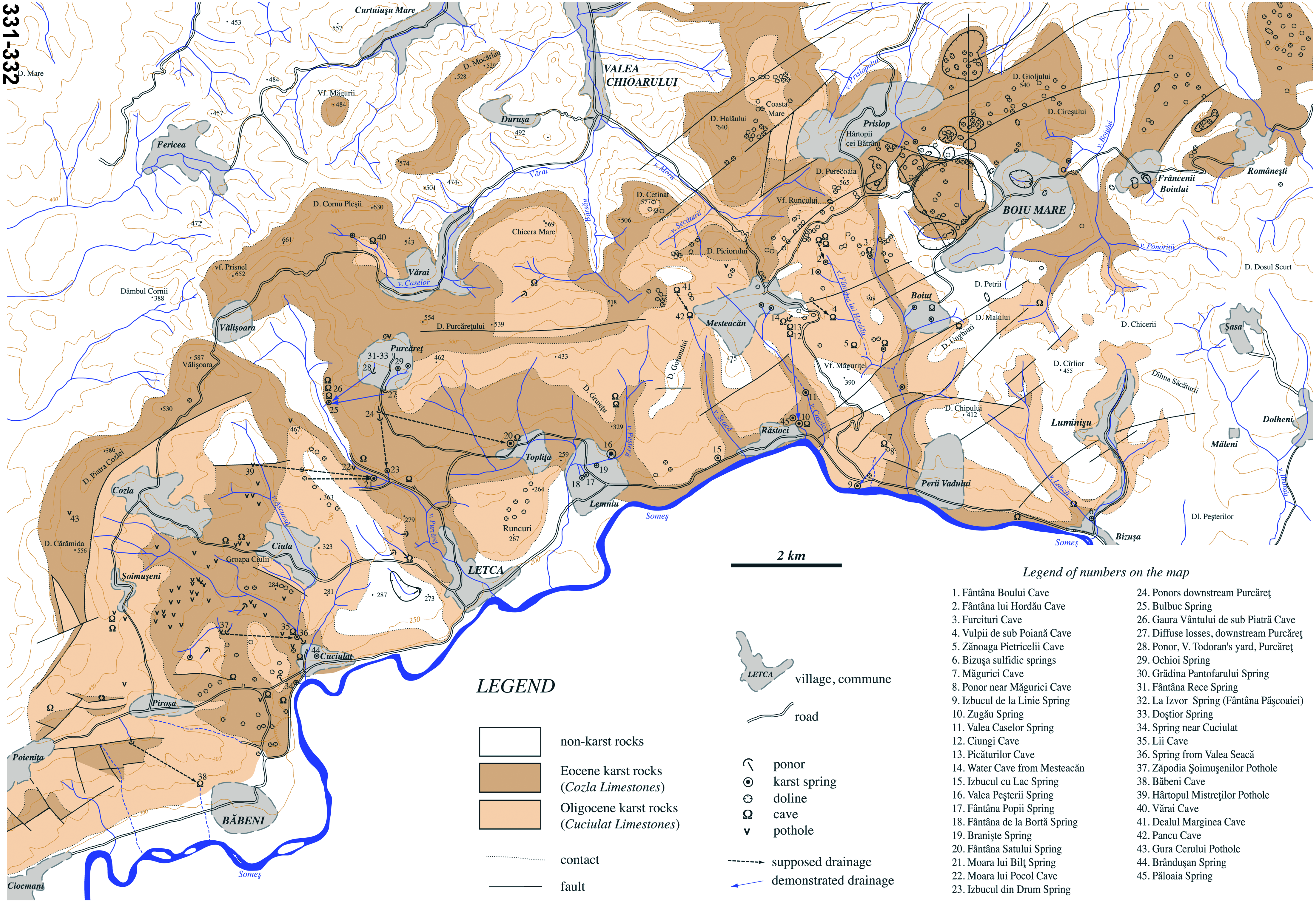

Figure 2. Hydrogeological map of the Someş Plateau (geological base after Rusu, 1977; karst after Istvan et al., 1992).

No.	Name	GPS coordinates		Type	Date	Discharge	Temp.	pH	EC
		N	E			(l/s)	(°C)		(µS/cm)
1	Fântâna Boului Cave	47-23-371	23-32-867	spring	Aug. 2001	0.5 - 1	10.6	7.11	1171
					Oct. 2001		7.9	7.03	1351
					Nov. 2001		9.7	7.94	1040
2	Fântâna lui Hordău Cave (Tomii Cave)	47-23-554	23-32-252	spring	Aug. 2001		10.8	7.64	1223
					Sept. 2001	<1	10.7	7.6	487
					Oct. 2001	0.1	10.9	7.52	2456
					Nov. 2001		9.2	7.96	1567
					Oct. 2008		9.8	8.42	1160
					Jan. 2009		6.6	8.19	1190
					Apr. 2009		9.1	8.33	1220
5	Zănoaga Pietricelii Cave			cave stream	May 2000		6.4	7.99	480
6	Bizuşa sulfide Springs	47-20-679	23-36-208	spring	Sept. 2001		14.9	6.2	1910
					Oct. 2001		10.1	5.92	1980
					Oct. 2008		16.3	6.87	2560
					Jan. 2009		15.8	6.97	2500
					Apr. 2009		16.2	7.16	2510
9	Izbucul de la Linie Spring	47-21-406	23-32-352	spring	Oct. 2008		10.9	7.71	840
					Jan. 2009		9.3	7.64	610
					Apr. 2009		12.5	8.12	920
10	Zugău Spring	47-21-661	23-32-038	spring	May 2000		8.6	6.66	483
					Aug. 2001		9.5	7.41	742
					Sept. 2001	10	9.5	7.53	791
					Oct. 2001	5	11	6.5	812
					Oct. 2008		13	7.51	550
					Jan. 2009		7.7	7.78	710
					Apr. 2009		9.5	7.96	560
11	Valea Caselor Spring			spring	May 2000		5.6	7.01	480
12	Ciungi Cave			cave stream	May 2000		8.3	8.06	
14	Water Cave			cave stream	May 2000		7.4	7.88	501
15	Izbucul cu Lac Spring			spring	Aug. 2001		12.2	15	
16	Valea Peşterii Spring	47-21-393	23-29-144	spring	Sept. 2001	>10	9.7	7.6	617
					Oct. 2001		11.4	7.22	819
					Feb. 2002	40-50	6.5	7.35	535
					Oct. 2008		13.7	7.08	690
					Nov. 2008		11.4	7.46	710
					Dec. 2008		11.3	7.52	780
					Jan. 2009		11.4	7.59	830
					Feb. 2009		12.3	7.82	710
					Mar. 2009		11.4	7.86	740
					Apr. 2009		11.9	7.67	700
17	Fântâna Popii Spring	47-21-213	23-28-838	spring	Aug. 2001	<10	12.2		
					Sept. 2001	<10	9.7	7.04	821
					Oct. 2001	1	11.5	6.7	863
					Feb. 2002	~15	6.2	6.85	602
					Oct. 2008		11.3	7.3	640
					Jan. 2009		10.3	7.43	540
					Apr. 2009		10.3	7.66	580
18	Fântâna de la Bortă Spring	47-21-156	23-28-818	spring	Sept. 2001	1 - 5	10.3	6.65	884
					Oct. 2001	0.1-0.2	12.4	6.18	1058
					Feb. 2002	3.75	7.1	6.63	812
					Oct. 2008		11.4	7.06	720
					Jan. 2009		9.07	7.16	600
					Apr. 2009		10.4	7.44	710

Table 1. Physical parameters measured in different karst waters across the Someș Plateau (the identification numbers in Table 1 are paired to locations in Fig. 2); the 2008-2009 data are from Todoran (2009a, b).

19	Braniște Spring	47-21-395	23-29-143	spring	Sept. 2001	<1	10.2	7.49	545
20	Fântâna Satului Spring	47-21-525	23-27-961	spring	Aug. 2001		10.6	7.2	657
					Sept. 2001	~22	9.2	7.51	583
					Oct. 2001		8.9	6.69	813
					Feb. 2002	100	7.9	6.9	490
					Oct. 2008		11.1	7.53	790
					Jan. 2009		9.9	7.56	670
					Apr. 2009		12.2	7.74	650
21	Moara lui Bilt Spring	47-21-208	23-26-152	spring	Sept. 2001	5 - 10	9.6	7.8	521
					Oct. 2001	1 - 2	10.9	6.85	578
					Oct. 2008		10.5	7.64	790
					Nov. 2008		10.4	7.68	680
					Dec. 2008		6.4	7.8	690
					Jan. 2009		8.5	8.12	640
					Feb. 2009		8.5	7.84	710
					Mar. 2009		9.5	8.19	610
					Apr. 2009		15.7	7.68	640
23	Izbucul din Drum Spring	47-21-197	23-26-250	spring	Oct. 2008		10.8	7.36	810
					Nov. 2008		10.4	7.38	730
					Dec. 2008		9.4	7.29	720
					Jan. 2009		9.7	7.54	720
					Feb. 2009		9.7	7.39	770
					Mar. 2009		8	7.46	670
					Apr. 2009		9.8	7.61	800
25	Bulbuc Spring	47-22-011	23-25-534	spring	Aug. 2001		9.3	7.25	722
					Sept. 2001	5 - 10	9.5	7.53	617
					Oct. 2001		10.4	6.68	912
					Nov. 2001		10.2	7.63	830
					Oct. 2008		11.4	7.81	560
					Nov. 2008		9.6	7.48	840
					Dec. 2008		6.9	7.92	740
					Jan. 2009		8.2	8.6	730
					Feb. 2009		9.7	8.03	800
					Mar. 2009		7.9	8.58	670
					Apr. 2009		12	7.76	680
27	Difusse losses			ponor	Sept. 2001	0.1			
28	Ponor, V. Todoran's yard			ponor	Sept. 2001	0.02			
29	Ochioi Spring	47-22-210	23-26-401	spring	Aug. 2001		9.7	7	835
					Sept. 2001	<1	9.8	7	678
					Oct. 2008		10.4	7.44	960
					Nov. 2008		9.2	7.3	900
					Dec. 2008		8.6	7.27	810
					Jan. 2009		8.1	7.61	730
					Feb. 2009		8.2	7.43	840
					Mar. 2009		8.3	7.48	740
					Apr. 2009		9.8	7.67	680
30	Grădina Pantofarului Spring	47-22-203	23-26-369	spring	Aug. 2001		10.1	7.03	768
					Sept. 2001	<0.1	9.7	6.92	580
					Oct. 2001		10.4	6.3	513
					Oct. 2008		10.2	7.6	750
					Jan. 2009		6.8	7.78	600
					Apr. 2009		10.1	7.84	540

Table 1 continued

31	Fântâna Rece Spring	47-22-209	23-26-401	spring	Aug. 2001		14.8	7.15	536
					Sept. 2001		10.3	7.34	540
					Oct. 2001		11.4	6.65	411
					Oct. 2008		9.9	7.47	740
					Nov. 2008		8.7	7.8	630
					Dec. 2008		8.9	7.17	630
					Jan. 2009		8.8	7.74	540
					Feb. 2009		8.2	7.54	650
					Mar. 2009		7.5	7.54	550
					Apr. 2009		8.6	7.89	530
32	La Izvor Spring (Fântâna Paşcoaiei)	47-22-257	23-25-563	spring	Aug. 2001		10.9	8.2	710
					Sept. 2001	<1	9.4	7.14	520
					Oct. 2001	<0.01	10.7	6.27	999
					Oct. 2008		10.4	7.2	880
					Jan. 2009		8.1	7.42	690
					Apr. 2009		7.5	7.15	910
33	Doştior Spring	47-22-343	23-25-566	spring	Aug. 2001		9.7	7.66	724
					Sept. 2001	2 - 3	10.1	7.5	613
					Oct. 2001	0.4 - 0.5	10.5	6.79	748
					Nov. 2001		10.5	7.58	751
34	Spring near Cuciulat			spring	Aug. 2001		10.4	7.31	760
					Sept. 2001	>10	10	7.73	752
					Oct. 2001		11.4	6.26	648
35	Lii Cave	47-19-710	23-24-939	spring	Sept. 2001	>20	9.4	7.51	485
					Oct. 2001		10.5	6.31	577
					Oct. 2008		10.4	7.85	780
					Jan. 2009		8.5	7.32	690
					Apr. 2009		10.2	8.06	720
44	Brânduşan Spring			spring	Aug. 2001		10.2	7.67	
					Sept. 2001	1 - 3	10.1	7.2	
					Oct. 2001		11.2	6.48	
45	Păloaie Spring	47-21-700	23-31-964	spring	May 2000		8.6	6.92	494
					Oct. 2008		12.2	7.76	880
					Nov. 2008		4.9	7.85	890
					Dec. 2008		11.2	7.72	780
					Jan. 2009		10.6	7.68	830
					Feb. 2009		9.3	7.84	450
					Mar. 2009		8.7	8.04	780
					Apr. 2009		14.8	8.16	830

Table 1 continued

the karst is well developed on Eocene-Oligocene rocks, the area being actually one the most representative of karst developed on deposits of these ages in Romania (Onac et al., 1989). It is believed that the karst in this area is much younger than in other typical karst regions of Romania (e.g. Apuseni Mountains, Southern Carpathians, and Banat Mountains) (Fig. 1), and several factors account for these developments. The most important relate to lithological and structural aspects as well as to the tectonic history of this region.

The *Cozla Limestones* are compact, massive, with limited primary porosity although distinct reefal (and highly porous) horizons are also interbedded at various levels. These limestones had been laid down in centimeters to several meters thick banks, with clear bedding planes. According to direct observations in caves, these contacts represent also the main drainage axes along which conduits developed. The limestone horizons of the overlying *Cuciulat Formation* are normally 2-3 m thick and repeatedly interbedded with sandstones, clays and marls. They cover regressively the *Cozla Limestones* and have a limited areal distribution today (Fig. 2). The genesis of caves and conduits in these limestones mainly relates to the deposits underlying the limestone banks. In the majority of cases, the limestone banks form the ceiling of caves, with the cave conduits developing mainly in clastic rocks through lateral river erosion and wall/ceiling collapse (Istvan & Zachan, 1983).

The carbonate units form monocline structures dipping (less than 20°) towards south and east. The development of caves along bedding planes following the monocline inclination of strata (although directionally mainly controlled by a system of faults) is the main characteristic of underground cavities in this region, especially for those developed in Oligocene deposits (Istvan & Zachan, 1983).

The Eocene-Oligocene karst rocks are (or have been) sandwiched between the impermeable clastic deposits of *Jibou-Racoţi-Valea Nadăşului Formation* (the basement unit) and *Ileanda Formations* (on top). Many important karst springs discharge at the contact with the clays in the very base of the *Cozla Formation*, and most of the cave conduits that reach the base of the limestones have been modeled in a typical phreatic regime.

The bituminous clays/slates of the overlying *Ileanda Formation* (Oligocene-Miocene) played also a particular role in the karstification of this region. Although with a patchy area distribution today (as a result of selective river erosion), locally, these deposits still attain a thickness of circa 20-30 m (exceptionally 50-60 m). It is very likely that before most of these deposits have been removed, they have had a strong control on the infiltration rate and in the initiation and evolution of karstification in the underlying carbonate deposits. Firstly, this unit is responsible for the aggressiveness of the meteoric/groundwater percolating down through the limestones. The large amounts of secondary gypsum precipitated within cave environments are related to the presence of native sulphur and gypsum in the bituminous clays/slates of *Ileanda Formation* (Onac & Todoran, 1987; Onac, 1991).

Secondly, the clastic sediments found within cave environments originate from this unit. The abundance of the clayey fraction in suspension in the water-flows draining this unit suggests that the sediment flux (and associated mechanical abrasion) from this unit is still very high. Indeed, the presence of large clayey deposits in most caves within both *Cuciulat* and *Cozla* formations indicate that the sediment flux from the *Ileanda Formation* had a strong impact on cave conduit development and evolution. There are many conduits which are completely in-filled by such deposits; many cave sectors show direct evidence of several sedimentation/erosional phases, from complete in-filling (rock terraces, wall notches, ceiling channels as well as pockets of clays in alcoves on cave walls) to the reactivation of subterranean passages. It is not clear (due to lack of data) if these aggradation events reflect only internal flow dynamics or show a paragenetic evolution related to the climatic cycles (stadials/interstadials) reflected in the geomorphological evolution of the Someş River Valley.

Locally, the structural geology of some of the units was further complicated by tectonic processes, which produced minor amplitude steps responsible for the so-called "chess table-like" structure expressed as an almost regular network of support fissures/small faults oriented NE-SW and NW-SE. It is considered that the area was tectonically quite stable, and only recently have tectonic movements initiated the development of secondary porosity and of deep karstification in the region (Onac et al., 1989). There is however clear evidence for tectonically-controlled underground drainages playing an essential role in the speleogenesis in this part of the Someş Plateau (Todoran & Onac, 1987; Istvan et al., 1992, 1995). Occasionally, cave conduits formed exclusively following tectonic accidents, with strong vertical development of passages and high hydraulic conductivity. There are several examples of open deep shafts reaching from the top to the base of the *Cozla Limestones*, some with high-volume waterfalls (Giurgiu et al., 1983; Rist & Diaconescu, 1992).

Karst hydrology

According to the hydrological regional classification of karst terrains in Romania of Orăşeanu (1993), the Someş Plateau hosts a typical post-tectonic cover karst. The karst possesses both underground and subaerial flow components, and a wide range of discharge volumes and flow rates, from seepage/percolating flows to phreatic and locally shaft flow have been documented. The underground drainages are developed mainly on a W-E direction, in contrast with the dominant N-S direction of superficial flow (Istvan, 1995). However, because of the limited thickness (maximum 100 m) of the karst deposits and the presence of impervious intercalations (which may restrict the hydrogeological continuity), the karst aquifer(s) is/are quite restricted on a vertical scale.

Considering the structural geology of the area it is likely that the karst aquifers recharge mainly through infiltration from direct precipitation. The precipitations in this region total about 600-800 mm annually (Pop, 2001). The dense networks of swallow holes drain underground most of the precipitation falling directly on limestones. Precipitations falling on impermeable deposits (e.g. *Ileanda Formation*) are rapidly evacuated by surface runoff and ultimately reach the limestones and in most cases infiltrate as allogenic, highly undersaturated recharge water. Indeed, widespread karst-capture phenomena are responsible for the short epigeal hydrographic networks (with exception of Purcăreţ Valley, 8 km long and Sacă Valley, 5 km long), as well as for their diversion and fragmentation (Fig. 2).

Most of the waters sinking through dolines or karren (diffuse) and caves or ponors (diffuse/organized) emerge either at the foothills of the plateau and along the Someş River bank, or on the Someş tributaries, at the contact with the underlying impervious deposits (Fig. 2). The large number of permanent sumps and flooded cave sectors in the lower half of the *Cozla Limestones* suggest that this part is completely saturated. The caves developed in these limestones usually have 2-3 levels of conduits (Giurgiu et al., 1983), probably reflecting the fluvial control of the nearby Someş River Valley.

Because of the limited hydrological data, it is not clear if the stratigraphic units host corresponding hydrogeologic counterparts. The presence of clayey beds within limestone horizons especially in the *Cuciulat Formation* may indeed separate locally the karst aquifer into several hydraulic systems (Ford & Williams, 2007). Though there is a well-defined system of faults and fissures, tectonic features are not detectable in these deposits (e.g. clay beds). As such, the vertical movement of flow might be restricted locally resulting in the establishment of several small groundwater reservoirs as indicated by the presence of many small springs. Therefore, the hydrological characteristics of karst developed in the *Cuciulat* unit are the extremely variable flows and discharge rates, mirroring closely recharge variations through precipitations. During the drought years, many of the springs and underground flows drain out, suggesting limited retention capacity in the *Cuciulat* strata. The caves developed on these deposits show only one level of karstification, overall evidence for vadose modelling and only small water courses due to the fact that these deposits form isolated small plateaus with limited areal extent.

Many caves (or sectors of caves) developed in the *Cozla Limestones* do not communicate in normal pluvial conditions but form large flow drainage systems at times of flooding (spring-time melting and occasional flash-floods). Direct observations by cavers show that the volumes of waters stored underground can be very high following flash-floods when many caves are partly flooded and large lakes form, some lasting for long periods of time. These results point to a well-karstified complex in the *Cozla Limestones* with high secondary and tertiary porosity, with permanent phreatic levels, temporary overflow routes and occasionally reactivated resurgences.

Karst waters

Variations of physical parameters and water chemistries in different discharge points could help characterize the hydrogeochemical processes occurring in the karst and the recharge areas, as the karst springs and wells represent the only source of water for the majority of people living in this part of the Someş Plateau. However, bulk measurements performed on such a large scale and surface area (i.e., *most* of the important karst springs reported are located in very different settings) would not offer sufficient hydrogeochemical information for a detailed characterization of the karst aquifers. Nonetheless, there are striking similarities in the behaviour of these springs with respect to their temperature, pH and conductivity. During the summer months, water temperature values have been between 9-11°C in July and 10-12°C in August, dropped to 9-11°C in September, most likely as a result of enhanced contribution of rainwater and then increased back in October almost to the values recorded in August. Measurements performed in February at some of the springs show a more consistent decrease (to values of 6-8°C), associated with the lowering of outside temperatures and the amount of waters received from surface streams. pH values (generally between 6.8 and 8) have a minimum in October, then increase slowly with the outside temperature decrease.

These measurements show that, indifferent of the recharge area, lithology and structural settings, variations in the temperatures and precipitations of the area have a strong influence on the karst aquifers. As in most karst areas, the residence time and volume of water stored underground varies widely at different stages of the hydrological year and it is therefore likely that recharge and discharge variations are accompanied by some changes in water chemistry (Ford & Williams, 2007). In our case, chemical differences might account for the fact that the *Cuciulat* strata discharge mainly infiltrated surface waters and epikarstic storage, while the springs in the lower part of the *Cozla limestones* discharge from the vadose/phreatic storage, with longer residence times underground. The complex intercalations of clayey layers, the abundance of clays in the underground, as well the bituminous composition of the *Ileanda Formation* result in the presence of carbonate, sulphate, chloride and other ions in the solution, in some cases with very elevated values.

Therefore, before drawing more consistent conclusions on the chemical characteristics, it is advisable that more empirical data and water-tracing experiments are conducted in order to determine the catchment boundaries and recharge areas of different springs, and characterize the nature (diffuse vs concentrated) and extent of recharge area(s).

Karst drainages

Bizusa area

Three short caves and several hydrogen-sulphide rich springs (no. *6* on Fig. 2) are known from the southeastern part of the study area. Except for temperature, TDS, EC measurements and a chemical analysis showing a content of up to 4.2 mg/L H_2S and ~350 mg/L sulphate in these springs, there are no other hydrogeochemical data available. A small balneology spa exploiting these waters has been established here several decades ago. The high H_2S content of these springs is most likely related to the presence of gypsum and native sulfur in the *Ileanda Formation*. The $\delta^{34}S$ value of the dissolved sulphate in these springs is -33.7‰ (Onac, *unpubl. data*). Further isotopic investigations are now undertaken to shed light on the origin of these waters.

Boiu Mare - Mesteacăn - Răstoci area

In terms of exokarst diversity and distribution, this area is by far the most representative of the Someş Plateau. Large doline fields are found here near the villages of Prislop, Boiu Mare and Mesteacăn, and several short underground drainages are likely developed along the right side of Fântâna lui Hordău Valley (*2-5*, *41*, *42*) (Istvan et al., 1992). The longest caves in the area are Ciungi (*12*; 568 m) and Măgurici (*7*; 543 m). Fluorescein tracing of a ponor in the eastern part of the Măgurici Cave entrance has proven a connection with Izbucul de la Linie (*9*), a spring with permanent and constant discharge of ~50 l/s (Baboş & Mureşan, 1981). This is in contrast with the orientation of the main passages of the Măgurici Cave, which would indicate a paleo-flow direction towards the Sacă Valley.

Zugău Spring (*10* in Fig. 2) is one of the most important permanent karst resurgences on the Someş Plateau. The water resurfaces at the base of the *Cozla Limestones* through a small shaft (1.2 × 0.6 m), completely flooded. A mean water discharge of circa 0.63 m^3/s as well as the morphology of the surrounding area does not offer any clue on the recharge area, although it is evident that the water resurfaces along a fault line (Rist, 1996).

The tracing with fluorescein of the small river in the Ciungi Cave in May 2000 revealed that there is an underground connection between this cave and the Zugău Spring (Vereş, 2000). These results confirm that the recharge of this important spring occurs in the Mesteacăn-Boiu Mare area, although the insignificant stream flow in Ciungi Cave at the time of tracing suggest that the spring collects waters from multiple sources. A transit time of circa 110 hours between the cave and the spring (1.6 km as the crow flies) indicate a long underground passage (or residence time) for waters, or low flow velocities. Nonetheless, these results suggest the presence of a complex hydrogeological karst system in the region, draining the swallets of the Purcăreţ-Boiu Mare area and traversing the entire Oligocene-Eocene sedimentary sequence. Moreover, the waters are apparently drained beneath the Caselor Valley in a sector where the stream has a surface flow. Topographic survey suggests that this passage occurs probably less than 10 m below the river bed, in a sector of the Caselor Valley where there are also two important karst springs (*11*; Rist, 1996).

Purcăreț - Letca - Lemniu area

Several underground drainages were tested in this area, which has the highest number of karst springs. In terms of flow rates, the largest springs are Valea Peşterii Spring (*16*; Lemniu, ~50 l/s) and Izbucul Fântâna Satului (*20*; Topliţa, ~30 l/s), both reaching over 100 l/s at high flow. Several smaller springs are found also in the Lemniu Village (*17*, *18*, *19*), and they most likely recharge from the Gorunului Hill area. All these springs are at the level of a former meander of the Someş River.

Izbucul Bulbuc (*25*, left slope) and Moara lui Bilţ (*21*, right slope) are two other important springs in this area, located in the Purcăreţ Valley, upstream from Letca. Although their normal flow rates are less than 10 l/s, they both discharge relatively long underground drainages. While the recharge areas for Valea Peşterii Spring (*16*) and the other smaller springs from Lemniu (*17-19*) can only be estimated, better evidence exists for other springs in the area. At present, Moara lui Bilţ and Fântâna Satului are used for drinking water, yet the locals have relatively little knowledge about their recharge areas. In our opinion, the recharge area for Fântâna Satului Spring may be the slopes situated west of Topliţa and towards Purcăreţ Village, forming probably the longest underground drainage in this part of the Someş Plateau (circa 2.2 km). The Topliţa community raised several complaints based on visual observations of fruit mash from the distillery in Purcăreţ resurfacing in Fântâna Satului Spring. For these reasons, they blocked an active ponor and re-orientated the surface stream. Tracing with fluorescein of several discrete losses in the deviated surface valley (and upstream the ponors), proved their connection with Bulbuc Spring (*25*). The link of another ponor, close to the centre of Purcăreţ Village (V. Todoran's yard, *28*) with the Bulbuc Spring was proved by rhodamine tracing. A connection with the distillery in Purcăreţ was also observed at Bulbuc Spring; at high flow rates, the water carries out fruit mash. Gaura Vântului de sub Piatră (*26*), very likely a fossil level of the same drainage system, is also periodically filled with black sediments containing plum pits, much unlike soils and clays from the cave area.

Moara lui Bilţ Spring (*21*), situated on the right side of Purcăreţ Valley, drains the longest cave discovered so far in the Someş Plateau, Moara lui Pocol Cave (*22*; 3492 m, Rist 1992; Istvan, 1994). The cave consists mainly of a long E-W active canyon-like passage (1045 m in length) with six sumps, followed by a zigzag of NE-SW and E-W passages. The streams tributaries to the cave river reach this long and nearly rectilinear tunnel via two passages, one coming from the north and the other from SW (Minghiraş & C.S. Montana, 2008). Taking into account the passage orientation, the probable recharge points are the potholes and swallets near Valea Ascunsă (*39*, about 2 km straight line), upstream the village of Ciula. The actual entrance of the cave, situated 200 m upstream the spring, is fossil, but there are known cases during floods when excess water from the active passage was drained towards the cave mouth, forming an 8 m waterfall. This would point to an important contribution of rainwater input directly through potholes and ponors which are inactive most of the time.

Cuciulat - Băbeni - Cozla area

The southwestern part of the investigated area also hosts a high density of surface and underground karst forms. Dolines and potholes are numerous, especially in the Şoimuşeni Forest, where more than 30 potholes occur on an area less than 5 km^2. The deepest potholes in the Someş Plateau are reported from this area, one of them (*43*) crossing the entire limestone deposits (-64.5 m) (Rist & Diaconescu, 1992; Minghiraş & C.S. Montana, 2008). Several karst springs with flow rates generally up to 10 l/s discharge the water collected in the higher parts of the plateau. The springs are located both on the level of the Someş River and on the tributaries, the most important being the one flowing through Lii Cave (~ 20 l/s, *35*, *36*). Lii Cave, 1.5 km long and developed along E-W fracture lines, is supposed to represent the underground drainage of a short surface stream north of Piroşa Village as well as of the waters supplied by potholes from the Şoimuşeni Forest; an underground river sumped at both ends was discovered by cavers in Avenul din Zapodia Şoimuşenilor (*37*), at a depth of -20 m (Rist, 1992; Minghiraş & C.S. Montana, 2008).

A second underground drainage, 1.5 km long, is the one at Băbeni Cave (*38*), probably connected with the only active ponor identified in the area.

Synthesis and outlook

The lithological diversity and structural features specific of this area are factors that greatly influenced the karstification and the evolution of the drainage systems in the Purcăreţ-Boiu Mare karst area. The local neotectonic particularities in conjunction with high permeability of the fissured and bank-sedimented limestone and clastic beds are principal factors responsible for the disorganization of meteoric circulation at the surface and the development of a complex hydrogeological drain flow in the area. Moreover, the tectonic factors are also responsible for a very high secondary and tertiary porosity, for controlling the direction of karstification, of the amplitude and the extent of hydraulic conductivity between different sectors as well as the underground water storage capacities.

It is therefore necessary to continue acquiring primary data for a realistic estimation of karst water-balance in the region and attempt modelling of the karst aquifer(s) sustaining the springs. In addition, further hydrogeochemical studies could assist in water resource estimations, quality controls and management policies.

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