3.8. JIUL DE VEST - CERNIȘOARA BASINS[1]

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Abstract

Retezatul Mic (Piule-Iorgovanu Mountains) represents a distinct orohydrographic unit of the Southern Carpathian Mountains, which is drained by Lapuşnicul Mare River in the north, Jiul de Vest River to the east and Cernişoara River and its tributaries to the south. The Retezatul Mic Mountains (Piule-Iorgovanu Mountains) are located between Buta and Jiul de Vest Rivers and form an alpine karstic plateau (2,000 m above sea level) of Jurassic limestones. On this plateau an extensive network of dry valleys was developed and shaped by glaciers, which deeply eroded the carbonate (limestones) and noncarbonate rocks. The massif is formed predominantly of Upper Jurassic-Lower Cretaceous (J_3-ap) limestones, poorly to medium karstified, disposed in a syncline structure oriented northwest-southwest. The syncline is deeping to the southwest under the sedimentary rocks of the Danubian Autochthonous (tu_3-sn) and crystalline rocks of the Getic Nappe. The Eastern flank of the syncline is affected by the vertical movements of the Cerna-Jiu Fault, and is overlain by granitic and crystalline rocks. The study area represents a hydrogeological basin of 80.62 km^2, of which 32.77 km^2 are limestones. All three rivers (Lăpuşnicul Mare, Jiul de Vest, Cernişoara) originate in this karstic plateau, and contribute to the recharge of the Cerna Spring (Q_{mean} = 1.985 m^3/s; Q_{max} = 10.5 m^3/s; V_{dyn} = $7.18 \cdot 10^6$ m^3/s)[2].

Keywords hydrology, karst spring, dye studies, carbonate rocks, hydrogeology

Introduction

The Retezatul Mic Mountains are located between Buta and Jiul de Vest Rivers, alpine karstic plateau of Jurassic limestones, where an intensive dry valley network was developed and shaped by glaciers, which eroded deeply into the limestones and noncarbonate rocks.

The Jiul de West and Cernişoara Rivers are located in the western part of the Southern Carpathians and form the natural boundary between the Retezat and Godeanu Mountains to the north and west and the Vâlcan Mountains to the south and collect both surface and ground waters of the karst area.

The topography is dominated by a karstic plateau located at 2,000 m elevation, oriented northeast-southwest, between the Piule, Stănuletele Mare and Piatra Iorgovanului Mountains. The Borăscu (Eocene) peneplain, present across the Carpathian Mountains, was identified at the highest elevation of this plateau (De Martonne 1906), with extensions toward Jiul de Vest (2-4 km long),

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[1] *Some of the data in this chapter was previously published as an original article in "Carbonates and Evaporites", June 2010 Springer-Verlag, as "Geology and Hydrogeology of the Jiul de Vest-Cernişoara Basins, Romania: Ioan Povară and Gheorghe Ponta"*

[2] *The values are based on November 1981 - November 1982 hydrologic cycle*

Buta and Lăpuşnicul Mare Rivers. The last two stages of the Alpine Ice Age (Riss and Würm) have shaped a topography consisting of glacial cirques and valleys at the edge of the plateau (Soarbele, Iara, and Scorota Rivers). The Cernişoara Basin is dominated by limestone ridges, crossed by deep gorges created by the Cernişoara River and its tributaries.

The climate is continental, with ranges typical for high mountain areas. Between November 1981 and November 1982 the total rainfall was 1,356 mm, slightly over the multi-annual average (1,300 mm) for this area (Bulgăr et al. 1984). The snow lasts for more than 200 days above 1,800 m elevation, and the maximum value of the water reserve in the snow layer is 300 mm. This was recorded in March 1982 and is characteristic for the 1,300-1,800 m elevation range, where over 65% of the Cerna Spring recharge area is located. The maximum snow melting takes place in April and May, while in early June the snow recharge reaches zero. The maximum daily rainfall in the summer is 62.8 mm, while evapotranspiration is about 480 mm/year.

The hydrographic network is divergent, with the orientation of the most important rivers (Jiul de Vest and Cernişoara) influenced by the main tectonic structures in the area (the Cerna-Jiu Fault and the Getic Nappe) or by lithological contacts (Buta and Lăpuşnicul Mare). The surface runoff of Jiul de Vest and its northwest-side tributaries are temporary. During the dry season, more than 8 km of the Jiul de Vest River is dry.

A brief history

The geological investigation of the region began at the end of the nineteenth century. The first geological sketch was drawn by Inkey (1892), which was later revised by Mrazec (1897). M. Murgoci (1906, 1910) is the first geologist to recognize the crystalline structures in the Ţarcu-Godeanu Mountains as a large outlier belonging to the Getic Nappe; later, Codarcea (1940, 1941) completed a significant study of the geology and tectonic structure of the region. Additional contributions to the geology of the area were made by Gherasi (1937), Pop (1963), Codarcea and Năstăseanu (1964), Codarcea and Răileanu (1968), Năstăseanu (1967, 1979), Bercia and Bercia (1975), Conovici (1999), etc.

The Godeanu Mountains were described by Niculescu (1965) in a comprehensive geomorphological study. A general presentation of the Jiul de Vest karst landforms (the limestone area of the Retezat Mountains) was presented by Niculescu (1960) and Bădescu (1991), while a study of the most important caves, horizontal and vertical, of the Jiul de Vest Basin was completed by Ponta et al. (1984a, b), Ponta (1998), and Ponta and Terteleac (2006).

In 1967, T. Orghidan, Margareta Dumitrescu and I. Vintilescu presented the theory that the recharge area of the Cerna Spring includes the upper part of the Lăpuşnicul Mare Basin, but this idea failed to be proved (Vintilescu, 1972)[3]. The first hydrogeological study was performed by Pascu (1968, unpublished). He suggested an underground connection between the sinking stream cave in the Turcineasa valley and Cerna Spring and brings forward the hypothesis of a large water transfer from Jiul de Vest River to Cerna Spring. Later studies (Povară 1976, 1980;

Bulgăr and Munteanu 1982[4], Bulgăr et al. 1984; Ponta et al. 1984a, b), pointed out that the carbonate succession from the Cerna-Jiu Syncline is part of the Cerna Spring recharge area.

At the beginning of the 20-th century, 14 caves were known in the Cerna Valley area. In 1961, the "Emil Racoviţă" Speleological Institute of the Romanian Academy initiated an extensive study in the Cerna Valley, during which 47 new caves being identified (Avram et al., 1964, 1966).

Beginning in 1978, Focul Viu Bucureşti Grotto, Cristal Timişoara Grotto, and several others local grottos, began an extensive search for caves in the Jiul de Vest-Cernişoara Valley. By 1982, 622 caves were surveyed in the area.

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[3] *In September 12, 1967, 10 kg flourescein was injected in Lăpuşnicul Mare, upstream of Lunca Berhinei. The dye was not detected at Cerna Spring.*

[4] *Bulgăr A, Munteanu I (1982) Evaluarea potenţialului hidrologic al zonelor de carst din bazinele hidrografice Jiul de Vest, Cerna Superioară şi Dâmboviţa (unpublished).*

The geology and hydrogeology of the area

Geology

The Carpathians Mountains are part of the Alpine-Himalayan Mountain Chain formed 35 million years ago during the Tertiary alpine orogeny. The three mountains regions of the Carpathians located in Romania are: the Eastern Carpathians, Southern Carpathians, and Western Carpathians (Apuseni Mountains).

The Southern Carpathians, where the Retezatul Mic Mountains are located, consist of four structural units:

- *Danubian Autochthonous Unit* – consists of mid grade metamorphosed basement with granitoides intrusions and molasses deposits, Permian to Carboniferous age, overlain by Mesozoic deposits.
- *Getic Nappe* – consists of crystalline rocks, mid- to high metamorphosed of Carboniferous age with some granitic intrusions, covered by molasses formation, Permian to Lower Cretaceous age.
- *Supra-Getic Nappe* – consists of lower grade metamorphosed crystalline rocks overlain by Mesozoic limestones.
- *Severin Nappe* – consists of Tithonic-Cretaceous formations, associated with ophiolitic complexes.

The Danubian and Getic domain consist of shallow-water deposits of Mesozoic age that overlie crystalline and sedimentary rocks of Paleozoic and Precambrian age. The deposits of the Getic Nappe have been thrust eastward over the Danubian deposits, along the Getic thrust fault. A segment of Upper Jurassic-Upper Cretaceous flysch-type rocks occurs between the Getic and Danubian Nappes, known as the Severin Nappe, represent remnants of oceanic deposits that extended eastward into the flysch deposits of the Eastern Carpathians. The placement of the Getic and Severin Nappes most likely occurred during late Cretaceous to early Tertiary.

Site geology

The geology of Jiul de Vest-Cernişoara area is comprised of Danubian Autochthonous's units and of metamorphic formations of the Getic Nappe (Fig. 1). In the north, the crystalline rocks and granites are overlain by Jurassic deposits consisting of Liassic sandstones and Middle Jurassic-Aptian limestones and dolomites. These deposits are exposed in a synclinal structure with the southern slopes cut by a fault which is the interface between limestones and crystalline rocks. Along a parallel fault the Jiul de Vest River is sinking, and recharging the Cerna Spring.

The Danubian domain. The basement of the Cerna-Jiul de Vest area consists of crystalline schists of the Drăgşanu and Lainici-Păiuş series and granite massifs. The Vârful lui Stan-Curmătura Olteţului tectonic line (Berza et al. 1984) is the boundary between the two crystalline units. In the northwest portion of the Vâlcan Mountains, the lower part of the Danubian Domain consists of the remnants of an ancient sedimentary cover, affected by a metamorphic stage (probably Hercynian). Between the Oslea Mountain and Coada Oslei, this formation is overlain by the crystalline rocks of Drăgşanu and Lainici-Păiuş series, and consists of metamorphosed sedimentary rocks, several hundreds of meters thick (Pop 1973). A sequence of 200-300 m re-crystallized (Oslea limestones), white or gray limestones are underlain by layers of slates and sandstone-like slates.

The Getic Domain is represented by the Godeanu Outlier, as it was defined by Murgoci (1906), with further details and information provided by Streckeisen (1934), Gherasi (1937), Bercia and Bercia (1975) and Conovici (1999). Between Lăpuşnicul Mare and Cerna, this domain is represented by two structural units: the Godeanu Unit in the upper part (part of the Getic Nappe) and the Borăscu Unit (digitations) in the lower part.

- The Godeanu Unit consists of the Precambrian metamorphic rocks of the Sebeş-Lotru series, in which lenses of crystalline limestones and skarns occur.
- The Borăscu Unit, identified on the south side of Lăpuşnicul Mare River, under the Godeanu Outlier, is a crystalline formation similar to the Getic Nappe, formed by a series of small nappes oriented east and southeast. These small nappes include Permian and Mesozoic rocks, calcareous sandstones and marly limestones, both with low hydraulic properties. The crystalline formations are

overlain by Permian deposits, 20-30 m thick formed by conglomerates, sandstones, and siltstones.

In the upper part of Scorota valley, between Piule, Piatra Iorgovanului Mountains and the Lăpuşnicul Mare River, underlying the limestones, a succession of sedimentary rocks, 10-20 m thick (Lower Jurassic) consisting of sandstones and red to purple microconglomerates was identified.

In the north the metamorphic rocks and granites are overlain by Jurassic deposits consisting of Liassic sandstones and Middle Jurassic-Aptian limestones and dolomites (the Cerna-Jiu sedimentary zone). The limestones are stratified into 15-20 cm thick layers, pale gray to cream color. The bedding plane dips south 40 to 60 degrees. The thickness of carbonates deposits ranges between 1,500 m and 2,000 m in Retezatul Mic Mountain to about 200 m around Cerna Spring. These deposits are exposed in a synclinal structure (Fig. 2). A fault transects the southern slope which is the contact between limestones and crystalline rocks.

The Mesozoic sedimentary cover of the Jiul de Vest-Cerna area may be divided into two sectors, lithostratigraphically and structurally differentiated:

1. The area between the Lăpuşnicul Mare and Jiul de Vest Rivers (Piatra Iorgovanului, Scăriţa, Piule, and Pleşa Mountains), the sedimentary series outcrops in a northeast-southwest oriented syncline (10.5 km long and 3-5 km wide), enlarged to the west, where it is covered by the crystalline schists of the Getic Nappe. The Liassic deposits (quartzitic conglomerates, arkoses, sandstones, and slates) unconformably overlay the Permian conglomerates, followed by calcareous sandstones (Dogger) and blackish, fractured limestones with chert (Malm) overlain by a limestone reef structure (Aptian), 500-600 m thick. The sedimentary cycle ends with Upper Cretaceous wildflysch, known as the Nadanova Formation.
2. In the area South of Obârşia Cernişoarei the sedimentary sequence is incomplete, the Liassic sandstones and the calcareous sandstones (Dogger) are missing.

The most frequent sedimentary cover consists of quaternary glacial and fluvio-glacial deposits.

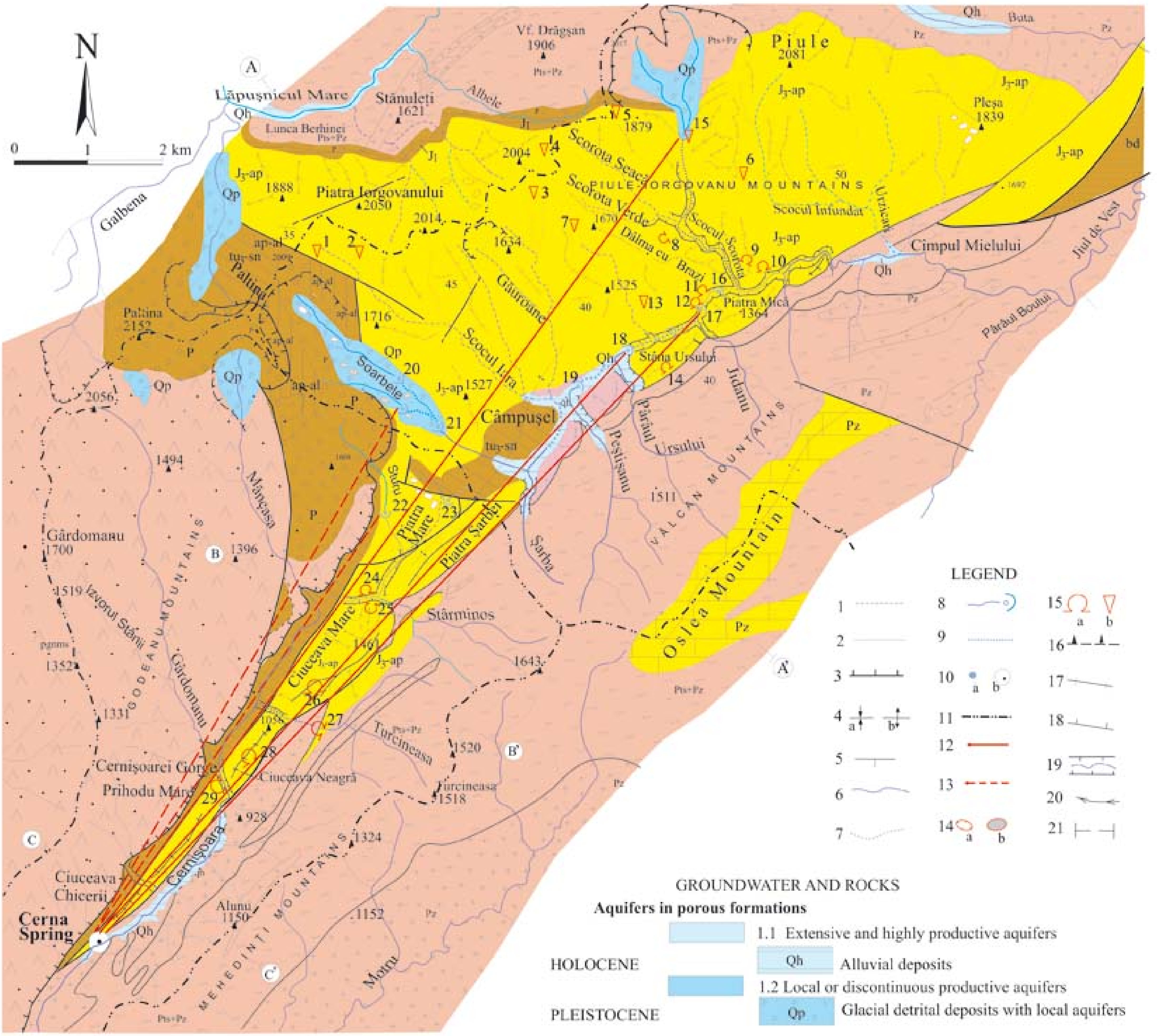
The structure of this mountain is the result of multistage tectonics, affecting the crystalline-granite formations of the Precambrian basement. Transgressively and unconformably overlaying these are 1,500 m thick Mesozoic deposits, forming an asymmetric, northeast-southwest oriented syncline. The syncline plunges to the southwest, while its thickness decreases. The Jurassic limestones (calcareous sandstone) and the Cretaceous deposits (arenitic, algal, and bioclastic limestones), are more than 1,000 m thick, and overlain by the Upper Cretaceous detrital sediments (clays, marls, and sandstones with Senonian conglomerates) (Pop 1963, 1973).

In the western sector of the area, the Mesozoic sedimentary cover is overlain by the Getic's Nappe crystalline rocks, while the limestones crop out only on a small area, gradually narrowing and decreasing in thickness toward Cerna Spring. The tectonic evolution of the Godeanu Outlier and of the Borăscu Digitation involved the "squeezing" of limestones and wildflysch against the "wall" of granites and Danubian crystalline elements in the eastern portion of the nappe's leading edge, along the Cerna Fault (Miocene: intra-Burdigalian). The wall acts as an impermeable barrier, directing the underground flow toward the south.

Hydrogeology: Occurrence and Availability of water

The availability of ground water in the Jiul de Vest - Cernişoara varies widely, largely due to the geologic complexity of the area. The water-bearing characteristics of the aquifers are discussed based on the physical characteristics of the rocks or sediments in the area (porosity and permeability, granular or fractured), and the occurrence of springs and sinking streams. Dye studies, which were used to define the hydrogeologic watershed of each basin, are also discussed.

Figure 1. Hydrogeological map of the upper part of Jiul de Vest and Cernișoara Rivers Basins (Geology after Pop, 1963, Geological Map 1:200,000, Baia de Aramă sheet, and Geological Map 1:50,000, Oslea sheet, unpublished).



GROUNDWATER AND ROCKS

Aquifers in porous formations

		1.1 Extensive and highly productive aquifers
HOLOCENE	Qh	Alluvial deposits
		1.2 Local or discontinuous productive aquifers
PLEISTOCENE	Qp	Glacial detrital deposits with local aquifers

Karst aquifers

		2.1 Extensive and highly productive aquifers
MESOZOIC	J_3-ap	Carbonate rocks
		2.2 Local or discontinuous productive aquifers
PALEOZOIC	Pz	Crystalline limestones

Fissured aquifers

		3.1 Local or discontinuous productive aquifers
MIOCENE	bd	Sandstones, conglomerates, clays
UPPER CRETACEOUS	tu_3-sn	Sandstones, conglomerates, clays
LOWER CRETACEOUS	ap-al	Sandstones, conglomerates, clays
LOWER JURASSIC	J_1	Sandstones, arkoses
PERMIAN	P	Conglomerates, sandstones, siltstones
PRECAMBRIAN		Metamorphic rocks Danubian of Autochthonous

Strata (granular or fissured rocks) forming insignificant aquifers with local and limited groundwater resources or strata with essentially no groundwater resources

		4.1 Minor aquifers with local and limited groundwatwr resources
PRECAMBRIAN/ PALEOZOIC		Granites and granitoides
		4.2 Strata with essentially no groundwater resources
PRECAMBRIAN		Metamorphic rocks of Godeanu Unit

JIUL DE VEST RIVER BASIN

1. Avenul cu Gheaţă din Muntele Stănuleţi
2. Avenul nr. 1 din Curmatura Stănuleţi
3. Avenul Mare cu Zăpadă din Albele
4. Avenul de sub Albele
5. Avenul Mare din Plaiul Drăgşanilor
6. Avenul din Stâna Tomii
7. Avenul cu Gheaţă din Dâlma Brazii cei Vineţi
8. Peştera cu Gheaţă din Dâlma cu Brazi
9. Peştera Zeicului
10. Peştera Ursului din Cracul Stâna Tomii
11. Peştera nr. 5 de deasupra Ponorului IV
12. Peştera nr. 1 cu Gheaţă din Cheile Jiului de Vest
13. Avenul Mare din Scocul Piatra cu Gheaţă
14. Peştera din Cioaca Ursului
15. Avenul ponor din Scocul Scorotei
16. Ponorul IV din Scocul Mare (Jiul de Vest)
17. Ponorul III din Scocul Mare
18. Ponorul II din Scocul Mare
19. Ponorul I din Scocul Mare
20. Ponorul I din Scocul Soarbele
21. Ponorul II din Scocul Soarbele

CERNIŞOARA RIVER BASIN

22. Ponorul din Şarba
23. Ponorul de sub Lacul Raţei
24. Peştera Mare din Vâlcel
25. P. Albă din Ciuceava Mare
26. Peşterile din Ciuceava Mare
27. Ponorul din Ogaşul Sec (Turcineasa)
28. Peştera Rece
29. Peştera Ramonajului

1. Geological boundary. 2. Fault; 3. Overthrust; 4. Syncline (a); Anticline (b); 5. Strike and dip of inclined beds; 6. Perennial surface stream; 7. Temporary stream; 8. Sinking stream; 9. Seepage in riverbeds; 10. Nonkarstic spring (a); Karstic spring (b); 11. Watershed; 12. Groundwater flow direction established by tracing experiments; 13. Hypothetical groundwater flow direction; 14. Sinkhole (a); Suffosion sinkhole (b); 15. Cave (a); Shaft (b); 16. Glacial cirque; 17. Limestone ridge; 18. Sub-vertical wall; 19. Gorge; 20. Steep valley; 21. Hydrogeological cross-section line.

Aquifers in porous formations

Glacial detrital deposits with local aquifers and the alluvial deposits, with extensive and highly productive aquifers, are located along the Soarbele, Scorota, Jiul de Vest, and Cernişoara Rivers. Water is concentrated in open pore spaces between the grains, pebbles, and boulders. Some small springs and seeps are identified, and their flow depends on the precipitation and snow melting. The thickness of these deposits is between 2 and 8 meters.

Karst Aquifers

The water in the crystalline limestones of the Oslea Mountains is concentrated in small fractures, and along bedding planes, with locally productive karst aquifers. Small springs (less than 1 liter/second) can be present at the contact with non-calcareous rocks. The thickness of the crystalline limestone ranges between 200 and 300 meters.

Extensive and highly productive karst aquifers occur in solution cavities, joints, fractures, and along the bedding planes of the Mesozoic carbonate rocks. This aquifer has a more extensive network of interconnected fractures than any other aquifer in the region. These interconnected fractures serve as a conduit, leading the waters from the Jiul de Vest Basin toward Cerna Spring. Tracer studies demonstrate that the upper part of the Jiul de Vest River is recharging Cerna Spring.

Fissured Aquifers

No rocks belonging to the "Extensive and highly productive aquifers" subcategory are in the area. A wide range of sandstones, conglomerates, and siltstones from Lower Jurassic to Miocene representing the "Local or Discontinuous productive aquifers" subcategory are present. These units generally yield small quantities of water to springs, which at the interface with limestones, sink underground.

Groundwater in the metamorphic rocks of the Danubian Autochthonous occurs along fractures, joints, and bedding planes. These metamorphic occasionally are capable of supplying moderate quantities of water to springs. These metamorphic rocks form an impervious layer under the limestone deposits are up to 600 m thick.

Strata (granular or fissured rocks) forming insignificant aquifers with local and limited groundwater resources or strata with essentially no groundwater resources.

The Precambrian deposits of the Godeanu Unit (Godeanu Outlier – part of the Getic Nappe) essentially do not represent a ground water resource. Minor aquifers with local and limited groundwater resources are found in the Precambrian/Paleozoic granites and granitoides and Permian conglomerates, sandstones and siltstones. The water is concentrated in fractures/joints.

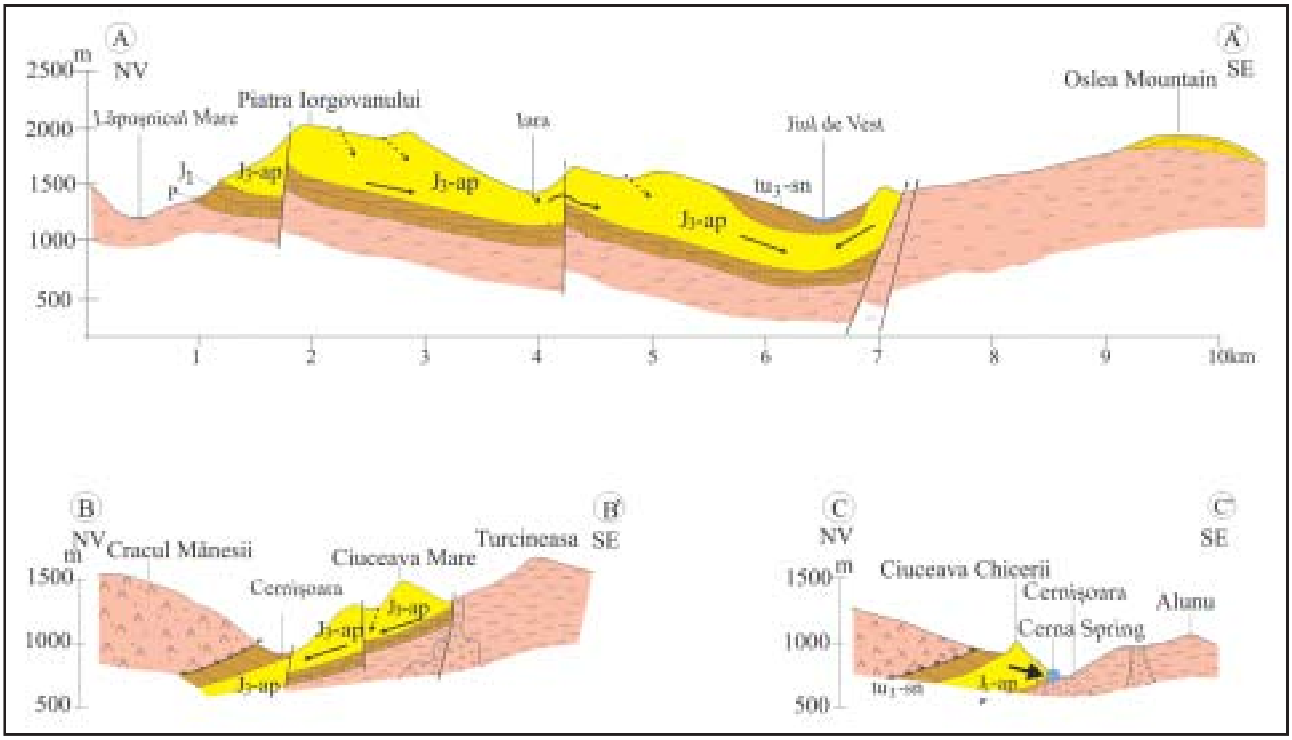


Figure 2. Cross sections in the Jiul de Vest-Cernișoara Basins (for legend see Fig. 1).

Karst Landforms

The area underlain by limestones is extensive (Table 1). Rainfall is abundant and the karst vertical potential exceeds 1,000 m. Exokarst landforms are weakly represented. Various types of karrens, small- to medium-sized sinkholes, canyons (dry or with temporary flow), and gorges were identified.

The limestones of the Jiul de Vest Basin (23.8 km^2) form a karstic plateau oriented east-west (Piule, 2,080 m - Piatra Iorgovanului, 2,014 m), which continue with a narrow ridge to the southwest, towards Cerna Spring.

The tectonically controlled karrens are present extensively across the site, with most identified in the lower part of the Soarbele and Iara valleys and on the southern slope of the Albele Mountain (Niculescu 1960). Small-sized sinkholes (10-15 m in diameter and 5-8 m deep) are found on Pleşa, Albele, and Stănuleţi Mountains. The most interesting are the subsidence sinkholes, formed on the west side of the Soarbele Valley, and the suffusion sinkholes formed on the glacial deposits of the same valley (Bădescu 1991). In two of the sinkholes from the upper glacial level of the Soarbele Valley, the presence of impermeable clay deposits favored the appearance of perennial lakes.

The endokarst of the Jiul de Vest Basin is represented by 328 caves. Only 6.4% are longer than 100 m, while 2.9% are vertical caves (Fig. 6). The most karstified interval is between elevation 1,100 and 1,200 m, where 61% of the caves, horizontals and verticals, have developed (Fig. 3). The microtectonic measurements revealed that most of the caves occur at the intersection of the Cerna-Jiu Fault with adjacent fractures (Ponta et al. 1984a, b) and are in the vicinity of sinking streams of the Jiu de Vest riverbed. Five vertical caves, 55-92 m deep, between elevations 1,750 and 2,000 m, host perennial ice accumulations: Avenul Mare cu Zăpadă from Albele-Găuroane (Fig. 4), Avenul cu Zăpadă from Scorota Seacă, Avenul cu Gheaţă from Dâlma Brazii cei Vineţi, Avenul cu Gheaţă from Piule, and Avenul cu Gheaţă from Stănuleţi. The perennial ice from these caves recharges the groundwater during periods with low precipitations. The water resulted from precipitations and snow melting infiltrates along vertical fractures and occasionally generates vertical caves. One of the most important vertical caves (shaft) is Avenul din Stâna Tomii with 114 m drop (Fig. 5).

Most of the northwest-side tributaries of the Jiul de Vest River are located on limestones (Scocul Iara, Găuroane, Scorota Verde, Scorota Seacă, and Urzicari), and have occasional surface runoff, following heavy rainfall or snow melt. Only two tributaries (Soarbele and Scorota cu Apă) have an upper sector developed on nonkarstifiable rocks, where the flow is perennial. Once the streams enter the limestones, the waters disappear underground through sinking streams, or diffuse infiltration of the riverbed. The snow melts (April-June) and the rain storms (June-July) may provide a continuous flow to the confluence with Jiul de Vest River.

The tributaries on the southeast side of Jiul de Vest (Pârâul Rece, Pârâul Jidanului, Pârâul Ursului and Peştişanu Rivers) have 99% of their basins developed on nonkarstifiable rocks of the northern slope of the Vâlcan Mountains. Before reaching Jiul de Vest River, they cross a limestone ridge, through short gorges, which represents the eastern flank of the Cernişoara syncline. Downstream, Jiul de Vest River sinks underground, and the riverbed is dry from the latter part of July until October-November. The Jiul de Vest River sinks along a parallel fault upstream of Câmpul Mielului and recharges the Cerna Spring through underground pathways (Povară 1976).

The absence of the antithetic faults adjacent to the sinking streams along of Jiul de Vest River supports the hypothesis that the underground drainage toward Cerna Spring is recent, most probably in the Riss-Würm Interglacial Stage.

The limestones of the Cernişoara Basin, outcrop on a small area (4.30 km^2), and are part of the Eastern flank of the Cernişoara syncline, underlying the nonkarstifiable formations of the Getic

	Area (km²)	Cernişoara	Jiul de Vest	Lăpuşnicul Mare
Nonkarstifiable rocks	47.85	27.45	19.46	0.935
Limestones	32.77	4.30	23.820	4.650
Total	80.62	31.75	43.285	5.585

Table 1. The area of the Cerna Spring hydrogeological basin.

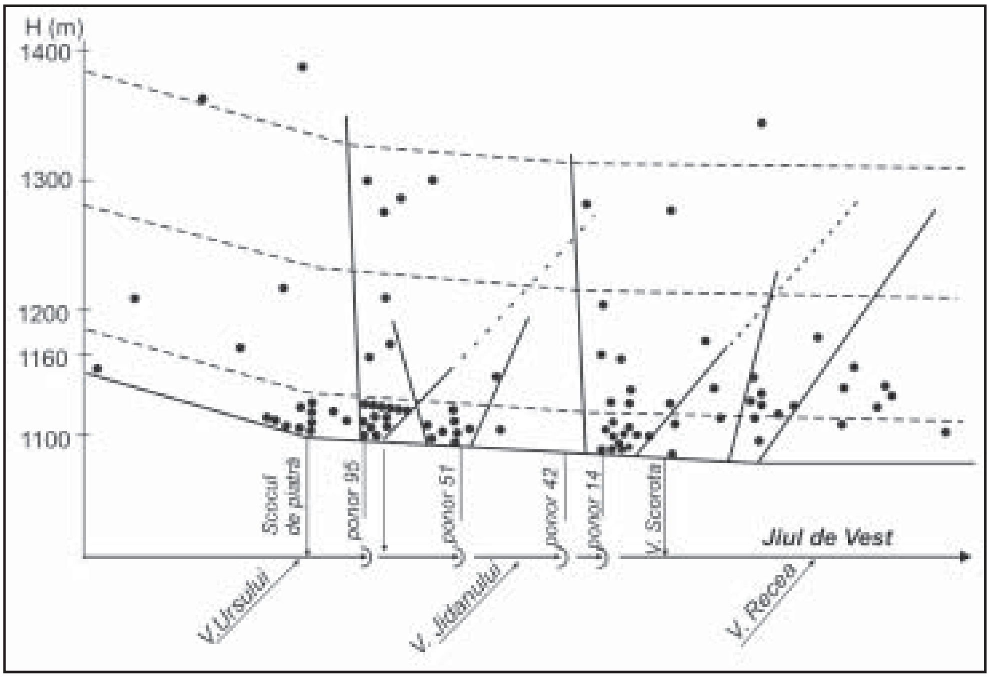


Figure 3. The distribution of the caves in the Jiul de Vest Basin, according to elevation (Ponta et al. 1984b). Reproduced from Povară and Ponta (2010) Geology and Hydrogeology of the Jiul de Vest-Cernișoara Basins, Romania. Carbonates and Evaporites 25 (2) Springer-Verlag.

Nappe. South of the saddle (water divide) with Jiul de Vest, a plateau oriented northeast-southwest, is at 1,300-1,400 m elevation, and is several crossed by valleys (Sturu, Şarba and Lacul Răţii). Along them, perennial sinking streams and small antithetic faults have been developed.

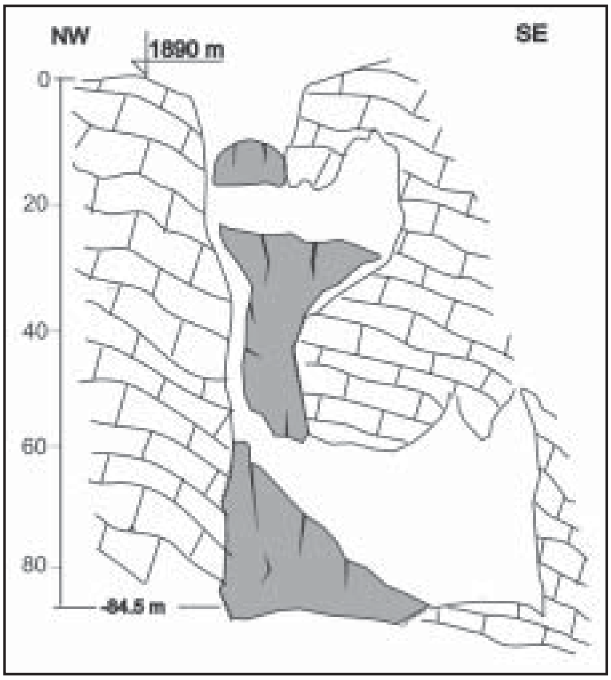


Figure 4. Avenul Mare cu Zăpadă from Albele-Găuroane located at 1,925 m elevation, host an ice deposit estimated to 12,500 m^3, the largest one in the Southern Carpathians (Ponta et al. 1984b).
Reproduced from Povară and Ponta (2010) Geology and Hydrogeology of the Jiul de Vest-Cernișoara Basins, Romania. Carbonates and Evaporites 25 (2) Springer-Verlag.

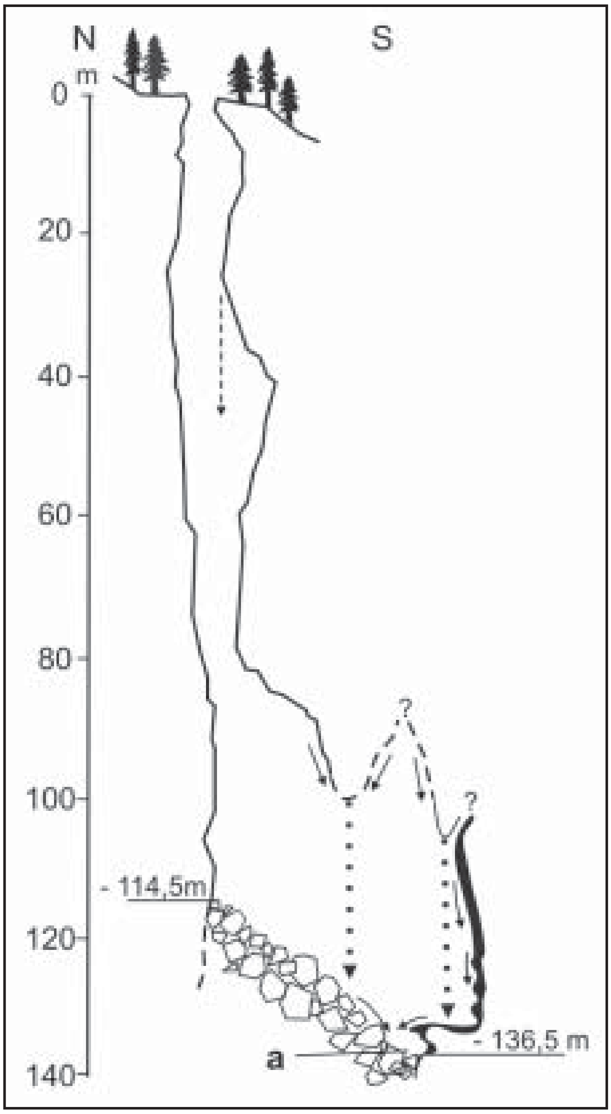


Figure 5. Avenul din Stâna Tomii (longest drop in Romania -114 m; Survey, Focul Viu București Grotto) (in Bleahu et al., 1976).

The increased fragmentation of the plateau by the Cernişoara tributaries led to the formation of an elongated limestone ridge oriented NE-SW, known as *”ciuceve”*. The ridge is about 1,500 m wide in the upper part of the Cernişoara River, gradually narrowing and decreasing in thickness toward Cerna Spring. In the area of “ciuceve”, the karren fields are the predominant karst feature.

The endokarst is represented by 294 caves, 79.9% are less than 50 m long, and 58% are in the 800-1,000 m elevation range (Fig. 6).

Underground flow

The main groundwater flow within the karst aquifer is influenced by three structural-tectonic and physiographic features:

- The occurrence of the limestone in a wide, asymmetric synclinal structure, with the eastern flank cut by the Cerna-Jiu Fault, which is parallel to the leading edge of the Getic Nappe. East, the limestone deposits are in contact with impermeable crystalline formations.
- The gradual deeping of the syncline axis from the northeast to the southwest, under the nonkarstifiable formations of the Godeanu Outlier.
- The general slope of the karst surface from 2,000 m in Jiul de Vest to only 700 m in the Cernişoara Basin.

Consequently, the underground flow is driven from the northeast to the southwest, parallel to the Cerna-Jiu Fault. Groundwater in the entire structure is discharged through Cerna Spring. The Jiul de Vest-Cernişoara karst area is about 32.77 km^2, where 10 active sinking streams have been identified. Several dye studies using flourescein, and In-EDTA proved the connection between the sinking streams of the Jiul de Vest River and Cerna Spring, which confirmed that Cerna Spring’s recharge area included the entire karst area of Retezatul Mic Mountains (Pascu 1968, unpublished; Povară 1976, 1980; Bulgăr et al.1984; Ponta et al. 1984a). The most important features are presented in Table 2.

The average theoretical flow velocity ranges between 32.5 and 55.5 m/h (0.886 - 1.33 km/day) and is typical for conduit flow. In 1982 the Geological and Geophysical Prospecting Company with the Institute of Nuclear Physics (IFIN), Bucureşti completed a tracer study in the Scorota sinking stream. The stream is situated at the contact between impermeable crystalline rocks and the Jurassic limestone at an elevation of 1,390 m and 13,350 m from Cerna Spring, which is at an elevation of 700 m above sea level (Ponta 1998).

On August 9, 1982, 100 g of indium-EDTA was used in the Scorota sinking stream, which has a flow of 25 l/s. The travel time of the tracer to Cerna Spring, 13.3 km away and 700 m lower in elevation, was 28 days; the recorded velocity was 55.6 m/h (Fig. 7). As much as 33% of the tracer was recovered (Ponta et al. 1984a). The low level of tracer recovery points to high dilution or lateral dispersion, from the main drain to the adjacent structures. Based on this study, Cerna Spring’s recharge area include the entire karst area of Retezatul Mic Mountains.

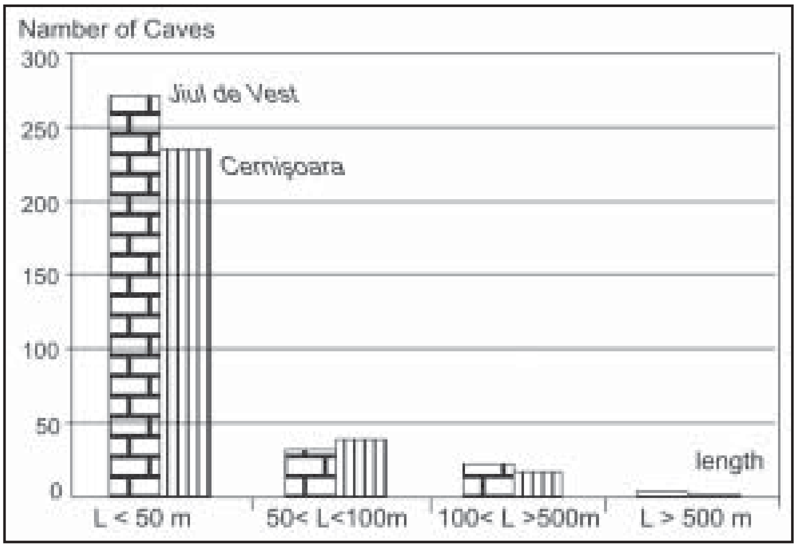


Figure 6. The distribution of the karst cavities according to cave’s length (data from Goran 1982). Reproduced from Povară and Ponta (2010) Geology and Hydrogeology of the Jiul de Vest-Cernișoara Basins, Romania. Carbonates and Evaporites 25 (2) Springer-Verlag.

No.	Inlet	H (m)	Outlet	H (m)	L (km)	ΔH (m)	Tracer	T (hours)	V km/d	Year	References
1	Scorota Sinking Ponor	1410	Izvorul Cernei	710	13.3	700	In	240	1.33	1982	Ponta et al., 1984
2	Jidanului (Caprei) Creek	1140			12.1	475	F	282	1.029	1975	Povară, 1980
3	Ursului Creek	1180			10.95	470	F	228	1.15	1974	Povară, 1980
4	Ştirbu (Peştişanu) Creek	1170			9.9	460	F	268	0.886	1974	Povară, 1976

H-elevation, in meters; L-horizontal distance between sinking streams and springs; ΔH-difference vertical elevation between sinking stream and springs; T-tracer, time of first arrival; V-apparent velocity; F=Flourescein; In= In-EDTA

Table 2. Dye studies completed in Jiul de Vest-Cernișoara Basins.

Water budget data

The meteorological and hydrological parameters were measured between November 1, 1981 and October 30, 1982, to determine the volume of water disappearing underground along Jiul de Vest riverbed and recharge the Cerna Spring. The infiltration along the slopes and the riverbed of the Jiul de Vest River was evaluated. The water budget was calculated, based on the following elements (Bulgăr et al., 1982):

- Precipitations redistributed for the winter season based on the rate of water released from the snow layer.
- Distributions of the water reserve function of the basin's elevation (Fig. 8). The graph was generated based on 81 measurements of snow depth (thickness), located between 1,050 and 1,950 m elevation.
- Evapotranspiration (Turk's formula).
- Surface runoff at Câmpul Mielului, along the Jiul de Vest River (downstream of limestone/noncalcareous rocks interface).

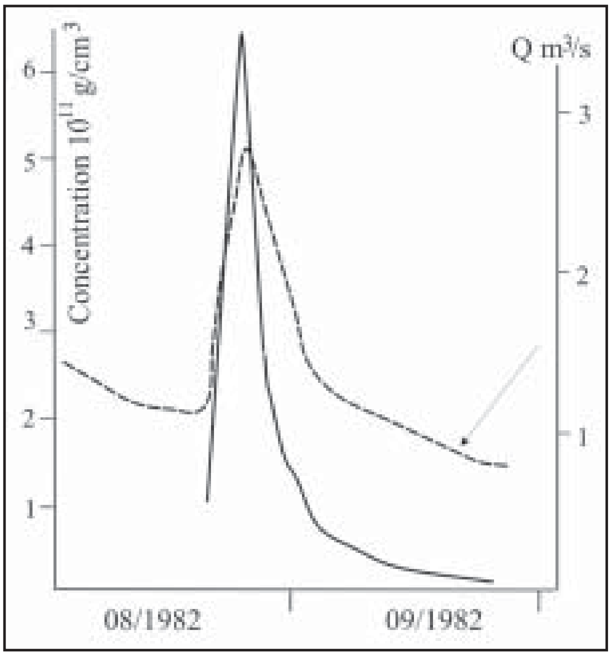


Figure 7. Scorota Valley-Cerna Spring In-EDTA concentration with discharge.

To calculate the volume of water from snow the following formula was used:

$C = (0,1 + 0,12\,X + kv)T + 1$

Where

C – Thickness of the melted snow (mm);
X – Rain (mm);
T – Air average temperature (°C);
k – Degree of forestation (0.3 – 0.1)
v – Wind speed (m/s)

The snow lasts for more than 200 days above 1,800 m elevation, and the maximum value of the water reserve in the snow layer is 300 mm. This was recorded in March 1982 (Fig. 9) and is characteristic for the 1,300-1,800 m elevation range, where over 65% of the Cerna Spring recharge area is located. The maximum snow melting takes place in April and May, as shown on Cerna Spring hydrograph.

The evaluations of the real evapotranspiration were based on Turk's formulas, adapted to the local temperate-continental mountainous climate (Fig. 10). Because in the formula of the water budget, the evaporatranspiration is a negative number, the results shows how important are the infiltrations to the Cerna Spring discharge.

The discharge of the Jiul de Vest River was recorded at Campul Mielului (limestone/noncalcareous rocks interface between November 1981-October 1982 (Q_{min} =0.277 m^3/s; Q_{mean}= 0.02 m^3/s; Q_{max}=57 m^3/s) (Bulgăr et al, 1982).

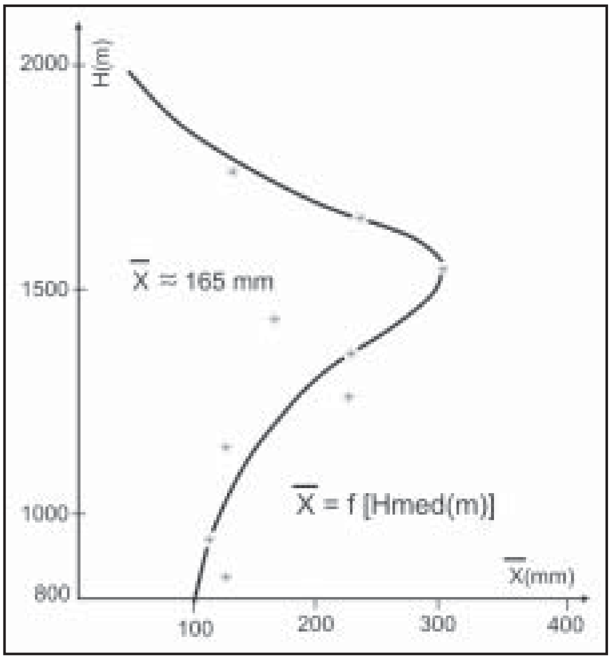


Figure 8. The distribution of water reserve resulted from melting snow versus the elevation of hydrographic basin (after Bulgăr and Munteanu 1982).

The infiltration rate was calculated based on the amount of rain, real evapotranspiration, and Jiul de Vest River's discharge. The infiltration is almost zero during winter (Fig. 11). At the beginning of March 1982 the infiltration values began to increase, to 3,500 × 10^3m^3 in the first part of April 1982, with the maximum value recorded of 4,040 × 10^3m^3 in October 1982. The total volume of infiltration for the karst area between November 1981 - October 1982, was 34.24 × 10^6 m^3 (Bulgăr et al, 1984), which is equivalent with 759 mm of rain, versus 191 mm of surface runoff and 290 mm evaporation.

Cerna Spring karst system

Cerna Spring is on a small, northwest-side tributary of the Cerna River, Ogaşul Obârşiei, 100 m upstream of the confluence, at 710 m elevation. Its hydrogeological basin (watershed) is 80.6 km^2, of which 40.6% are limestone outcrops. Part of the flow is through karst conduits 20-35 cm in diameter. At the spring, air bubbles are released as result of the decompression process accompanying the accessional Vauclusian Spring.

The only systematic hydrometric records were performed by National Institute of Hydrology and Meteorology from Bucharest, Romania during November 1, 1981-December 31, 1982. Occasionally, Cerna Spring flow-rate data were recorded, the largest being of 10.5 m^3/s (May, 1980).

The hydrograph of the spring flow rate and rainfall recorded at Câmpul lui Neag highlights a connection between rainfall and flow rate, as well as a delayed response of the flow rate to the rain event (Fig. 12).

The parameters based on the recession hydrograph analysis performed for the period August 25-September 30, 1982 (Fig. 13), following the method issued by Mangin (1975), points out certain drainage features confirmed by the field data:

- a poorly developed phreatic karst (low k);
- a quick discharge (high α = drainage coefficient);
- the significance of the surface runoff for the karst system recharge (high i);
- a rather short flow-rate decrease time ($t_i = 14$ days), related to the time span of the depletion of infiltration.

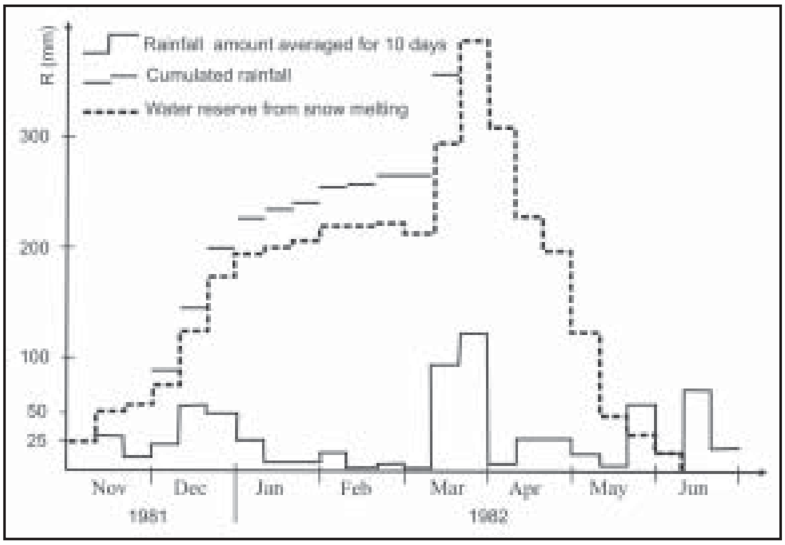


Figure 9. Water reserve resulted from snow melting during November 1981 - May 1982 (after Bulgăr and Munteanu 1982).

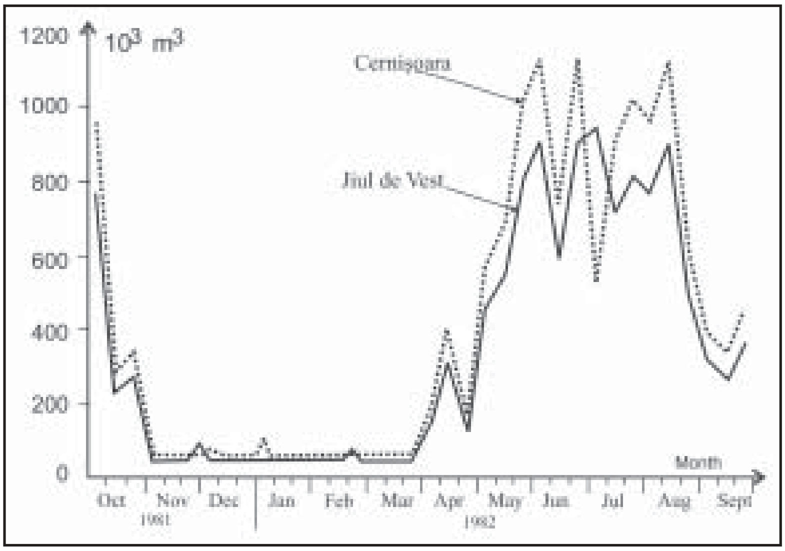


Figure 10. Rate of Real Evapotranspiration in Jiul de Vest-Cernișoara Basins (after Bulgăr et al, 1984).

Using the systemic analysis (Mangin 1975) of the Cerna Spring flow rate and of the rainfall recorded at Câmpul lui Neag, the following results were obtained (Table 3):

The simple correlogram and the spectrum of the variance density for the rainfall denote a low structured character of it for intervals of 14, 26 and 40 days.

The simple correlogram of the flow rate suggests a low decrease. The value $r_k = 2$ is reached after 43 days (MT), while the correlogram reaches 0 after 55 days. In this case, the memory effect of the basins developed on the nonkarstifiable formations on the southeast side of the Jiul de Vest River is also involved. These areas are mostly covered by superficial deposits and forests or pastures.

The regulation time (RT) for this system is 36 days and it highlights the duration of the rainfall influence. In this case we can also mention the influence of the nonkarstifiable rocks.

For Cerna Spring, the cross-correlogram for the year 1982 has a low inter-correlation coefficient (r_k), indicating a weak connection between rainfall and flow rate. This reaches a maximum value after 2 days (0.193) and becomes 0 after 18 days. The correlogram shape shows a significant supply from riverbeds (diffuse infiltration and swallow holes). The system has a low inertia, comprising a poorly developed phreatic subsystem. The low inter-correlation coefficient may be explained by the fact that the rainfall measured at Câmpul lui Neag is not significantly influencing Cerna Spring Basin.

Using the karst aquifer classification based on the results of the recession hydrograph analysis (Mangin 1975), we conclude that the Cerna Spring system is recharged by an aquifer that is more karstified upstream than downstream, with a delay in the supply process (type III: $k < 0.5$; $0.25 < i < 0.5$).

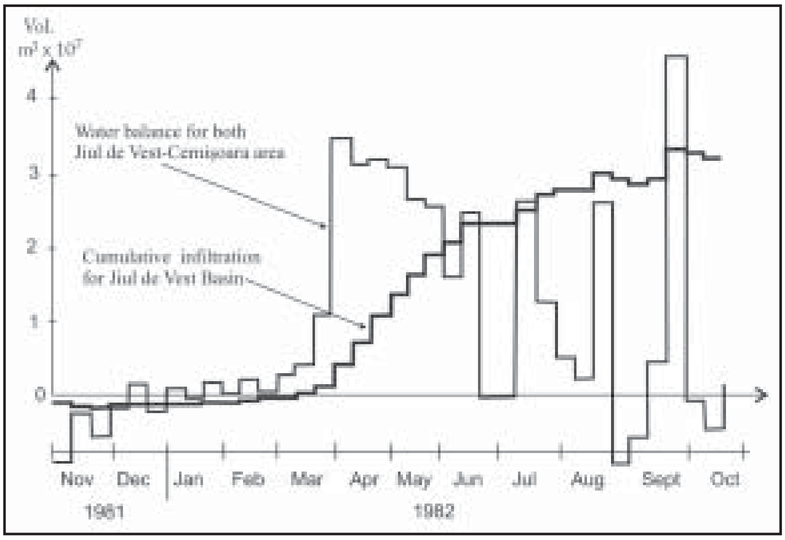


Figure 11. Rate of Infiltration in Jiul de Vest-Cernișoara basins (after Bulgăr & Munteanu 1982).

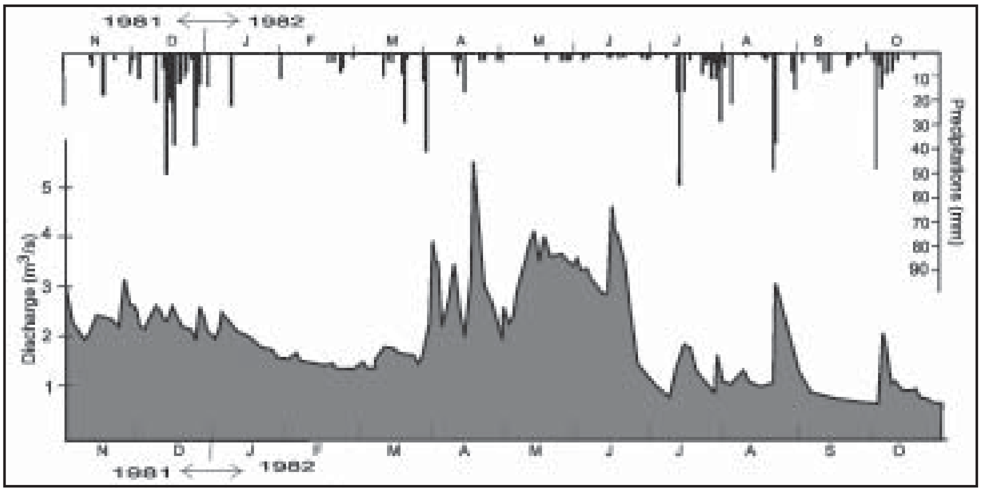


Figure 12. Hydrograph of the Cerna Spring flow rate with precipitations diagram recorded at Câmpul lui Neag (after Bulgăr & Munteanu 1982). Reproduced from Povară and Ponta (2010) Geology and Hydrogeology of the Jiul de Vest-Cernișoara Basins, Romania. Carbonates and Evaporites 25 (2) Springer-Verlag.

The systemic analysis was based on a single hydrologic cycle and the rainfall recorded at Câmpul lui Neag may be not representative for the Cerna Spring hydrogeological basin.

Conclusions

The Retezatul Mic Mountains are between the Buta and Jiul de Vest Rivers and are an alpine karstic plateau (2,000 m above sea level) developed on Jurassic limestones. An extensive network of dry valleys was developed and shaped by glaciers, which deeply eroded the carbonate (limestones) and noncarbonate rocks on the plateau. The mountain area of the upper part of Jiul de Vest, Cernişoara and Lăpuşnicul Mare Rivers is recharging the Cerna Spring. Cerna Spring is the most important karst spring of Romania, with a maximum recorded flow rate exceeding 10 m^3/s. The Cerna Spring recharge area is 80.6 km^2, of which 32.77 km^2 is covered by Mesozoic (J$_3$-ap) limestones. These carbonates crop out in a wide, asymmetrical syncline, oriented northeast-southwest. The syncline axis plunges toward the southwest. The groundwater flow is toward the southwest and is controlled by the syncline. South of Scocul Soarbele, the limestones are overlain by the Borăscu Nappe (lower part of the Getic Nappe).

The limestones have been less or moderately influenced by karst processes. The exokarst is represented by karren fields, dissolution, and suffusion sinkholes. Both categories of sinkholes are relatively small (diameter 4-15 m, depth 2-10 m). There are many caves, horizontal and vertical (328 on Jiul de Vest and 294 on Cernişoara). Most are short and more than 80% are less than 50 m long.

Surface water flow in all northwest-side tributaries of Jiul de Vest is ephemeral. Therefore, an important role in the recharge of the Cerna Spring is played by the seepage losses from the hydrographic network. The groundwater flow velocities determined with chemical and activable tracers range between 0.78 and 1.33 km/day. The maximum

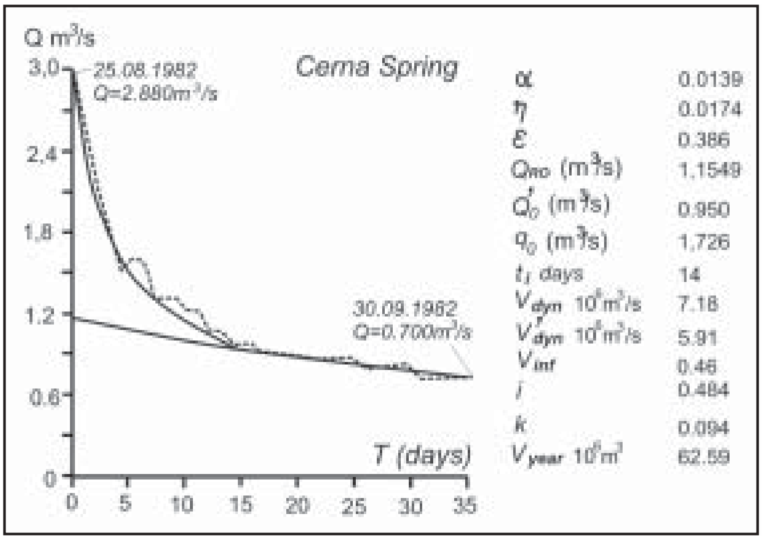


Figure 13. The recession curve and parameters for the Cerna Spring flow rate during August 25, 1982-September 30 1982. Reproduced from Povară and Ponta (2010) Geology and Hydrogeology of the Jiul de Vest-Cernișoara Basins, Romania. Carbonates and Evaporites 25 (2) Springer-Verlag.

	Qmax m³/s	Qmin m³/s	Qmax/Qmin m³/s	Qmed m³/s	α	Dyn. vol.	ME	TF	RT	M
Izvorul Cernei	5700	0.600	9.5	1.985	0.0139	7.18	43	0.084	36	C

ME = memory effect; TF = truncation frequency; RT = regulation time; α = discharge coefficient.

Table 3. The spring features for the 1981-1982 hydrologic cycle.

runoff is recorded between May and June when spring rainfall is combined with snow melting.

The Cerna Spring karst system is better developed upstream (Jiul de Vest Basin), while the water-filled karst is less represented. The system dynamic volume (V_{dyn}) is $7.18 \cdot 10^6$ m^3/s, while the annual runoff volume is $62.59 \cdot 10^6$ m^3/s.

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