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IULIAN POPA
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Pădurea Craiului Mountains (Apuseni Mountains, Romania)

Iancu Orăşeanu
S.C.Prospecţiuni S.A.

RESUME. Afin d'identifier des sources d'eau plate dans les montagnes Codru Moma et Pădurea Craiului, ou a soumis un nombre de 6 sources et la sonde S5 Moneasa a une recherche hydrogeologique complexe. Les sources ont ete mises en evidence comme probablement d'eau plate par des investigations anterieures, au caractere regional.

La recherche hydrogeologique complexe a consiste en etablir les conditions hydrogeologiques dans lequelles appairaissent les sources, l'observation a la sources de la variation des parametres physico-chimiques pendant au moin une anee et etablir la variation dans le temp de la composition chimique et de la charge bacteriologique, sur des echantill d'eau mis en bouteille et stockes dans des conditions de laboratoire. On a egalement analise le contenu en elements toxique et en pesticides des eaux, ansi que leur radioactivite.

Les sources etudiees ne sont pas amenagees, raison pour laquelle certaines d'entre elles presentent temporairement des charges bacteriologiques elevees, dues a une contamination locale, a la source (Feredeu, Izvorul Mare al Tărcăiţei, Ţucreşti).

Les eaux sont de type Ca Mg HCO_3 ou MgCa HCO_3, avec des mineralisations faibles (moins de 500 mg/l residuu sec), sans elements toxique et non-radioactives. Le contenu en pesticides depasse ches certaines sources de 2 fois la concentration maximale admise par les normes de potabilite. Les eaux ont une bonne stabilite chimique, a l'exception de la source Ţucreşti, laquelle est sursaturee par raport au calcite, ce-derniere presentant aves le temps de tendances a precipiter.

Le debit des sources est assez grand pour assurer une exploatation economique et presente un variabilite faible avec le temps, sous ce dernier aspect se distinquant les sources Feredeu et Răşchirata.

La sonde S5 Moneasa donne de l'eau plate.

1. INTRODUCTION

The regional hydrogeological investigations performed in the Codru Moma Mountains, outlined the occurrence of good quality groundwater sources, some of which can be bottled as table water.

These sources were subject of a complex investigation program, conducted by S.C. Prospecţiuni S.A., over a two period of time, 1991-1992 and 1994-1996, that resulted in:

- outlining the physico-chemical parameters of the sources, by means of systematic discharge, temperature, pH, electrical conductivity, dissolved oxygen, alkalinity and redox potential measurements;
- establishing the long term evolution of the chemical composition (especially labile elements and parameters: HCO_3^-, SO_4^{--}, Ca^{++}, Mg^{++}, dissolved oxygen, total hardness, residue on evaporation at 105^0C) and of the bacteriological content, both at the source and for samples bottled and stored in laboratory conditions;
- outlining the toxic elements and pesticides content, and the global α and β radioactivity.

In the framework of the conducted study, the laboratories of Prospecţiuni S.A. have performed the general chemical analyses and the toxic elements contents measurements. The bacteriological analyses have been performed at the Center for Prophylactic Medicine in Beiuş, under the leadership of dr. D. Mocuţa, and partly at the Food Chemistry Institute in Bucharest.

For determining the pesticides content, the water samples have been analysed in the Central Laboratory for the Control of Animal and Vegetal Origin Products in Bucharest, while the total α and β radioactivity has been performed by the laboratories of the Institute of Physics and Nuclear Engineering in Măgurele and in the laboratories of the Rare Metals Authority in Măgurele.

2. INVESTIGATED SOURCES

Codru Moma Mountains are situated in the western part of the Apuseni Mountains and they occur as a massive body which extends between the Neogene basins of Beiuş and Zarand. Moneasa and Crişul Văratec streams separate two distinct physiographic units: Codru Mountains - to the north, and Moma Mountains - to the south.

Codru Moma Mountains prevalently consist of Permian-Mesozoic sedimentary deposits. In the geologic constitution of their northern half are included Triassic and Early Jurassic limestones and dolomites, which form a continuous N-S striking strip. In the Moma Mountains, Triassic carbonate deposits form the lithologic background of the Vaşcău karst plateau (fig. 1).

The complex hydrogeological investigations program has included 6 springs (table 1). The program was also aimed at outlining the quality of water discharged by the well S5 in Moneasa spa.

Table 1. Characteristics of the sources.

No	Source	T	Q	TDS	RE	TH	S.I.		Pest.	α+β	Bac	
		^0C	l/s	mg/l	mg/l	^0d	lms	dol	ppb	mBq	a	b
1	Feredeu (Huta, Finiş)	11,2-13,0	55,0	518,1	316,2	16,03	0,038	0,086	0,0005		+	-
2	Izv. Mare al Tărcăiţei	10,0-10,6	70,0	687,7	285,2	15,15			0,0008	< 42	-	+
3	Well S5 Moneasa	14,2-16,4	4,9	302,0	151,8	6,7	-0,181	-0,463	0,0009	81	+	+
4	Răşchirata (Dezna)	8,2-8,8	35,9	639,9	267,5	13,8	0,164	0,004	0,0008	< 60	+	+
5	Valea Seacă (Dezna)	8,1-8,6	63,7	558,3	259,7	13,7	0,040	-0,212	0,0007	< 34	+	+
6	Ţucreşti (Vaşcău)	14,4-15,4	5,7	566,7	279,8	14,55	0,577	0,498	0,0007	55	-	+
7	Pancului (Remeţi)	9,5-10,2	29,0	514,6	332,1	15,2			0,0010		+	+

Note: T- temperature; Q-mean annual discharge; RE-residue on evaporation at 105^0C; TH-total hardness; S.I.-saturation index (lms-limestones; dol-dolomites); Pest-pesticides (sum of α HCH, β HCH and lindan); α+β - global radioactivity; Bact.-Result of bacteriological analysis: a- seasonal analysis; b-analysis of bottled and stored samples; (+)-bacteriological content less than maximum accepted contents for drinking water by STAS 1342-91 (m.a.c.); (-)-bacteriological content higher than m.a.c., at least at one sample.

The following general assertions are valid for the investigated springs:

- the springs are either not tapped at all, or tapped in a rudimentary manner, which results in a local bacteriological contamination, mainly ensuing to runoff water inflow. Due to this fact, in some cases concentrations do not comply with drinking water requirements;
- all studied spring waters from Codru Moma Mountains are $CaMgHCO_3$ or $MgCaHCO_3$ type, with low mineralization (fig. 2);
- the water samples collected from the springs displayed a good chemical stability over the one year monitoring period; The water of Ţucreşti spring is supersaturated with respect to calcite, being hence prone to carbonate scaling.
- the saturation indexes, computed by Netpath program, indicate that the water of most karst springs is saturated, to a larger or smaller extent, with respect to both calcite and dolomite. The Ţucreşti warm springs is supersaturated with respect to calcite and dolomite. Feredeu, Răşchirata and Valea Seacă springs have saturation indexes very close to the equilibrium;

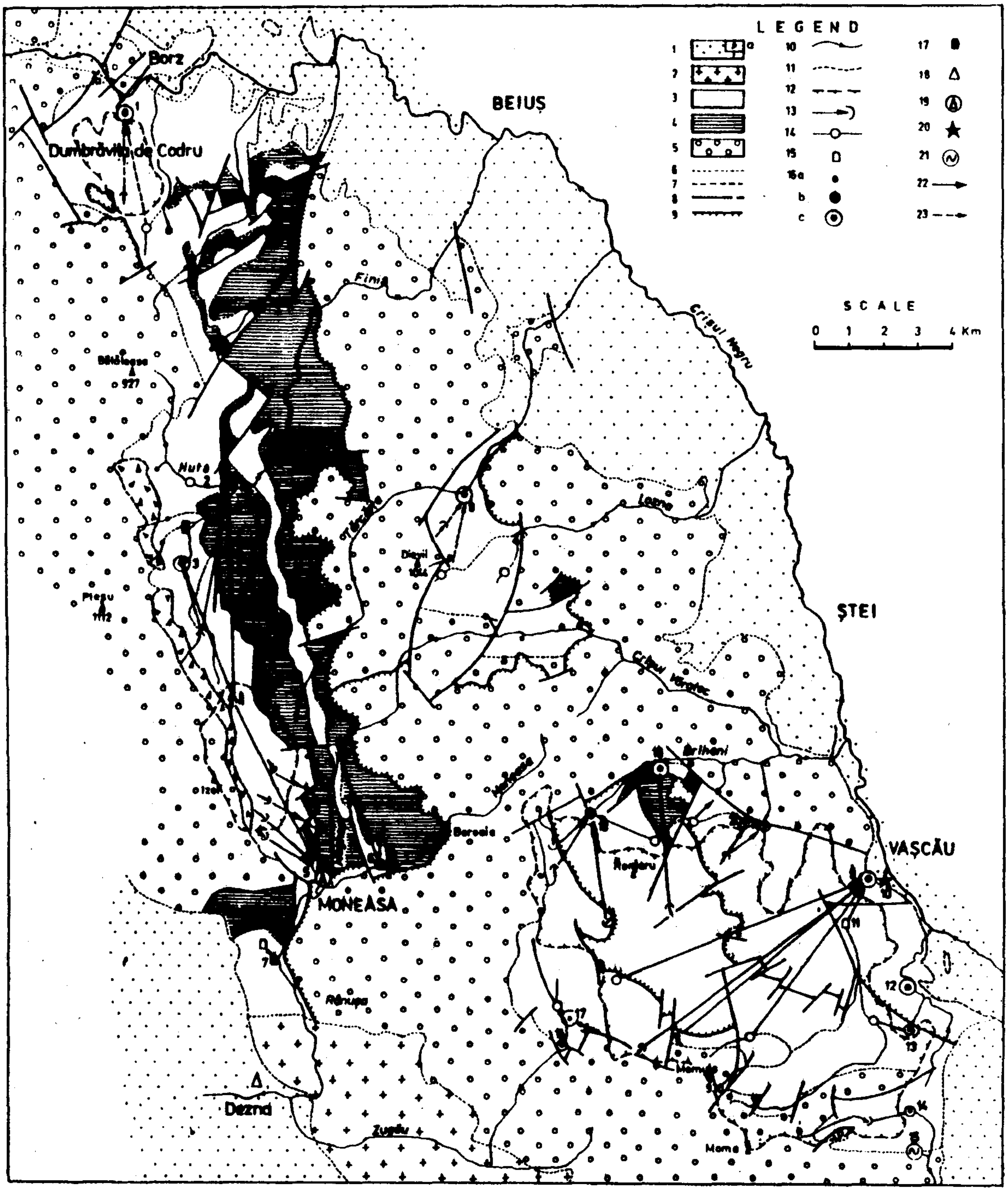

Fig. 1. Hydrogeological map of Codru Moma Mountains.

Legend. 1-Pannonian-Quaternary deposits (argillaceous shales, marls, sands, gravels; a-colluvium); 2-Neogene magmatites (agglomerates, andesites); 3-Carbonate mesozoic series (limestones, dolomites); 4-Mesozoic flysch-like series; 5 Prevalent detritic Permo-Mesozoic deposits (sandstones, conglomerates and less frequently argillaceous schales and rhyolites) ; 6-Geological boundary; 7-Boundary of colluvium; 8-Fault; 9-Overthrust front; 10-Course of perennial stream; 11-Course of temporary stream; 12-Boundary of endoreic areas; 13-Swallet; 14-Losses in flow along the riverbed; 1-Inflow cave; 16-Mean annual discharge of springs (l/s): a-less than 10; b - 11-50; c - 51-500; 17-Outflow cave; 18-Well with thermal water (t > 20°C); 19-Group of springs and wells with subthermal (10< t ≤ 20°C) and thermal waters; 20-Selected gas leaks associated with subthermal springs; 21-Ebb and flow spring; 22-Proved groundwater flow direction; 23-Presumed groundwater flow direction.

Key of the numbers on the map: 2-Feredeu spring; 4-Dosul Varului swallet; 5-Grota Ursului spring; 8-Izvorul Mare al Tărcăiţei spring; 10-Ţucreşti spring:; 16- Răşchirata spring; 17-Valea Seacă spring.

- the toxic elements content, analysed by means of the ICP equipment în "Prospecţiuni" S.A. laboratories, indicate Cr, Cu, Mn, Ni, Pb, and Zn contents below the maximum allowed concentrations;

- for some sources, the pesticides content exceeds up to 2 times the accepted concentration (0.0005 ppm);

- the waters are not radioactive;

- the gas outflows from Feredeu and Ţucreşti springs have a composition similar to that of the atmospheric gas;

- the main aquifers in Pădurea Craiului Mountains occur within carbonate rocks having undergone intense karst processes and which are deprived of covering deposits with either good filtering properties, or impervious. They are extremely vulnerable to pollution factors and do not include good quality waters (Orăşeanu, 1994).

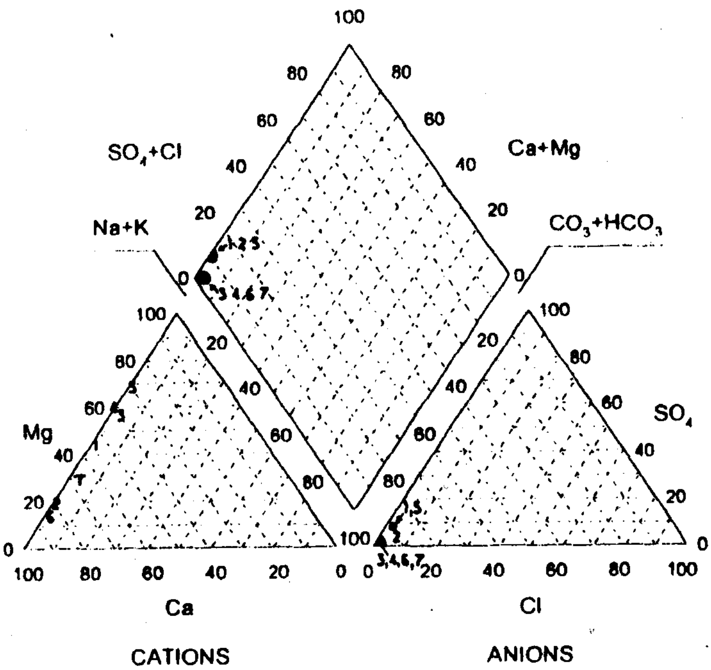

Fig. 2. Piper diagram with displays of chemical composition of studied springs from Codru Moma and Pădurea Craiului Mountains. (key of the numbers in table no. 1)

2. 1. Feredeu spring (figures 1, 2 and table 1)

Feredeu spring is located in the upper catchment area of Finiş stream, on the right side of Bălăteasa tributary, in the area that the locals call Huta (fig. 1, no. 2). Access to the spring became difficult after the Finiş-Huta-Brătcoaia narrow-gauge railway was dismantled.

The spring water upflows from between the alluvia which hide the contact between the Carnian-Norian upper dolomites and the Rhaetian marls. The spring recharge area is located further to the south, in the Brătcoaia closed basin: the water sinking through Dosu Varului swallet (fig. 1, no. 4) is forced northward in a deep, flooded circulation beneath the marls stack, as tracer tests performed by I. Orăşeanu and E. Gaşpar in 1977 and 1987 (Orăşeanu, 1987; Gaşpar & Orăşeanu, 1987) have proven. As a result of this deep circulation the spring water is permanently very clear, has a slightly elevated temperature (11.2-13°C), and displays strong gas outflows.

The average Feredeu spring discharge is 55 l/s, with very small fluctuations, ranging between 45 - 70 l/s. Since the spring is not tapped and is invaded by perennial aquatic vegetation, the bacteriological content displays large fluctuations as a function of season.

2. 2. Well S5 Moneasa (figures 1, 2, 3, 4 and table 1)

Moneasa resort is located in the central part of Codru Moma Mountains, in an area that underwent strong tectonic displacements, which resulted in an overthrusts structure (fig. 3). The reputation of the resort is due to the thermal water occurrences (both natural springs and drilled wells), with temperatures ranging between 24-32.8°C (Orăşeanu, 1987).

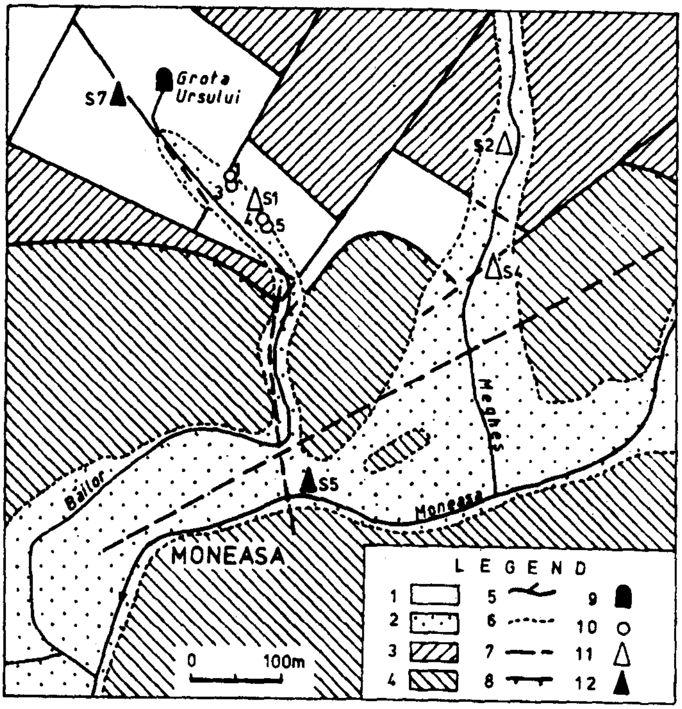

Fig 3. Hydrogeological map of Moneasa spa. (Geological data after Bleahu, 1965 & Bleahu et al., 1979, 1984)

Legend. 1-Triassic limestones and dolomites (ld-Ladinian black limestones with cherts; cr-Carnian white dolomites; J_1-Lover Jurassic red limestones); 2-Quaternary alluvium; 3-Norian argillaceous shales with sandstones and limestones; 4-Permian diabases, sandstones and shales; 5-Course of perennial stream; 6-Geological boundary of quaternary deposits; 7-Fault; 8-Overthrust front; 7-Outflow cave; 8-Thermal spring; 9-Well with thermal water ($t > 20^0C$); 10-Well with subthermal water ($10<t\leq 20^0C$).

The karst reservoir has a monoclinal, eastward dipping structure, with Werfenian quartzite sandstones at the bottom and flysch type Norian deposits at the top. In the south it is overthrusted by the Permian deposits of the Moma nappe (schists, sandstones, basalts).

The thermal water accumulation is the result of mixing between warm water upflows along fractures and cold water recharge from the north. The strong tectonic disturbances underwent by that area and the heterogeneity of its karst are mirrored by the lack of uniformity of the temperature of the water discharged by the wells and by the contrasting TDS contents, with specific time evolutions. The unimodal and narrow distributions are characteristic for thermal sources, the plurimodal and widely ones, for cold waters (Grota Ursului spring) and, in a little manner, of well S5 (fig. 4).

Well S5 (well no.4666) traversed a succession including Permian schists, sandstones and basaltes belonging to the Moma Nappe (0-275m) and then penetrated Triassic karstified limestones (275-340m) belonging to the Finiş Nappe. The water intercepted in Triassic limestones boast an artesian discharge of 4,6 l/s of water with a average temperature of 16^{0}C.

2. 3. Izvorul Mare al Tărcăiţei (figures 1, 2, 5 and table 1)

Izvorul Mare al Tărcăiţei is located some 13 km south of Beiuş town, on the right side of Tarcăiţa stream, 2 km upstream the homonym village (fig. 1, no. 8). It occurs as an upflow from alluvial deposits, in close neighbourhood of the northern slopes of Căptescu summit, where mainly Anisian dolomites outcrop.

The flood pulses in the spring of 1994 entrenched the streambed of Tărcăiţa next to the spring by almost 1 m. As a result, the spring discharges entirely into the stream, its former outlet being currently dry.

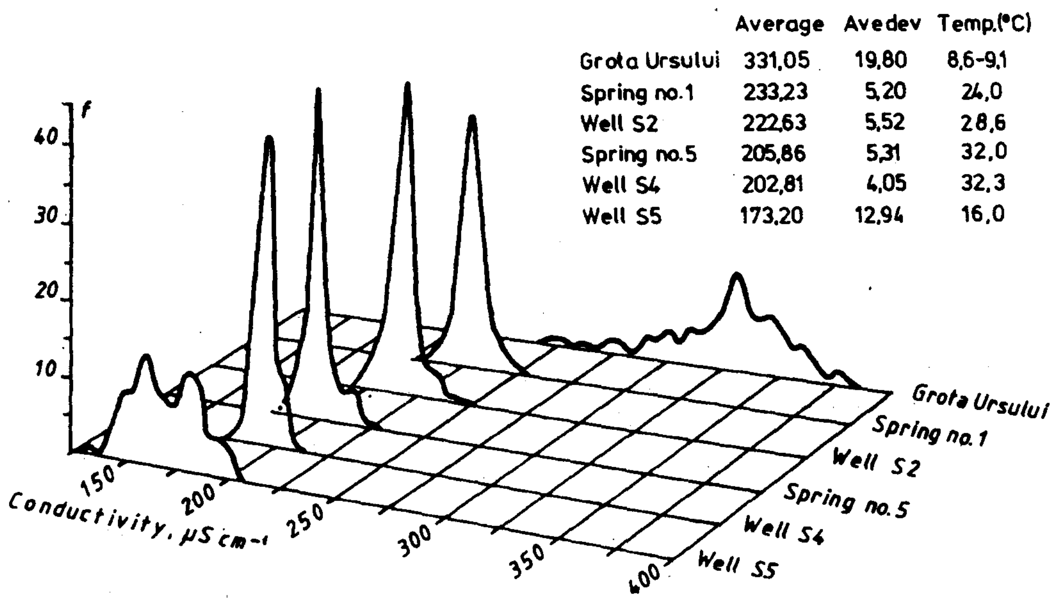

Fig. 4. Distributions of hydrochemical characters of waters in Moneasa spa.

The spring water, supplied by the karst area existing to the south, undergoes seasonal bacteriological contamination as a result of the cattle breeding performed in that area (fig. 3).

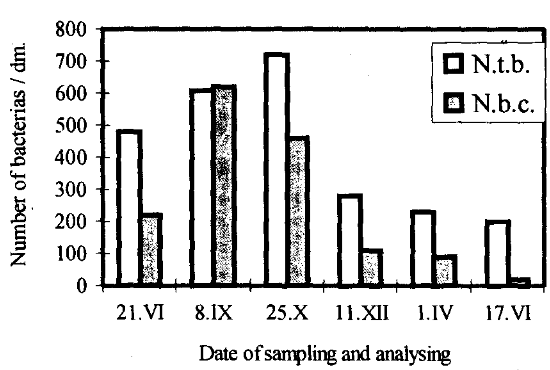

Fig. 5. Displays of the total number of bacteria (N.t.b.) and of the number of coliform bacteria (N.b.c.) in Izvorul Mare al Tărcăiţei spring in 1991-1992 time interval.

2.4. Răşchirata spring (figures 1, 2, 6, 7 and table 1)

Carbonate deposits in Vaşcău plateau host major water accumulations, that discharge at the plateau border through a few springs displaying high flow rates even in drought periods (Orăşeanu, 1985). Two of those sources, Răşchirata spring and Valea Seacă spring, are located at the south-western extremity of the plateau, in the upper catchment area of Zugău stream, which in the Dezna village joins Moneasa stream. A third source monitored in the framework of the program aimed at identifying new still water sources was the spring Ţucreşti, in the neighborhood of Vaşcau town.

Răşchirata spring is located 11 km upstream Dezna village, on the left side of Căpţălanul stream, a tributary of Zugău stream, in close neighbourhood of an old iron ore melting furnace and of a forestry hut (fig. 1, no. 16). The spring upflows from the scree slope, at the bottom of a wall where a few meters thick beds of Anisian dolomites outcrop.

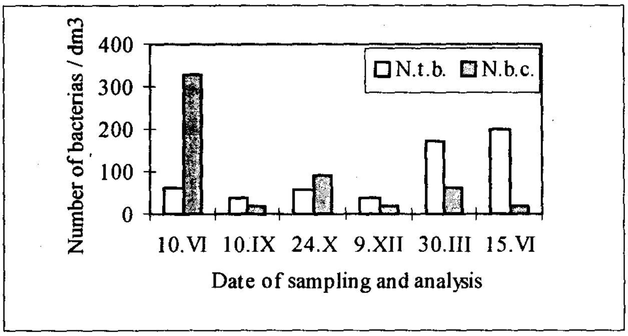

Fig. 6. Displays of the total number of bacteria (N.t.b.) and of the number of coliform bacteria (N.b.c.) in Răşchirata spring in 1991-1992 time interval

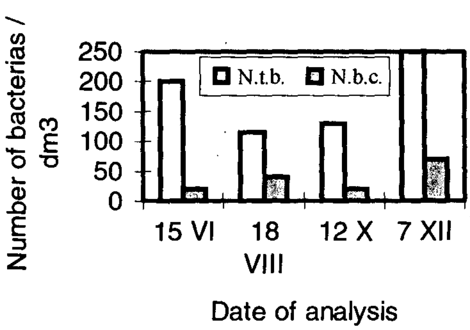

Fig. 7. Displays of the total number of bacteria (N.t.b.) and of the number of coliform bacteria (N.b.c.) in water sempled from Răşchirata spring at 15.VI.1992, stored and analysed

2. 5. Valea Seacă spring (figures 1, 2, 8 and table 1)

Valea Seacă spring is located 1 km upstream Răşchirata spring, on the left side of Valea Seacă, at its confluence with Căpţălanul stream (fig 1, no. 17). The water emerges through a couple of closely situated cracks, enlarged by the water. In 1987 the spring has been tapped by the mining exploration company IPEG Deva, the working site Dezna, for the supply of the iron ore washing pilot plant located upstream, at the site called La Grajduri. The water intake is currently dismantled.

In order to delineate the supply area of those two sources, fluorescein tracer was injected on 25 July 1994 in the Scăriţa swallet (4 l/s flow rate), the tracer being recovered in the Valea Seacă spring (located 1.05 km away and 45 m below) after about 11 hours. The same day, In EDTA tracer was injected in the diffuse total sinking section of Căpţălanul stream, located upstream its junction with Valea Seacă stream. 5 hours after its injection the tracer was identified in the Valea Seacă spring as well, 0.6 km away and 25 m below the sinking area. The tracing experiments have been conducted in co-operation with geologist engineer E. Căpraru, and the analysis of the In EDTA tracer concentrations has been performed in the IFIN laboratories in Bucharest.

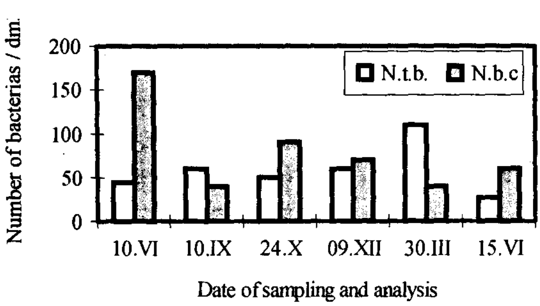

Fig. 8. Displays of the total number of bacteria (N.t.b.) and of the number of coliform bacteria (N.b.c.) in Valea Seacă spring during 1991-1992.

2. 6. Ţucreşti spring (figures 1, 2, 9 and table 1)

In the western part of Vaşcău town, four hypothermal springs (Sfărăşele, Rengle, Racova and Ţucreşti) emerge from the Late Triassic limestone of the plateau and from the Crişul Negru and Boiu streams alluvia. Their temperatures range between 14.5 and 17.2°C, their cumulated discharge amounts to about 15 l/s, and they display violent gas outflows. Gas outflows display a series of cold springs as well. The springs emerge along the NW-SE striking fractures system, that controlled the progressive Beiuş basin subsidence toward north-east.

The chemical composition of the sub-thermal water at Vaşcau is $CaMgHCO_3$ facies. In some instances the water displays iodide or even bromide character, as a result of reactions with the deposits filling the Beiuş basin. The same chemical character is also met in the case of other sub-thermal outlets in the basin (Ceica, Răbăgani, etc.).

Ţucreşti spring is located in the western part of Vascau town, at the bottom of Dealul Viilor (fig. 1, no. 10). The spring upflows from the Crişul Negru flood plain alluvia and is permanently invaded by grassy aquatic vegetation.

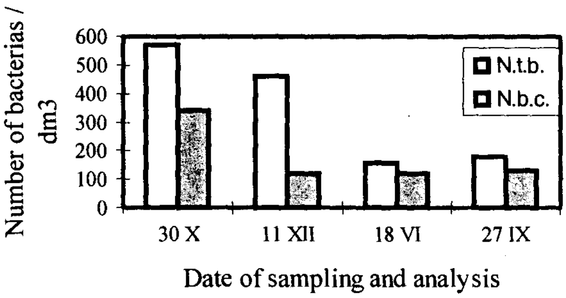

Fig. 9. Displays of the total number of bacteria (N.t.b.) and of the number of coliform bacteria (N.b.c.) in Ţucreşti spring during 1991-1992.

2. 7. Pancului spring (figures 2, 10, 11, 12 and table 1)

In the eastern part of Pădurea Craiului Mountains is situated the Remeţi graben, with Mesozoic limestones and sandstones borded by crystaline schists and igneous rocks (fig. 10).

Pancului spring is situated within Remeţi village, on the right side of the Iad stream, at 450 m a.s.l. (fig. 10, b). The source emerges at the bottom of a steep and grass covered slope debris, that continues with a limestone scarp. To the south and east of Pancului spring carbonate deposits form a synclinal structure, with the Anisian limestone being overlain by Hettangian - Early Sinnemurian quartzite sandstones and shales, and further on, in the structure axis, by Late Sinnemurian - Carixian limestone (Elena Popa, 1981).

Detritic and clayey Early Jurassic deposits are virtually impervious and force the water which infiltrates along the southern border of the graben, in the Selhişului stream catchment area, into a deep circulation, to re-emerge via Pancului spring. The spring enjoy gas outflows with a composition similar to that of the atmospheric gas (Orăşeanu, 1991).

T. Rusu (1988) in his comprehensive study concerning the karst in Pădurea Craiului Mountains suggests that Pancului spring might probably drain the water of Selhişului stream. The spring water is clear and only seldom, during heavy rainfall and snow melt periods it has a slightly opalescent colour. Figure 11 displays the total number of bacteria and total coliform bacteria contents of some springs, ilustrating a wide range of contents. In the same periods the bacteriological content increase in a moderate way (fig. 12).

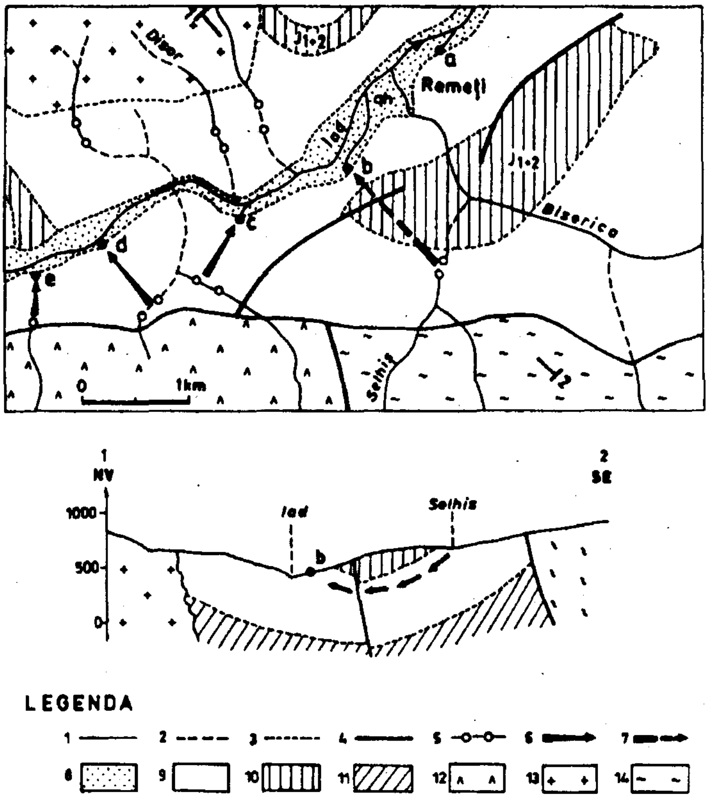

Fig. 10. Hydrogeological map of Remeţi area. Geological data after Elena Popa (1981).

Legend: 1-Course of perennial stream; 2-Course of temporary stream; 3-Geological boundary; 4-Fault; 5-Subterranean capture; 6- Proved groundwater flow direction; 7-Presumed groundwater flow direction; 8- Alluvium; 9-Mesozoic limestones; 10-Lower jurasic quartzitic sandstones and limestones; 11-Permo-Werfenian sandstones and conglomerates; 12-Rhiolites; 13- Dacites; 14-Crystaline schists.

Key of the numbers on the map: a-Tăul fără Fund spring; b-Pancului spring; c-Spring of Lunca Pizlii; d-Davelii spring; e-Strivinosu spring.

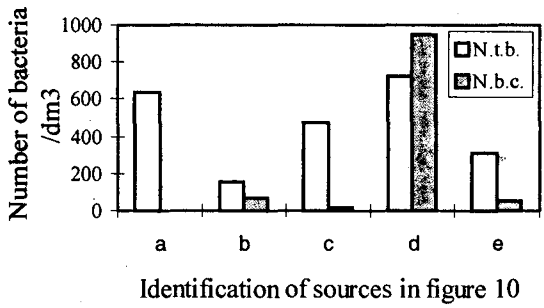

Fig. 11. Displays of the total number of bacteria (N.t.b.) and of the number of coliform bacteria (N.b.c.) in some springs water Remeţi graben.

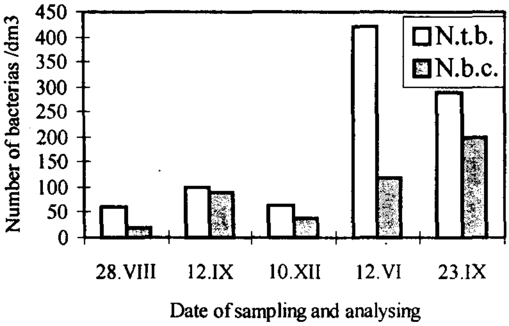

Fig. 12. Displays of the total number of bacteria (N.t.b.) and of the number of coliform bacteria (N.b.c.) in Pancului spring in 1991-1992 time interval

CONCLUSIONS

The regional hydrogeological studies performed in Codru Moma and Pădurea Craiului mountains have outlined the occurrence of many karst outlets, among which 6 springs and well S5 from Moneasa have been selected for complex investigations, aimed at the identification of new still water sources.

The investigated outlets are not tapped, and as a consequence some of them temporarily display high bacteriological loads. We assume the phenomenon to be the result of local contamination.

The water discharged by wel S5 Moneasa, Răşchirata and Feredeu springs display a remarkable constancy of the physico-chemical characteristics, circumstance that recommends them as still water sources. Similar properties displays the spring in Valea Seacă as well, its water being however slightly opalescent over short time intervals, during the very high discharge periods. In order to be ascribed to the same category, Pancului spring in Remeţi requires the hydrologic relationship with the swallets of Selhisului stream to be elucidated.

The water discharged by Izvorul Mare al Tărcăiţei is of good quality, unfortunately its sub-aerial outlet has disappeared ensuing to the interception by Tărcăiţa stream, whose streambed underwent a significant entrenchment during the high discharge period of 1994. In order to be included in the category of the still water sources, the spring must be tapped and the specific analyses must be repeated.

The water of Tucreşti spring is supersaturated with respect to calcite, being hence prone to carbonate scaling.

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