Theoretical and Applied Karstology. Vol. 3 (1987). pp. 215, to. 222

HYDROLOGICAL KARST SISTEMS IN PĂDUREA CRAIULUI MOUNTAINS

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A synthesis of a large amount of pieces of information and data of a geologic, hydrogeologic and hydrometeorological nature, as well as data concerning tracer labellings provides for the identification of the expanse of the major hydrogeological karst systems in Pădurea Craiului Mountains, as well as some of their hydrogeological parameters. Furthermore, current knowledge of underground networks belonging to this system is given.

The Pădurea Craiului Mountains, situated on the western side of the Apuseni Mountains, represent one of Romania's karst areas that has been most frequently investigated from a speleological, morphological and hydrogeologic point of view. With more than 600 caves and potholes, as well as with the Vîntului Cave, which is the largest in this country (more than 33 kms. long), they also place on a leading standing as far as explored cavities in this country are concerned.

The morpholoyical features of the exo- and endo- karst in this area were accurately defined in the works of Rusu (1968, 1978), Vălenaş and Drîmba (1978), Vălenaş (1980—1981), Vălenaş and Jurkiewicz (1980—1981), Jurkiewicz and Mitrofan (1984), a.o. The tracer labellings performed by Rusu (1981), Orăşeanu and Jurkiewicz (1982), Gaspar et al. (1983), Orăşeanu et al. (1984), Orăşeanu (1985), a.o. contributed to defining the major directions of underground water flow, while the observations made and measurements performed on the discharges of karst springs and of surface flows in the Pădurea Craiului area as well as on precipitations and air temperature, along with the works jointly conducted by researchers with the Intreprinderea de Prospecţiuni Geologice şi Geofizice, Institutul de Meteorologie şi Hidrologie and Institutul de Speologie "Emil Racoviţă" over 1982—1983 roundied off the hydrogeologic image of these mountains.

The aim of the present work is to survey the hydrogeology of the Pădurea Craiului karst by outlining the major hydrogeological karst systems, all while reviewing knowledge about them, as well as the speleological explorations effected in this area.

We should like to point out that a hydrogeological karst system (H.K.S.) includes both karst terrains, where underground waters boast a karst-type flow, and non-karst terrains where owing to the basin karst diffluence phenomenon, surface flow contributes, either totally or partially, to supplying the same source or group of interconnected sources for a given interval.

It is extremely difficult to set the limits of H.K.S. as their is a dynamic character caused by a permanent development of karst catchment phenomena. Further more, the position of these limits may fluctuate sensibly because of seasonal variations of underground water levels.

In consideration of all these dificulties, we should like to point out that the limits of the H.K.S. given on the enclosed maps (Fig. 1 and 2) are only informative, providing for an understanding of the distribution of underground flow between the major sources. These limits were set according to the results of tracer labellings and of the interpretation of the hydrogeologic balance of surface and depth waters for the aforesaid period of observations.

1. *THE H.K.S. OF THE PEȘTERA CU APĂ DE LA BULZ CAVE*

This system, which expands in the eastern part of the Pădurea Craiului Mountains, is mainly supplied by the runoff from the impermeable terrains of the northern slope of the Preluca peak which infiltrates in the underground through the ponors of the brooks of Ponorului (figure 1.1), Popii (1.2) and Stiopului (1.4) in the karst catchment depressing of Ponoare, and through the Sîncuta ponor (1.5) in the Chicera Arsurii depression. The system is also supplied by the infiltrations in the upper basin of the Boiu brook and the diffluence surface in this area suggests a future total catchment of the Boiu brook by the Peștera cu Apă de la Bulz cave.

The system mostly consists of Anisian dolomites and limestones and its impermeable floor is made up of Werfenian quartzitic sandstones. It discharges waters that are markedly troubled during rainfalls with an annual discharge of 131 l/sec and a high variability index.

The network is accesible only through its terminal areas through the Peștera cu Apă de la Bulz cave (1,600 m in length) and the caves of Cociului (391 m length and Sîncuta (4,200 m length).

2. *THE H.K.S. OF THE BRĂTCANILOR SPRING*

The Brătcanilor spring has one of the largest H.K.S. in the Pădurea Craiului Mountains and includes rocks belonging to Upper Triassic, the whole succesion of the Jurrasic and Lower Cretaceous. The system develops North-West to South-East, a direction highlighted by the tracer labellings performed in the Ponoraș and Secătura Brătcanilor area (Rusu, 1981), and the Luncilor Valley (Mișid) by the authors (Orășeanu, Jurkiewicz 1981). The last labelled area rounded off the image of this system, its expanse to the upper basin of the Mișidului valley accounting for the high value of the mean annual discharge (of 302 l/sec). The orienta-

Fig. 1. Distribution of main hydrogeological karst systems in Pădurea Craiului Mountains. 1 — Approximate hydrogeological karst systems limits; 2 — Surficial watershed between Crișul Repede and Crișul Negru rivers; 3 — Diffluence surface; 4 — Permanent surface course; 5 — Temporary surface course; 6 — Direction of underground water flow; 7 — Losses in flow along the riverbed; 8 — Spring; 9 — Ponor; 10 — Out flow cave; 11 — Inflow cave; 12 — Pothole.

tion of the system is imposed by the general tectonics of the area, with faults and geologic structures set in a North-East, South-West direction.

The system features low values of the discharge coefficient (the recesion curve discharge coefficient), (0,00244) and substantial amounts of underground waters stored early in the recession periods (4.78 $\times$ 10^6 cu.m). During periods of heavy precipitations, the water of the spring is markedly troubled.

Although the system's development is quite remarkable, the number of points of penetration into the possible major colector (also suggested by the high water transit velocity recorded when the Luncilor valley was labelled) is relatively low : the Ponoraș cave(figure 1.6 ; 3,800 m long and with a level difference of 211 m) the cave at Stanul Ciuții (figure 1.7 ; 611 m long and with a level difference of 41 m), the Barna pothole (figure 1,8 ; 697 m long and with a level difference of 98 m). The decolmatations effected above the Brătcanilor spring by the speleological club C.S.A. Cluj-Napoca, pointed to the presence of an underground void space roughly 50—60 m in length ; however subsequent collapses prevented further explorations.

The drain of the Macrei ponor-Moanei cave, which spans on 1,170 m and has a level difference of 104 m, is situated on the system's development area.

3. *THE H.K.S. OF THE VÎNTULUI CAVE*

The H.K.S. of the Vîntului cave, which at present, is the largest underground network in Romania, with roughly 33 kms already mapped, is characterized by a reduced developmetn area as compared with those of the other systems, as well as by an average discharge of only 30 l/sec. The research work conducted there showed that the recharge area of the underground flow in Vîntului cave was linked to the diffuse losses in the Recea brook basin (fig. 1.9), (Orășeanu, Gaspar, 1980—1981).

4. *THE H.K.S. OF THE IZBÎNDIȘ SPRING*

Situated immediately West of the Vîntului cave and probably genetically linked to it, is the H.K.S. of the Izbîndiș spring.

Consisting mostly of Anisian dolomites on which the ponors in the Cărmăzan depression (fig. 1·10) and the Groapa Blidirești hole (fig. 1.11) are located the system seems to be limited to the West by a tectonic alignment which puts Upper Jurassic (Callovian—Tithonic) limestones in contact with Anisian dolomites. However, the labellings effected in the Tomii ponor (fig. 1.12) show the influence radius of the system also extends West of that alignment.

The high discharge values (Qmed = 340 l/sec. Qmin = 49 l/sec) and the low values of the discharge coefficient (0.002—0.0037) suggest a flow through small-size fissures, supported by substantial water volumes registered early in recession periods (1.38—4.36$\times 10^6$ cu.m.)

From an explorative point of view, this system is also linked to the presence of one of the longest siphons explored in this country, an exploration of bad remembrance. The Izbîndiș cave, with a pan of roughly 400 m, extends above the spring and is linked to the underground flow through two wells.

5. *THE H.K.S. OF THE VADU-CRIȘULUI CAVE*

Withs the H.K.S. of the Vadu-Crișului cave we penetrate into the large karst plateaus in the norther part of the Pădurea Craiului Mountains.

The discharge of the system is strongly influenced by precipitations, while discharge coefficients are relatively high (0.008—0.0125), which bespeaks water flow and storage within a simple underground network. The volume of the water stored early in the recession periods is relatively low ($0.27—0.43 \times 10^6$ cu.m.), which also points to the existence of a less branched underground network.

Contrary to expectations the karst plateau at Imașul Bătrînului (fig. 1.13), which is entirely made up of Callovian—Tithonian limestones, provides for a penetration into the underground only through two caves (the Bătrînului cave — the Peștireu valley ponor with a span of 1,633 m and a level difference of 87 m) and the resurgent cave of Vadu-Crișului (900 m long.). The limit narrow access galleries in the terminal area of the Bătrînului cave (fig. 1.14) as well as the siphons in the cave at Vadu Crișului once again show that the lack of vigorous surface streams in the plateau areas, in the case of this massif, hinders the formation of larger-size galleries.

6. *THE H.K.S. OF THE SPRING AT MOARA JURJII*

The H.K.S. of the spring at Moara Jurjii is made up of Jurassic and Lower Cretaceous limestones of the Secătura plateau (fig. 1.15), which also represents its major suplly area. The discharge losses on the upper course of the Mniera valley, identified with the help of hydrometric measurements and labellings (Orășeanu, 1985) attested to their belonging to this system. We once again find a karst diffluence area which develops towards a total catchment of the upper course of the Mniera valley by the spring at Moara Jurjii.

The minimal discharge registered in low-water periods in the past three years maintained round 110 l/sec. The known underground network is confined to the 200 m of galleries explored in the Moara Jurjii cave.

7. *THE H.K.S. OF THE AȘTILEU SPRING*

The largest H.K.S. system identified in the Pădurea Craiului Mountains (with an expanse of 106 sq.kms) is that linked to the Aștileu spring. Initially known to be of a limited expanse, confined to the Mniera valley basin (the loss in the cave of Potriva — fig. 1.16) and, partially, to the karst plateaus of Hîrtoape (fig. 1.17) and Zgleamănu (fig. 1.18), the research conducted of late (labellings of the ponors of the Peștiș — fig. 1.19, and Poieni valleys — fig. 1.20) doubled the known area of development by pinpointing the diffluence surface in the Topa Rîu basin (Orășeanu, 1985).

From a geologic point of view, the H.K.S. develops along a mosaic of formations ranging from the Middle Jurasic to the Quaternary gravel of Oarzăna.

The discharge coefficients computed for various periods, which were either not influenced by precipitations, range from 0.0026 to 0.0043, according to the charge of the system at the beginning of the recession period. Both these low values and the high values of the discharges (Q_{med} = 365 l/s, Q_{min} = 74 l/s) point to the vast expanse of the H.K.S. and the impressive volume of water reserves (2—7 $\times$ 10^6 cu.m) at the begining of the recession periods accumulated in fine fissures mostly.

Besides the general drainage direction towards the Aştileu spring, a number of secondary drains : the losses of the Cordău valley (fig. 1.21) — the cave at Izvorul Gabor (fig. 1.22) — 2,707 m long and the losses in the Groapa Peşteranilor (fig. 1.23) Aurica cave —2,680 m long, are located on the diffluence area, which, from a hydrogeologic point of view, belong to the same H.K.S., with the gallery networks being, however, independent.

The main gallery system was explored both through the Mniera valley ponor known as Potriva's Cave (1,200 m long) and through the resurgence (the cave at Aştileu —2,000 m long).

Noteworthy is the fact that the long transit time in case of the labellings performed in the Topa valley indicates an underpresure flow in the most part of the system, with the exception of the terminal area, where a vadous flow was partially identified.

8. *THE H.K.S. OF THE TOPLIŢA DE VIDA SPRING*

The geologic research work, as well as mining operations performd in the Jofi—Albioara area called for detailed hydrogeologic studies. So, for instance the H.K.S. of the Topliţa de Vida spring was identified which consists mainly of Cretaceous limestones (ne-br), (massive and stratified limestones and bauxite) in the Sclavul Pleş plateau area (fig. 1.24) and Upper Jurassic limestones in the central part of the system. Towards the peripheral areas a whole package of Jurassic rocks outcrop to quartzitic sandstones (hettangian-sinemurian) on which small streams (the Bichii, the Hodişan) are formed, which, when entering the limestones, disappear through the ponors. The labellings performed (simultaneous multiple tracing with various tracers, as well as other labellings) proved that the Bichii (fig. 1.25), Merişor (fig. 1.26), Marchiş (fig. 1.27) and Fîntîna Rece ponor (fig. 1.28), as well as the ponor of the Baia Nişului brook (fig. 1.29) belong to the system (Orăşeanu et al. 1984) The general direction of the system is also shown by the system of fractures in the central area of the karst plateaus.

The average discharge for the 1982—1983 period stood at 158.2 l/sec. while the minimal discharge registered was of 26 l/sec. The low values of the discharge registered was of 26 l/sec. The low values of the discharge coefficient (0,00167 and 0.00186) point to a preferential flow through small-size fissures. The volume of stored water at the begining of recession periods for which discharge coefficients were computed were of 1.20 $\times$ 10^6 and respectively, 1.21 $\times$ 10^6 cu.m.

In point of exploration, knowledge of the underground network of this H.K.S. is rendered difficult by the relatively small size of the galleries. The most important underground void space is the cave in the 117 Jofi drift (fig. 2) which is 6 kms long and has a level difference of —130 m, while the resurgent cave at Toplița de Vida is known along 200 m, its exploration implying the surmounting of six siphons.

9. *THE H.K.S. OF THE TOPLIȚA DE ROȘIA SPRING*

The research work conducted by the EMIL RACOVIȚĂ Speologic Institute in Cluj Napoca, when prehistorical traces of footsteps were discovered in the Ciur—Izbuc cave, outlined most of the geomorphological features of the system. Previous research work led to the setting of the underground flow through the Ciur—Ponor cave (roughly 17 kms long, with a level difference of 180 m), whose galleries cross several times the entire succesion of karstifiable rocks belonging to the Jurassic and Lower Cretaceous and, sometimes, reaching quartzitic sandstones (in a number of gallery terminal areas).

The main active flow, which, as a matter of fact, is one of the most spectacular in this country, achieves an almost total penetration in between the Tinoasa ponor — Ciur Izbuc cave and the Ciur Ponor—Toplița de Roșia spring interrupted between the losses in the Ciur Izbuc and the tributaries in the gallery area called the Albioara upstream. We may also note the presence of a diffluence area on the Cuților valley, which will be probably completely caught by the Toplița de Roșia spring.

The discharge coefficients computed for the low-water periods in 1982 and 1983 amount to 0.00218 and 0.00298 for an average and minimal discharge of 72.9 and respectivelly, 11 l/sec.

The morphology of the endo-and exo-karst in this area features more than others do a perfect parallellism between the directions of the main galleries of the Ciur Ponor and Jofi caves and the directions of the Cuților, Albioara and Vida valleys which are the limits of the karst plateaus where these caves are located. This parallellism is due to both the uniform character of the fissure systems of the calcareous massif along this entire area and to a synchronous evolution, therefore, karst-forming processes at the surface and inside the massif in the same paleogeographic conditions. These conditions are mainly shown by the subsidence of the Beiușului basin, which hydrogeologically, translates into a rotation of the sense of the regional hydraulic gradient from West to South, a movement which implied a change in the same sense of the direction of flow of surface and underground courses.

The microtectonic profiles performed in the Albioara and Cuților valleys and the two inlets of the Ciur Ponor—Toplița de Roșia system highlighted a constant of the directions of the main fissure systems, therefore, of the tectonic factor of karstformation. Noteworthy is also the presence of a system of tension fissures with an average orientation N49°W/90° and of two shear fissure systems with an average orientation N27°E/81° SE and N56°E/78°SE, systems which imposed the directions of the drainage networks as well as the position of the vector of the local and regional hydraulic gradient.

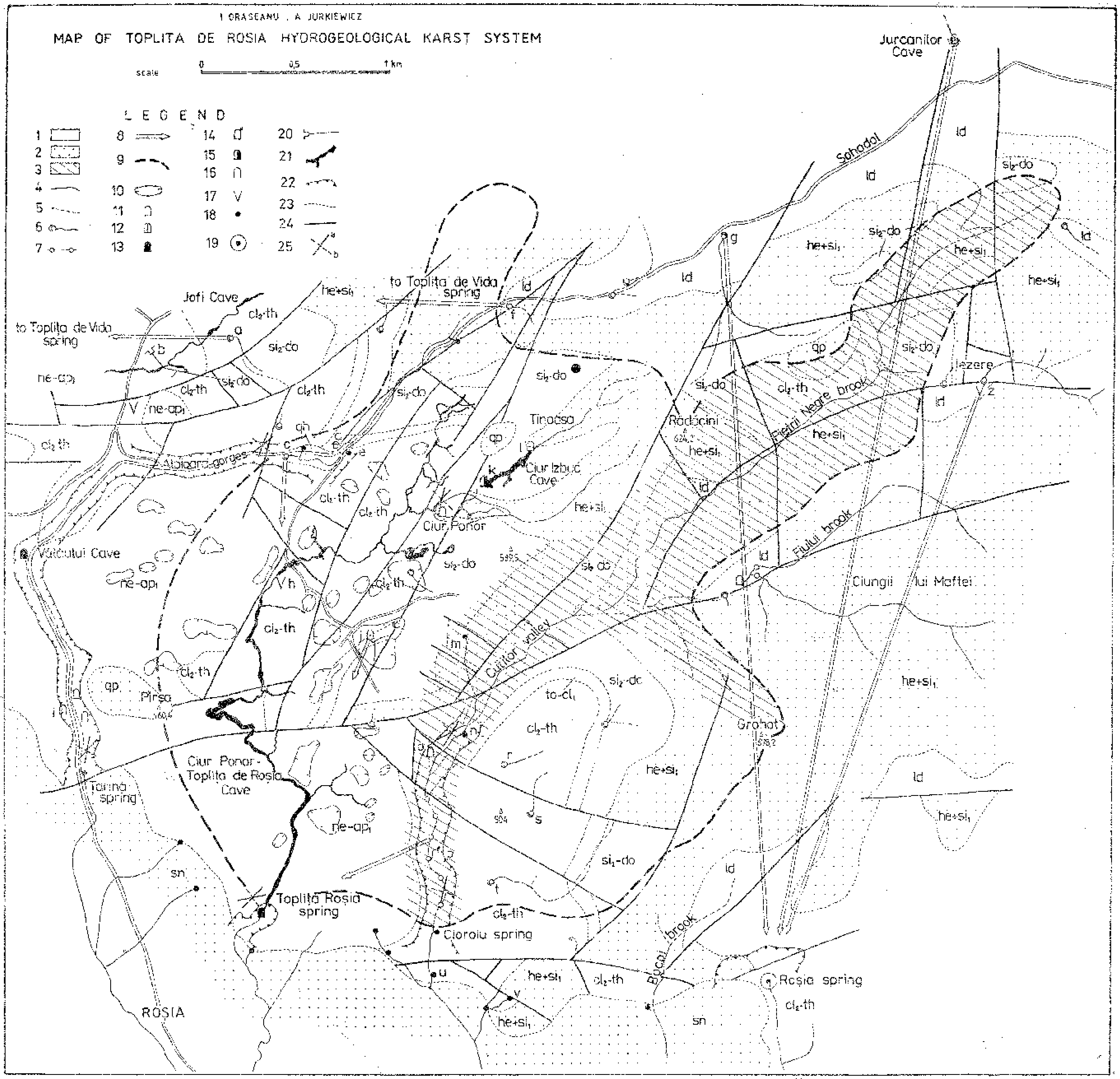

Fig. 2 Map of Toplita de Rosia Hydrogeological karst system (Geological data after D. Patrulius et al., 1966 and S. Bordea et al., 1986; Jofi cave map after I. Povară and V. Lascu; Ciur Ponor-Toplita de Rosia cave map after P. Brijan, A. Jurkiewicz, H. Mitrofan, I. Orăseanu, G. Ponta, and "Emil Racoviță", Bucuresti, "Focul Viu" Bucuresti, CSA Cluj Napoca, "Cristal" Oradea, GES Bucuresti speological clubs). a — Baia Nisului ponor; b — Jofi mine gallery; c — Albioara ponor; d — Albioara forest range; e — Blue spring; f — Poiana Frie ponor; g — Peste ponor; h — Boului pothole; i — Vacii cave; j — Deboș cave; k — Ciur Izbuc cave; l — Tinoasa ponor; m — Cioceanul spring; n — Viiii spring; o — Varii cave; p — Pestera care cintă cave; r — Groapa Viiii; s — Groapa lui Ocidă; t — Tic-ului ponor; u — Fintina Micli; v — Ciordul lui Mitireng; ld — Ladinian (reefal white limestones); he+si₁ — Lower Sinemurian + Hettangian (quartzitic sandstones); si₂-do — Domerian-Upper Sinemurian (encrinitic sandy limestones, limestones with Griphaea, limestones with cherts); to-cl₁ — Lower Callovian-Toarcian (limestones with Entolium, marls); cl₂-th — Tithonic-Upper Callovian (limestones); ne-ap₁ — Lower Aptian-Neocomian (limestones with pachyodonts); sn — Senonian (sandstones, shales); qp — Pleistocene (sands, gravels). *Legend*: 1 — Karstifiable terraines; 2 — Nonkarstifiable terraines; 3 — Diffluence surface; 4 — Permanent surface course; 5 — Temporary surface course; 6 — Ponor; 7 — Losses in flow along the riverbed; 8 — Underground connection established by tracer method; 10 — Karst depression; 11 — Permanent inflow cave; 12 — Temporary inflow cave; 13 — Permanent outflow cave; 14 — Cave tapping a underground stream; 15 — Temporary outflow cave; 16 — Fossil cave; 17 — Fossil pothole; 18 — Spring with approximate average flow under 5 l/s; 19 — Spring with approximate average flow from 20 to 160 l/s; 20 — Mine gallery; 21 — Cave passage; 22 — Key; 23 — Geological boundary; 24 — Fault; 25 — Main direction of rock fracturation a — shear cracks b — tensile cracks

10. *THE H.K.S. OF THE ROȘIA SPRING*

Situated East of the previously described system, the Roșia spring system is formed of Anisian and Ladinian limestones, covered by quartzitic sandstones (hettangian-sinemurian), which account 60—70 per cent of the system's development area.

The discharge coefficients computed for two prolonged low-water periods in 1982 and 1983 have extremely low values of 0.0017 and 0.001983 The large volume of underground water reserves at the start of recession periods seems to be mainly located on small size fissures.

The expanse of this system, which is probably very large owing to the substantial value of the average discharge (Qmed = 500 l/sec) as well as the labellings originaly performed in the Jurcanilor cave (fig. 1.30) and the Sohodol pothole (fig. 1.31), which is 1 km long and has a level difference of —100, was also shown by subsequent labellings and explorations in the Barc ponor (fig. 1.32) and the Stanu Foncii pothole (fig. 1.33), (2,700 m long ; level difference —339).

11. *THE H.K.S. OF THE TOPLICIOAREI SPRING*

This system, wich has been explored less, consists of Anisian limestones and mainly drains the waters of the Runcșor spring (fig. 1.34) through the vertical shaft at Intorsuri and the Fîntînele Huta (fig. 1.35) area in Poiana Damiș.

The system had a minimal discharge capacity of 66 l/sec in the low-water period of the 1982—1983 hydrologic year.

12. *THE H.K.S. OF THE DAMIȘENILOR SPRING*

The Damișenilor spring situated on the course of the Brătcuța valley on the left slope and downstream of the confluence with the Groapa Tivadarului valley, has a minimal discharge of 25 l/sec. The H.K.S. of this source extends to the West in the Glimee — Toaia-Peșteruța area within the locality of Damiș being mainly located on Anisian limestones and dolomites from the Jurassic base.

Acces to the gallery network was attempted through both the vertical shafts belonging to the system (Peșteruța — fig. 1.36 ; Toaia — fig. 1.37, 200 m long and a level difference of —60 m and Munău — fig. 1.38) and the Damișenilor spring where narrow galleries with sunken sections extending on 2,200 m have been explored and mapped.

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SISTEME HIDROGRAFICE CARSTICE DIN MUNŢII PĂDUREA CRAIULUI

Rezumat

Multitudinea de date cu caracter geologic, hidrogeologic şi hidrometeorologic precum şi cele referitoare la marcările cu trasori au permis trasarea limitelor sistemelor hidrogeologic— castice, poblemă deosebit de dificilă datorită caracterului lor dinamic imprimat de evoluţia permanentă a fenomenelor de captare carstică.

Aceste sisteme aparţin în majoritate unor izvoare cu debite ridicate situate în general la periferia masivului calcaros. Modul de organizare a drenajelor, zonele de difluenţă carstică şi unii dintre parametrii hidrogeologici fac obiectul descrierii fiecăruia dintre cele 12 sisteme hidrogeologice prezentate. De asemenea este reliefat studiul actual al cunoaşterii din punct de vedere explorativ al reţelelor subterane aferente acestor sisteme.

Manuscript received 17 December 1986; accepted in revised form 21 December 1987.

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