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GEOTRIP of the IAH Karst Commission

Romanian Karst of Southern Carpathians

Field Trip Guide

Editors
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A BRIEF INTRODUCTION TO THE GEOLOGY OF THE ROMANIAN DANUBE BANK, AS OBSERVED FROM SERBIA

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The Valley of the Danube is crossing the South Carpathians transversally, therefore revealing on its both banks an ideal geological profile which outcrops all tectonic units of this Alpine chain. The Danube Valley across the Carpathians can be correctly evaluated as one of the most spectacular geological sections in Europe, thanks to impressive outcrops with highly significant Sites of Special Scientific Interest (SSSIs, or preserved sites), geosites and other important geological outcrops (Popa, 2003). The Romanian bank is very well visible and highly interesting from a geological point of view when observed from the Serbian bank of the Danube, as it is the Serbian bank when observed from Romania. The structure of the South Carpathians shows a pile of tectonic nappes overthrusted from west eastwards. These units are the following:

1. The Supragetic Nappe (Streckeisen, 1934), with a thick metamorphic, basement sequence, strongly represented in Locva Mountains and outcropping along the Danube Valley west of Moldova Nouă up to Baziaș and Socol. Few and thin sedimentary patches occur northwards, close to Reșița;

2. The Getic Nappe (Munteanu-Murgoci, 1905), represented by basement rocks covered by a thick sedimentary sequence, belonging to several basins or sedimentary zones: Reșița, Rusca Montană, Pui, Holbav, and Cristian (next to Brașov, in central Romania) basins. Along the Danube Valley, metamorphic basement sequences outcrop between Drobeta Turnu-Severin and Orșova, belonging to the Severin and Bahna crystalline patches, nowadays being covered by the concrete structures for traffic safety. They still largely outcrop around around Cozla, including the Drencova gneiss. The sediments of the Reșița Basin, the only sedimentary basin of the Getic Nappe outcropping in the valley of the Danube, occur between Berzasca and Moldova Nouă, mainly represented by limestone formations, Upper Jurassic – Lower Cretaceous in age. These limestones represent a deep oceanic Upper Jurassic sequence followed by a Lower Cretaceous carbonate platform

sequence, and they were extracted in open cast mines in Coronini 1 and 2 quarries, well visible from the Serbian bank.

3. The Severin Nappe is a sedimentary unit including Upper Jurassic – Lower Cretaceous (Tithonian – Neocomian) flysch sequences represented by the Sinaia Beds. This unit outcrops in various areas of the Danube Valley, between Drobeta Turnu-Severin and Orșova at Vârciorova (Figure 1), upstream of the Cazanele Mari, at Grăniceri bridge and at mouth of the Sirinia stream, next to Cozla. The latter occurrence permitted the reassessment of the Drencova gneiss to the Getic Nappe, one of the most important geological discoveries in the South Carpathians in the nineties (Pop et al. 1997).

4. The Danubian Units (Codarcea, 1940) are outcropping within a large tectonic window beneath the Supragetic, Getic and Severin nappes, from Sirinia Valley eastwards, up to Vârciorova, between Drobeta Turnu-Severin and Orșova. The Danubian units yield a series of important basins or sedimentary zones, grouped into the Upper or Internal Danubian units (Sirinia and Presacina basins) and Lower or External Units (Cerna-Jiu and Coșuștea basins). Along the Danube Valley, the Sirinia Basin is well developed and frequently outcropped, stretching from Sirinia Valley up to Cazanele Mari. This basin includes Palaeozoic (Upper Carbonifeorus – Permian), Mesozoic (Lower Jurassic – Lower Cretaceous) and Neozoic (Miocene - Pliocene) sedimentary formations, subject to a classical geological contribution by Răileanu (1953, 1960). A contact between the Danubian Units and the Severin Nappe was described by Codarcea (1940), a classical and still surviving outcrop in the Valley of the Danube.

The Carboniferous sequence, represented by the Cucuiova Formation, is continental and coal bearing, very rich in fossil plants (Popa and Cleal, 2012), especially in Baia Nouă (Nove Doly). The Permian includes a terrigenous, red beds sequence (Povalina Formation) and a volcanoclastic sequence (Stariștea Formation). The Permian succession is characterized by a complex surtseyan volcanic sequence (Seghedi, 2010), with large rhyolitic magmatic chambers. Well visible from the Serbian bank, almost in front of Lepensky Vir archaeological site, the Trescovăț Peak is an iconic Permian magmatic chamber (Figure 1).

The Mesozoic succession yields Lower Jurassic coal measures with plants (Cioaca Borii, former Glavcina formation), followed by marine limestones from Lower Jurassic up to the Lower Cretaceous. The outcrop from Munteana – Dumbrăvița, between Jelișova and Sirinia valleys, yielding also the suspended fold visible from the Serbian Bank, is one of the rarest, complete Jurassic – Cretaceous marine sequences in Europe. The Middle Jurassic ferruginous limestones along the Saraorksi creek, next to the Serbian village of Svinița, include a palaeontological Site of Special Scientific Interest (SSSI), with a very diverse and well preserved ammonoid fauna (Figure 1). Such Middle and Upper Jurassic red nodular limestones outcrop in the Serbian Greben area, along the Serbian bank, better visible from the Romanian bank of the Danube. Also, well visible from the Serbian bank are the Zeliște and Veligan peaks, represented by the Lower Jurassic Cioaca Borii conglomerates unconformably overlaying the Permian red beds of the Povalina Formation, part of a large cuesta very well visible from Donji Milanovac (Figure 1). These conglomerates are covered by rare and endemic Banat pines (*Pinus nigra* var. *banatica*), which also cover the Trescovăț Peak.

The Danube Gorges (Cazanele Mari and Cazanele Mici in Romanian, Veliki and Mali Kazan in Serbian) represent preserved areas for fauna and flora on Urgonian reef facies with high relief energy. The Gorges are separated by the Dubova gulf. An important Site of Special Scientific Interest (SSSI) is the Bahna palaeontological site, with a well-preserved Miocene reef (Figure 1).

The Geology of the South Carpathians is essential for controlling the flora, the fauna and the human distribution and economy of this region. Established in 2003, the Iron Gates Natural Park is preserving these geological and biological values, as it is the second largest natural park in Romania, covering more than 120.000 hectares of unique natural heritage.

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Figure 1. Distribution of SSSIs and geosites in the Iron Gates Natural Park, as they were introduced by Popa (2003). Original illustration and caption by Popa (2003). Sites of Special Scientific Interest (SSSIs): 1. Saraorski SSSI; 2. Bahna SSSI. Geosites: 3. Cozla mine; 4. Camenița pit; 5. Bigăr coal mines (two galleries); 6. Buschmann gallery; 7. Stanca gallery; 8. Pietrele Albe gallery; 9. Munteana-Dumbrăvița outcrops and the "suspended" fold; 10. Trescovăț Peak; 11. Stariștea Valley; 12. Romanian Greben; 13. Zeliște and Veligan Peaks; 14. Tri Cule cuesta; 15. Selski Creek; 16. Cazanele Mari; 17. Cazanele Mici; 18. Cazanele Mici (Urgonian pillars); 19. Baia Nouă (Nove Doly); 20. Eibenthal; 21. Cucuiova; 22. Povalina. Important sites: 23. Between Stariștea and Jelișeva Valleys; 24. Jelișeva Valley; 25. Jelișeva "Sovrom Uranium" mine; 26. Povalina Valley; 27. Sirinia Valley; 28. Bigăr beds; 29. Sirinca Valley; 30. Between Boștița Mare and Svinița (Iardumovacia) valleys; 31. Svinita; 32. Between Iuți Valley and Selski Creek; 33. Iuți; 34. Tișovița Valley; 35. Vârciorova; 36. Between Gura Văii (Jidoștița) and Schela Cladovei.

CARBONATE DEPOSITS IN ROMANIA. HYDROGEOLOGICAL REGIONAL CLASSIFICATION OF THE KARST

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Carbonate rocks in Romania outcrop over a total area for which estimate range between 4400 km^2 (limestones and dolomites alone, Bleahu M and Rusu Th, 1965) and 5637 km^2 (4602 km^2 limestones and dolomites and 975 km^2 carbonate sandstones and conglomerates, Sencu V, 1968), being included in geological structures that belong to the Orogene (the Carpathian Orogene and the North-Dobrogea Orogene) and to the Moesian Platform.

The karstification and generation of the karst systems is subject to the same hydrochemical and hydrodynamic laws, irrespective of the tectonic structure, of the lithologic constitution and of the topographic setting in which the carbonate deposits occur. The structural and topographic setting specifically control the manner in which these systems are emplaced and develop and thus a distinction of the karst areas based on these features is useful in terms of a regional hydrogeological approach.

The variety of the structural and topographic settings in which carbonate rocks may occur is directly mirrored by the groundwater recharge, flow and discharge pattern, which has resulted in differentiating, in hydrogeological terms, between 4 karst types: the mountain karst (the karst of Carpathian Orogene), the peneplane karst (the karst of North Dobrogea Orogene), the platform karst (the karst of Moesian Platform) and the bedding karst (the karst of Carpathian post-tectonic covers) (Figure 2).

1. The mountain karst (the karst of Carpathian Orogene)

Within the Carpathian Orogene folded units, carbonate deposits are included in complicated geological structures, strongly folded and fractured, frequently involved in great overthrust nappes systems. The orogenic movements resulted in up-lifting these deposits at high altitude, thus creating large vertical expansions, hence strong hydraulic gradients, which together with their intense fracturing favored intense karst development processes.

Surface stream courses in the Carpathian Orogene karst areas frequently display a temporary flow character. The groundwater average transit velocity is often rather large, tracer tests documenting values of 2-100 m/hour. Underground residence time of the water is relatively small, while springs flow rates and water physical-chemical parameters exhibit a large variation in time over one hydrological year span. In terms of landforms, karst areas in the Carpathian Orogene display various features (mountains topography, high and low plateaus, limestone bars), that at their turn result in a certain specificity of the previously mentioned parameters. The flow rates of the main springs do not exceed $2 m^3/s$ as mean annual discharge.

2. The peneplane karst (the karst of North Dobrogea Orogene)

Carbonate deposits in Tulcea area of North Dobrogea Orogene, consisting of Triassic limestones and dolomites extending over an area of 149 km^2 (Bleahu M, and Rusu T, 1965), are involved in complicated geological structures, similar to the previous type. The flat topography of this area however induces a small gradient of the water table aquifers located within these deposits and a small groundwater flow velocity. The area has a deficit in rainfall regime (400-500 mm/year). The average flow rates of the main springs do not exceed 10 l/s. The main karst water flow is directed east-southeast, toward Razelm Lake, the structure plunging axially in that direction (Pascu M, 1983).

3. The platform karst (the karst of Moesian Platform)

Within the carbonate series of the platform areas, that display significant thicknesses and virtually horizontal structures, slightly or not at all folded, yet concerned by important systems of vertical faults, there are located large aquifers displaying very small hydraulic gradient and very slow groundwater transit time.

The northern part of the Moesian Platform, developed in the Romanian Plain and in South Dobrogea, includes in its geological layout a stack of Malm-Barremian limestones, up to 1500 m thick. These rocks outcrop over restricted areas in the southern part of the Romanian Plain (on the Danube border, at Giurgiu), yet they cover extended areas south of the Danube, in Bulgaria. The carbonate complex in the Romanian Plain extends over a 30,800 km^2 area; it progressively sinks northward, beneath younger deposits, reaching more than 2000m in depth in the Bucharest City area, where the aquifer reservoir has a thermal character (Zamfirescu *et al*. 1994). To the east, the Malm-Barremian limestones gently rise, to outcrop again on the Danube river border, at Hârşova and in South Dobrogea.

In South Dobrogea, the flat topography generates in the two karst aquifers that overlie one another, the Malm-Barremian and the Sarmatian one, small hydraulic gradients, that impose very small transit velocities, estimated to 2.6-5.4 m/year for the first aquifer and to 0.8 m/year for the second one

(Davidescu F D, Tenu A, Slăvescu Ana, 1991). These aquifers have been investigated in detail and they are extensively exploited, representing the only water supply source in this area (Pitu N, 1980).

Babadag basin is the post-tectonic cover of the North Dobrogea Orogene, consisting prevalently of limestones and sandy limestones of Cretaceous age, with its thickness reaching 1000 m, has the configuration of a syncline structure, of 732 km^2 area, out of which limestones outcrops occupy 332 km^2. It strikes north-northwest - south-southeast, plunging eastward, beneath Razelm Lake and the Black Sea. The karst aquifer has a small hydraulic gradient, which imposes a slow groundwater transit to the east, where it probably discharges through submarine discharges (diffuse, springs or line of springs).

4. The bedding karst (the karst of Carpathian post-tectonic covers)

The sediments of the Carpathian Orogene post-tectonic covers have been deposited in basins, with unsteady basement (intermittent subsidence) and they consist of alternating rocks of various lithologic constitutions, in which carbonate rocks are frequent and may often reach thicknesses of several tens of meters, outcropping over an area of about 540 km^2. They have a monocline, slightly inclined structure and are slightly concerned by major tectonic features.

Such a setting occurs on the north-western border of the Transylvanian Basin, where within the Eocene and Oligocene deposits series there occur two, 20 and 30-60 m thick limestone horizons, separated by alternating, 40-70 m thick marl and gypsum layers.

Aquifers hosted in bedded limestones have reduced resources, their recharge being supported mainly by surface runoff from non-carbonate terrains. The discharges of the springs are reduced and display large seasonal fluctuation. There are many karst systems extending over small areas but with a highly organized drainage structure.

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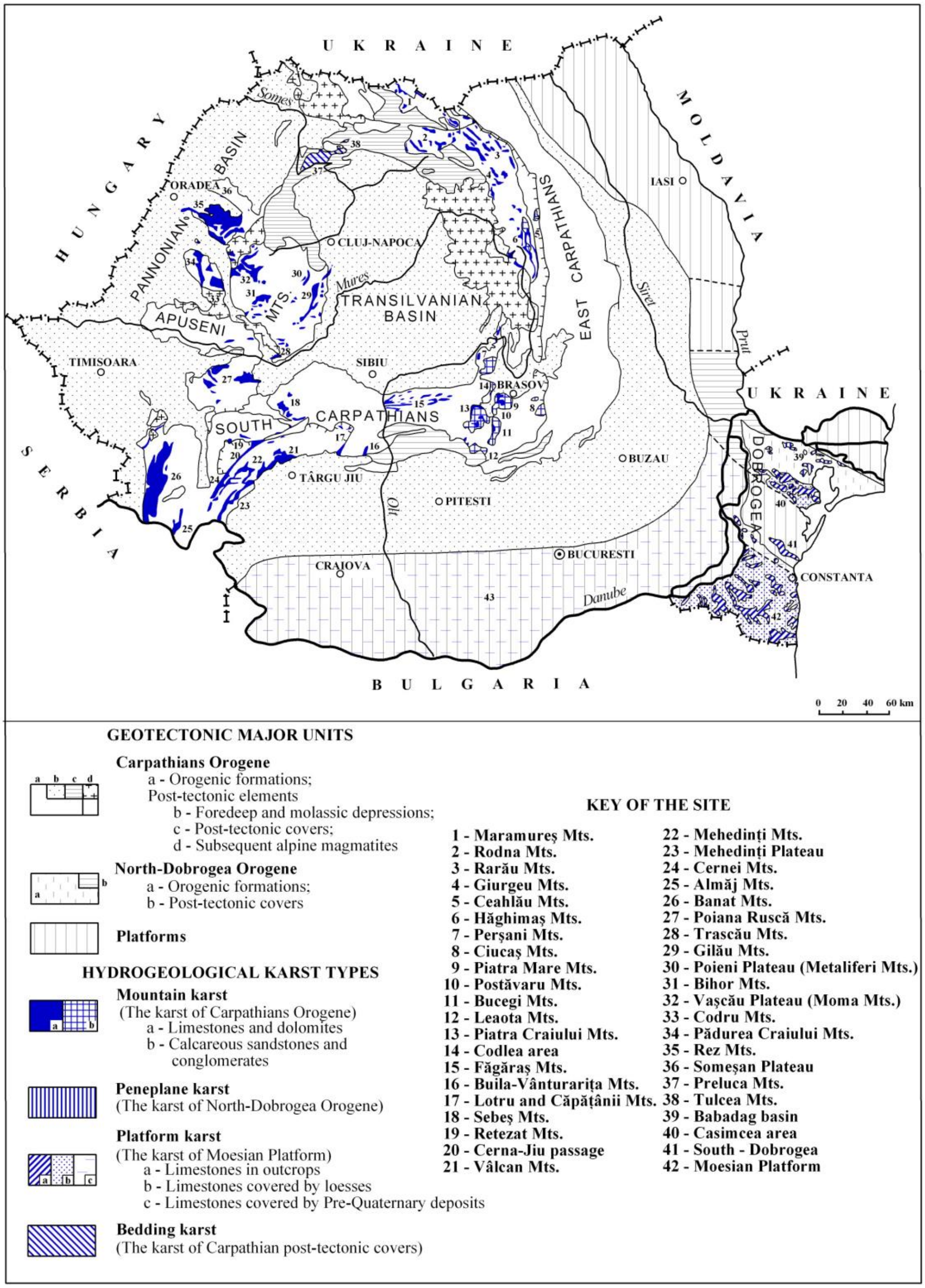

Figure 2. Distribution of the hydrogeological karst types in Romania (Structural map after Săndulescu M, 1984).

SHORT HISTORY OF THE HYDROGEOLOGICAL INVESTIGATIONS OF KARST IN ROMANIA

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In Romania, as in other countries, the first information on karst springs and groundwater flow has been provided by geographers, geologists and cavers. In the year 1901, the Romanian geologist S. Mihuția has performed the first tracer testing of an underground stream course in Romania. By labelling the water of Ţarina stream with charcoal powder, he outlined the hydrologic connection between Câmpeneasca cave, in Vaşcău karst plateau, and the Boiu spring, next to Vaşcău town (Mihuția, 1904).

In 1908, the Marghitaş and Buhui dams were built on Buhui stream, the lakes being the only ones in Romania placed on limestone. Downstream the Buhui Lake, the water controlled by the dam is then distributed in the limestone area and feeds, together with Certej spring, the underground flow of Buhui cave. At the end of the cave there is an artificial underground lake, representing the main water-supply for the city of Anina via an artificial gallery, of 1.3 km long (Sencu, 1967).

The first systematic hydrologic investigation of the landforms in the karst areas of Romania has been performed by the Institute of Speleology "Emil Racoviță" (ISER) and by the Institute of Geography. Starting from the very first papers published by the scientists of those two institutions, Şerban M, Coman D, and Viehman I (Bihor Mountains, 1957), Rusu T, Racoviță Gh and Coman D (Bihor Mountains, 1970), Viehman I (Bihor Mountains, 1958, 1966), Sencu V (Anina area, 1970, 1978, 1986), Rusu T (Pădurea Craiului Mountains, 1960-1988), Trufaş V (Sebeş Mountains, 1965) along with Bișir and Pascu M, from ISPIF Company (Cerna area, 1967, 1969) one can notice their obvious concern for identifying the groundwater flow paths, fluorescein tracer tests being performed in this respect.

Over the time interval of 1960-1988, the karst areas in Pădurea Craiului Mountains have been subject to detailed karst topography and hydrology investigations conducted by Rusu T, who performed a multitude of fluorescein tracer tests, by which he outlined the main karst flow directions. The integral publication of those results occurred in the year 1988.

The Institute of Speleology "Emil Racoviţă", specifically Povară I, has carried out over 1965-2007 periods, an extensive activity of investigating the karst hydrogeology of Cerna River catchment area, of Mehedinti Mountains and Plateau, West Jiu area and South Dobrogea. The chemistry of the karst waters in Pădurea Craiului, Cerna graben and Mangalia area made the object of very detailed studies authored by Marin C.

The impressive "Karstic Morphology" of Bleahu M, that has been published in 1974, is in fact a comprehensive encyclopaedia about the karst and its genesis, a work of a highly positive impact on karst researches in Romania and not only. Starting from the year 1970, the department of hydrogeological surveys of Prospectiuni S.A. company has carried out a constant activity aimed at investigating the most carbonate rocks areas in Romania, in order to complete hydrogeological maps, to compute the water budget, to assess the groundwater resources, to delineate the main karst flow paths and to outline the groundwater chemistry. In order to delineate the groundwater flow paths, the Prospectiuni S.A. Company has performed about 170 tracer tests, many of them in cooperation with the Tracer group of Institute of Physics and Nuclear Energy (IFIN) led by Gașpar E. For these tracer tests, there have been initially used radioactive tracers (Iodine-131, Bromide-82), and after the year 1980, activable tracers (In-EDTA, Dy-EDTA, La-EDTA), fluorescent tracers (fluorescein, rhodamine B) and whitening optic agents (stralex).

The National Institute of Hydrology and Water Management (NIHWM), performed hydrologic investigations, including tracer tests and studies with environmental isotopes.

Starting with 1983, a series of conferences dedicated to *Theoretical and Applied Karstology* (TAK) was organized by the Emil Racoviţă Institute of Speleology (ISER) and Prospecţiuni S.A. The conference papers and posters were published in seventeen numbers of the TAK *Journals*.

Hydrogeological knowledge of karst areas was the subject of PhD theses performed by Țenu A (1979), Rusu T (1979), Pitu N (1981), Povară I (1997), Moldoveanu V (1999), Orășeanu I (2000), Istrate Al (2001), Iurkiewicz A (2004), and Rotaru A (2009).

The volume *Karst Hydrogeology of Romania* edited by Iancu Orăşeanu and Adrian Iurkiewicz in 2010 is fully dedicated to the karst hydrogeology unifying in a coherent manner the characteristics of the most Romanian karst aquifers and karst systems distributed over large areas with complex geomorphological and geo-structural features from Carpathians to the Black Sea coast.

During the recent years few other monograph volumes were published i.e. Istrate A (Bucegi Mountains, 2012), Povară I (Cerna Valley, 2012) and Orăşeanu I (Apuseni Mountains, 2016).

Along the decades more than 100 speleological clubs were founded, enrolling some 10,000 members that largely contributed to the registered number of around 12,500 caves. A certain number of clubs and speleologists also contributed to the most recent volume regarding *Cave and Karst Systems of Romania* edited by Ponta Gh and Onac B, that is a systematic review of the representative aspects concerning some of the most significant Caves of Romania. The volume has been published in 2019 as part of the *Springer* series of *Cave and Karst Systems of the World* coordinated by James W. LaMoreaux.

Main Reference:

Orăşeanu I, Iurkiewicz A, (eds.), 2010, *Karst Hydrogeology of Romania*, Ed. Belvedere, Oradea, 444p.

KARST AREAS IN THE SOUTHERN CARPATHIANS BETWEEN MOTRU AND OLT RIVERS

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(chapters adapted from *Karst of Romania, Selected Routes from Southern Carpathians*, second edition, Silviu Constantin Editor, Bucharest, 2006, Field trip guide published on the occasion of the fourth Conference “Climate Change — The Karst Record” a special edition of the XIXth International Symposium of Theoretical and Applied Karstology, *Băile Herculane — Romania, May 25–29, 2006*, with author’s permission*)*

One of the most interesting field trips in the karst of Romania is undoubtedly the one along the main limestone areas located on the southern slope of the Southern Carpathians. This is a two-day trip which starts in the Motru Valley. From here on, two alternatives are equally attractive: the first one is to visit the karst areas and basins in the northern part of Mehedinţi Mountains, such as the valleys of *Motru Sec*, the karst around the village of *Cloşani*, or the remote limestone peak of *Piatra Mare Cloşani* (1421 m) and its dissected limestone pavements and deep shafts. This area albeit included in this guide-book will not be visited.

The second alternative is to pay a visit to the northern and central sectors of the Mehedinţi Plateau, which extend south of Baia de Aramă. The favorable position of the “Emil Racoviţă” Institute’s laboratory hut in Cloşani makes both of these field trips easily accessible and also facilitates the access to the limestone areas from the south of Vâlcan Mountains.

However, our visit will start at the site at *Ponoarele* that has been longtime a textbook example of karst morphology for it concentrates on a small area two large depressions with active swallets, a karren field, a natural bridge and several caves including the 5 km-long Bulba system.

Beginning with Vâlcan Mountains, the Southern Carpathian range straightens up along a W-E direction. From this point, the geological structure becomes somehow simpler including almost exclusively deposits of the Danubian Domain. The cores of the mountain ridges are formed by the crystalline schists of the basement, while on the margins limestone patches belonging to the sedimentary cover outcrop. They are dissected by deep valleys originating on the impervious basement or, in some cases, from glacial cirques; in all cases, these valleys have cut deep gorges within the limestone bodies.

The gorges and associated caves from the Southern Carpathians were since longtime used as a last refuge for the inhabitants facing various invasions and as a preferred place for hermits and monks in search of isolated spaces. It is the reason why, beginning from Motru valley, a chain of “gorges-caves-monasteries” may be encountered. Among them, the most important are the *Tismana*, *Polovragi*, and *Bistriţa* monasteries, each one located within or near limestone gorges and caves.

Other spectacular gorges that may be visited are the *Sohodol Gorge*, near the town of Târgu Jiu and the *Galbenul Gorge*, in Parâng Mountains, where the extensive underground system of *Muierilor Cave* has formed.

MEHEDINTI MOUNTAINS — THE NORTHERN SECTOR

The Obârşia Cloşani – Piatra Mare Massif represent the northern part of the Mehedinţi Mountains. The massif is limited to the south by the *Brebina Valley* and to the east by the *Motru Valley*. The main ridge is developing on a SW–NE direction, the highest elevation being of 1421 m asl. (Piatra Mare a Cloşanilor Peak). The massif is divided in two sub-sectors by the *Motru Sec River,* which cuts transversally the limestone ridge approximately in its middle sector. Functionally, these two morphological sectors form a unitary karst massif.

Geological Data

The Getic Unit is represented by the *Bahna Outlier*, a rest of the *Godeanu Nappe* developed on the right flank of the Cerna River. The metamorphic deposits overlie the wildflysch deposits of the Danubian Unit or those of the Obârşia Unit. With an irregular and discontinuous development, the deposits of the Obârşia Unit are a tectonic mixture of ophiolites and metamorphic and sedimentary rocks. The Obârşia Cloşani – Piatra Mare Massif is a syncline ending with asymmetric flanks: the western one forms the main ridge of the massif; to the east, the flank is represented by the limestone outcropping near Baia de Aramă. Due to this structure the overthrusting units (*Getic* and *Obârşia* Nappes) were preserved along the syncline axis.

Tectonically, the massif is delimited by two major faults. To the South, this limit coresponds to a strike-slip fault: the Godeanu – Obârşia – Baia de Aramă Fault along which the Brebina Valley flows. To the east, the Motru Fault represents the other major tectonic limit. A secondary fault is the Motru Sec Fault, which allowed the river with the same name to cross over the main ridge, forming a short gorge sector.

Karst features

The limestone surface outcroping in the Obârşia Cloşani - Piatra Mare Massif, is around 33 km^2. The massif represents a bar-karst type, modelled mainly by the fluviatile processes. Locally, small plateaus can be identified. The most common surface karst features can be recognized especially on the plateaus: sinkholes, sinkhole valleys, blind valleys, covered grikes, etc. Also, the plateaus show the most disorganized hydrographic network. The limit of the plateaus can be traced at 850 m altitude. Below this elevation steep valley sides cut by gulleys prevail. A somehow different landscape is shown by the structurally-induced cuesta of the Piatra Mare ridge (with a cliff exceeding 200 m) and the small gorge developed along the Motru and Motru Sec valleys.

Over the entire massif they have been recorded 114 cavities. Most of them do not exceed 50m in length. The longest caves are *Peştera Lazului* (3201 m) and *Peştera Martel* (4133 m). The deepest shaft of the massif is *Avenul de sub Godeanu*, reaching –114 m in depth. Despite the great number of cavities there is no evidence of a very developed subterranean network.

The hydrogeological functioning of the massif is quite complicate. There can be recognized several karst drainage systems. The most important is the *Motru Sec –Baia de Aramă*. The karst springs are located on the south-eastern flank of the syncline, near Baia de Aramă, along a fault lineament oriented N–S; their flowrates range between 235 and 11 l/s. Their catchment area was proved by tracing tests and covers the northern half of the Obârşia sector and the entire Piatra Mare sector (Figure 3, Bandrabur *et al,* 2010).

The springs are mainly supplied by the diffuse losses in the riverbed on Motru Sec. The analyses show a complex functioning with two flowing components: a rapid, less important, one, and a slow and steady one. These conclusions argue for a functioning structure probably with a less developed main drain and important annex system (Rotaru *et al,* 1995). Another karst system develops on the southern part of the Obârşia sector with a single spring located west to the *Obârşia Cloşani* village. Few other local systems, generally of epikarstic type show only a temporary functioning.

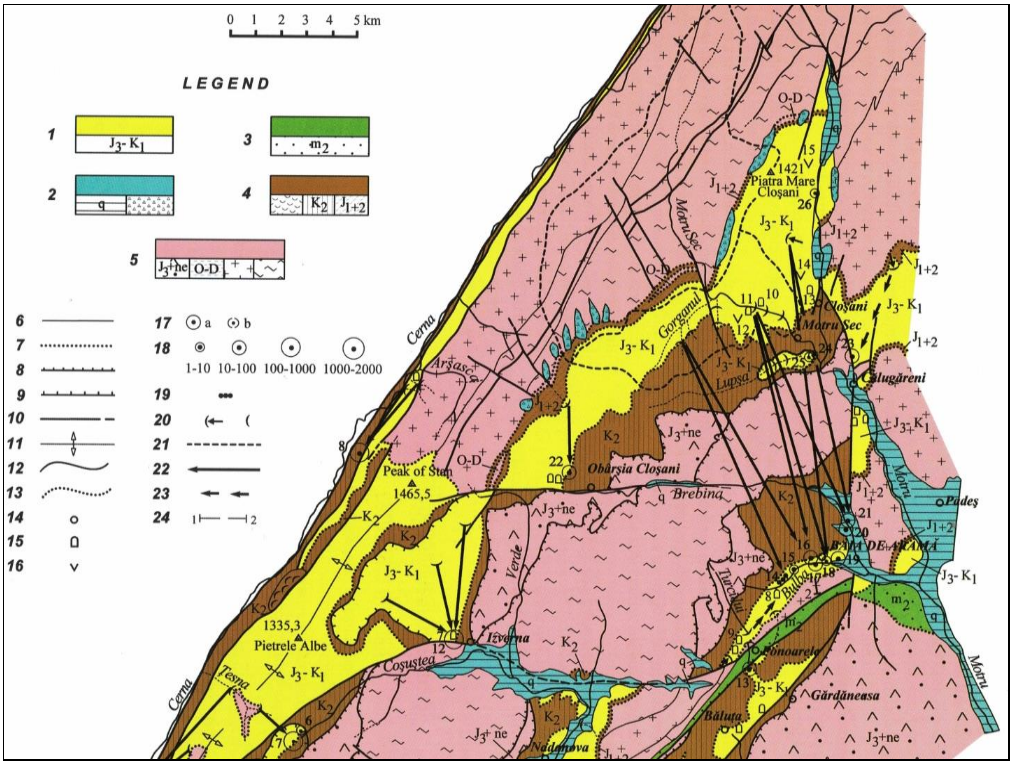

Figure 3. Hydrogeological map of the Mehedinți Mountains and part of the Mehedinți Plateau (Bandrabur et al. 2010)

Legend: **1**. Mesozoic carbonate series, fractured and karstified, characterized by intensive groundwater flow; Numerous karst systems with important water resources; Springs with flow rate up to 2000 l/s; Mesozoic limestones (J3-K1); **2**. Quaternary detritic deposits with reduced thickness and extension, hosting granular aquifers of local importance; alluvial deposits (q) and screes; **3**. Detritic deposits with permeability of fissures and pores with reduced thickness and extension; Discontinuous water accumulations in the more permeable terms; Miocene sands, gravels and clays (m2); **4**; Deposits including rock-complexes of variable permeability, occasionally aquifer forming; Holocene landslides; Cretaceous marly-limestones, sandstones and clays (K2); Jurassic clays and sandstones (J1+2); **5**. Mesozoic ophiolites (J3+ne), Palaeozoic shists (O-D), Precambrian and Palaeozoic granites and schists of large thickness and extensions. Heterogeneous and anisotropic distribution of fissure permeability; **6** - Geological boundary; **7** - Unconformity boundary; **8** – Overthrust plane; **9** - Wedge; **10** - Fault; **11** - Anticline; **12** - Perennial surface course; **13** - Temporary surface course; **14** - Locality; **15** - Cave; **16** – Pothole (Aven); **17** - Perennial spring (a); temporary spring (b); **18** - Sources discharge (l/s); **19** - Group of springs; **20** - Ponor; **21** - Limit of the hydrographic basin checked by hydrometric gauging sections; **22** - Underground flow direction established by tracer experiments; **23** – Inferred groundwater flow direction; **24** - Hydrogeological cross-section line.

The outlets of the Motru Sec – Baia de Aramă karst system (the karst springs at Brebina)

The karst system of Motru Sec – Baia de Aramă is drained by a group of 43 springs (Goran, 1978); eight of them are perrenial and have the highest flow rates. They are located along a lineament that starts 2 km NW from Baia de Aramă (in the alluvial plain of Brebina) and continue to the SW to reach the Bulba valley (approximately 2 km SSW from Baia de Aramă). The more important springs are in the northern part with flow rates exceeding 250 l/s. Tracer tests allowed the identification of the limits of the karst system. Slavoaca *et al.* (1985) have performed two tracer tests: one on the right-side tributaries of the Gorganul Valley and the other one on the Motru Sec river, upstream Motru Sec hamlet. The two tracers were found in the karst springs at Baia de Aramă. The mean transit period was around 200 hours. Diaconu (1989) has proved the link between the water losses in the *Izvorele* area and the same springs at Baia de Aramă.

Cloşani Cave

Cloşani is one of the most famous and, at the same time, one of the most studied caves of Romania. It is known at least from the beginning of the XIXth Century; during the late '60s, several laboratory-cubicles were built in the cave in order to facilitate biospeleological experiments. In the final zone of one of the passages, a station for monitoring terrestrial tides was established in 1969. Besides the biospeleological studies, the crystallography of the calcite speleothems made the object of a detailed study (Diaconu, 1990), while the results of cave topoclimate monitoring were published by Racovita *et al*. (1993).

The cave is developed in massive limestones of Upper Jurassic–Aptian age and it is located at 433 m asl, on the right side of *Motru Mare* River (Cloşani village, Gorj County). It consists of two main passages with a total length of 1458 m disposed over an elevation range of only some 15 m (Figure 4). The two passages split after a short entrance zone: the first one (*The Laboratory Passage*) follows broadly a direction parallel to that of *Motru* River. The second passage, known as *The* '*M. Ghica*' *Passage* or *The Crystals Passage*, is located at an upper level, *c.* 8 m in average above the Laboratory Passage. Its orientation towards the NW suggested that it has been formed by the small stream of *Izvorele*, which currently parallels the Motru River. Detailed accounts on cave morphology and genesis are given by Bleahu *et al*. (1976), Decu *et al*. (1978) and Diaconu (1990); the last author also published an extremely detailed plan of the cave (Figure 4).

The passages of the cave display the whole range of classical speleothems plus several exceptional forms which may be found within the Crystals Passage. The erosional traces are practically hidden within the entire cave by the abundant speleothems. Besides the large number of columns, stalagmites and flowstone domes, the floor of the Crystals Passage displays large rimstone pools covered by large-size calcite spar.

During 1998 and 2000, more than 60 samples from this cave have been dated by U-series alpha spectrometry (Figure 4); subsequently, a number of 18 dates have been determined by TIMS U-series method for two exceptional samples. These dates have shown that the age of the flowstones deposits in Cloşani cave (especially those from the entrance area and the massive speleothems in Laboratory Passage) often exceed 350 ka; in some cases, even the 500 ka limit of the TIMS method. However, most of the speleothems seem to have grown during the MIS 5 to 3, with a slight decrease of the overall growth rate during stage 4. A dating experiment on the age of the different levels of pool-crystals yielded consistent results, which indicate that the maximum pool precipitation has occurred between *c*. 110 ka and *c*. 50 ka (Constantin & Lauritzen, 1999; Constantin, 2003).

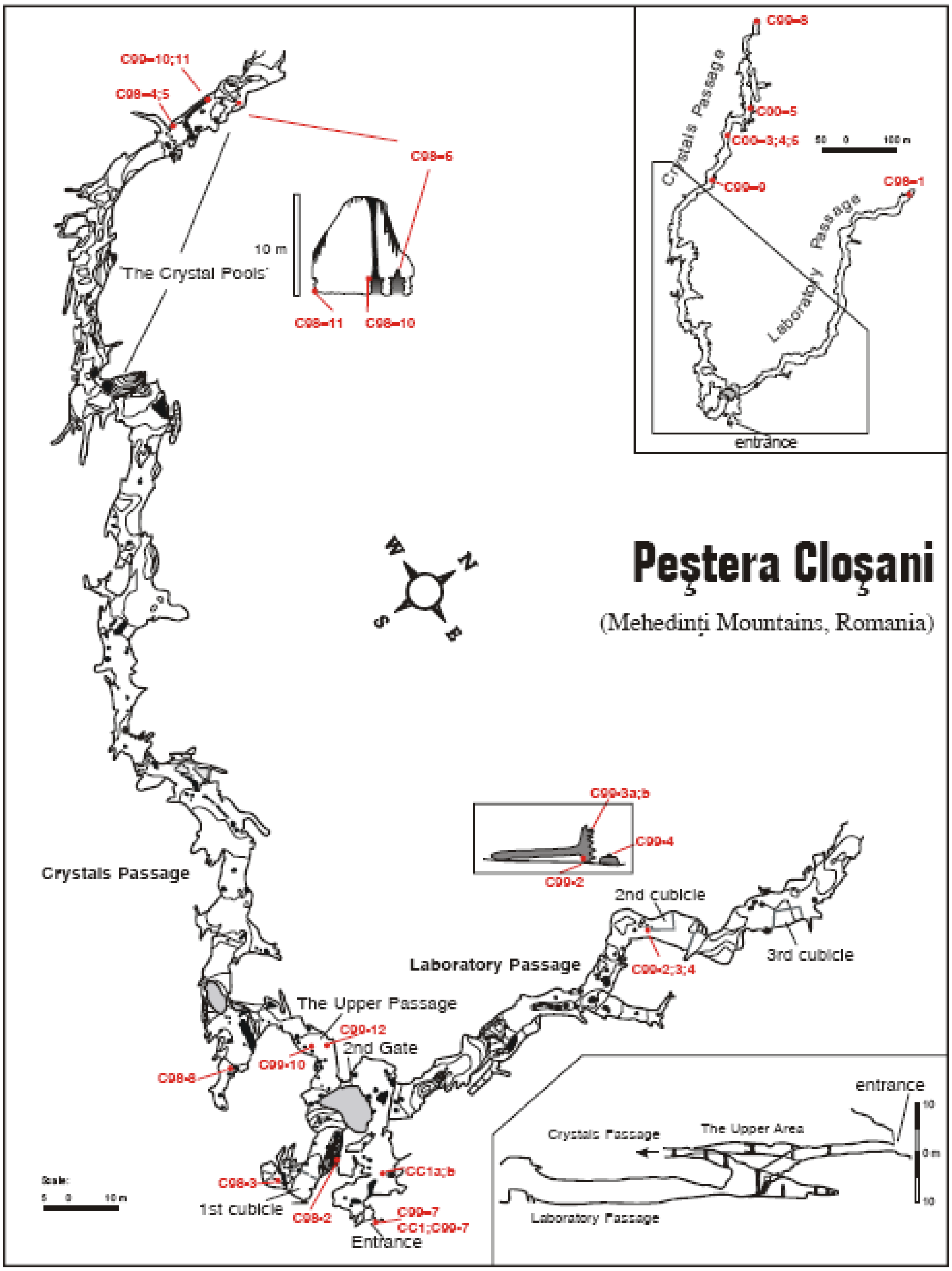

Figure 4. Map of Cloşani Cave and the location of the speleothem sampling points (after Constantin, 2003; cave plan from Diaconu, 1990, simplified).

THE KARST OF THE MEHEDINTI PLATEAU (BAIA DE ARAMĂ–BALTA–PONOARELE–BULBA)

The karst in Mehedinti Plateau has a rather small surface, but displays a great variety of surface features and hosts some large underground system which makes it one of the most important karst areas in the country. More than 200 caves have been surveyed (among them, Topolnita is 20.5 km long, and three other cavities exceed 3 km in length); to this, we may add the presence of *cornets* — karst cones typical for this area, the numerous karst depressions, limestone pavements and the well-known natural bridge at Ponoarele.

Regional framework

Mehedinţi Plateau is lithologically, morphologically and hydrographically linked to the external part of the Southern Carpathians, by which it distinguish through its lower elevations. It is bordered by Mehedinţi Mountains (NW), Almăj Mountains (W) and the Getic Foothills (SE). Transversally, the plateau is interrupted by the Danube Gorge in the SW and the Motru Valley in the NE.

Within these limits, the plateau has the shape of a rectangle, whose long sides parallel the Carpathian range (NNE-SSW). Mehedinţi Plateau has basically the same geological structure as the neighboring units; its distinctiveness is only given by the "plateau aspect" and the lower elevations of only 400–500 m.

Geology, landscape and hydrography

The maximal elevation of Mehedinţi Plateau, of 885 m asl is recorded in the Paharnicul Peak, located in its central-western side; the average elevation ranges between 500–600 m, while the lowest altitudes vary from 250–300 m at the contact with the Getic Foothills (SE), 150–200 m in Turnu Severin Depression (S) and only 50–75 m in the Danube Gorge (SW). The main relief units are defined by petrographic and structural discontinuities into blocks of different geological structure, massivity and altitude.

The main fragmentation line develops from NE to SW and matches the general structural model, while the secondary ones are due to the strike-slip faults generated during the Neogene uplifting (NW-SE). Those main directions form a tectonic network including distinct petrographic (from West to the East) and geomorphic units (from North to South).

Geological structure

The geological structure of Southern Carpathians includes two main tectonic units: the Danubian Autochtonous and the Getic Nappe; between these may be occasionally found the crust and sediments of an oceanic crust domain: the Severin Unit. This structure has formed by the subduction of the Danubian Unit under the Getic Nappe between the end of Jurassic (Kimmeridgian-Tithonian) and the end of Cretaceous (Campanian-Maastrichtian).

Karst units and main objectives

Taking into account the disposition of the limestone areas and the differences in the karstification, one can divide the karst in Mehedinţi Plateau into four main units of which we shall visit the one from the northern area.

The karst from the northern area

In the northern part of the Mehedinţi Plateau there are two parallel karst areas: *Baia de Aramă – Ponoarele*, to the east and *Gârdăneasa-Băluţa* to the west but the later will not be visited. They are separated by granitic intrusions and by a Miocene graben; the eastern zone is raised with some 150–200 m with respect to the western one, through a tectonic cliff.

The karst zone of Baia de Aramă-Ponoarele

This karst area lies between the Valley of Brebina (N) and Zăton Lake (S) (Figure 5) and it is developed on behalf of the Barremian-Aptian limestones. Upstream of this zone, on both sides of the limestones two closed depressions are formed:

- *Zăton and Ponoarele*, which are flooded at high waters. The surface waters are captured through the caves *Zăton* (105 m in length) and *Bulba* (5 km, developed on three levels). Two levels (inactive and temporary flooded) of this drainage may be found in the Peştera Podului (734 m in length), whose wide passages link Zăton Lake and Ponoarele depressions. On the surface, lies one of the most interesting limestone pavements in Romania — the karren field at Ponoarele. Near the northwestern entrance in the cave the Natural Bridge at Ponoarele is located. This bridge (30 m long, 13 m wide, 11 m high and 9 m thick) supports a local road and was formed by the collapse of a part of the cave's ceiling.
- *The karst system of Zăton-Bulba* (Figure 5) was formed by the underground catchments of the brooks Valea Gheorgheştilor and Valea Mare in the Zăton Depression and those of Turcului and

Morilor valleys in the Ponoarele Depression. The watercourses drain towards the north, through the Bulba Cave and re-appear at some 3 km in a spring located on the right side of Bulba Valley. On the surface, the surface drainage is missing and the path of the cave is well marked by a sinkhole alignment (Băloşi Valley) and by several lateral swallets. The system is hosted by the Barremian-Aptian limestones and lies between the valley of Brebina (N) and Zăton Lake (S). It includes the karst system of Zăton-Bulba (see "main objectives" section) and the outlets of Motru-Brebina system (see *Mehedinţi Mountains*).

The karstic complex of Ponoarele is part of the Geopark Mehedinti ROSCI0198 declared natural protected area according to the Law No 5/2000 and corresponds to the 4th category IUCN.

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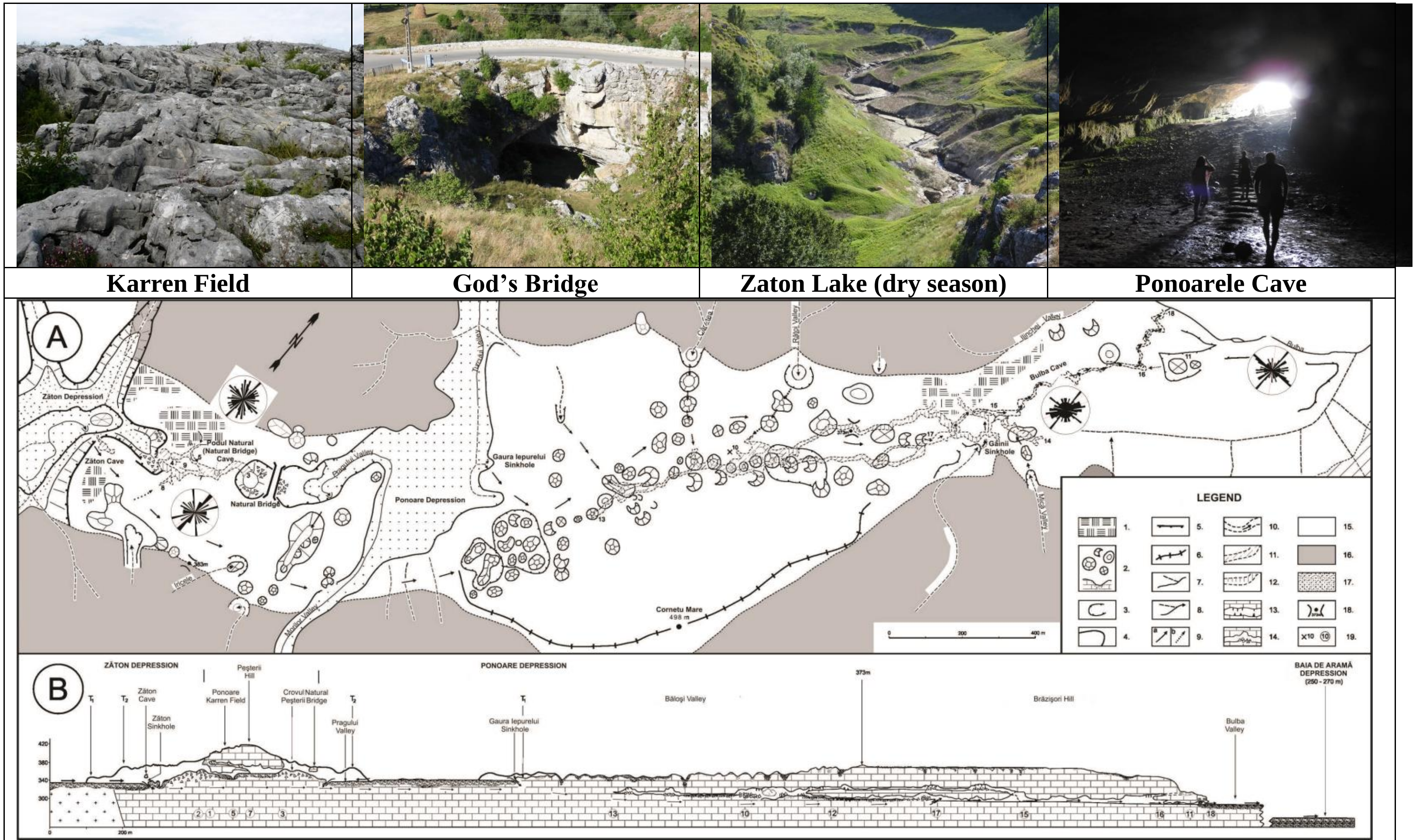

Figure 5. **A:** Zăton-Bulba karst system (Mehedinţi Plateau) with rosette diagrams of microstructural features; **B**: Cross-section
1. karren field; 2. sinkhole; 3. blind valley; 4. karst depression; 5. vertical cliff; 6. limestone ridge; 7. river; 8. swallow hole; 9. underground drainage; 10. active passageway; 11. temporary active passageway; 12. dry passageway; 13. speleothems; 14. collapsed rocks; 15. limestone; 16. non-karst rocks; 17. alluvial layer; 18. settlement; 19. mapping point (from Vlaicu et al. 2010). All photos courtesy of *Iulian Popa*

VÂLCAN MOUNTAINS (General aspects and subsequent chapters)

Adrian IURKIEWICZ, *University of Bucharest*

The Vâlcan Mountains extends over more than 900 km^2 from *Motru* valley to *Jiu* deep valley with altitudes that mainly ranges between 400-500 and 1800 m. Integrated within the western group of Southern Carpathians, the Vâlcan Mountains have a longitudinal ridge oriented WSW – ENE, lowering abruptly to the NNE (Petrosani Depression) and in steps towards the south. To the southern slopes of these mountains important calcareous areas are located, where all representative karst features as dolines, ponors, caves and sinkholes largely occur.

Specific surveys and researches as well as regular discharge gauging were conducted throughout the years by different companies and governmental institutions. These have concluded around 1964 to start tapping the main karst springs of the area namely Izvarna and Vâlceaua for the water supply of the cities of Craiova and Tg. Jiu respectively. Further information on main karst systems of Southern Vâlcan were offered among others by Ilie (1970, 1973), Sencu (1967), Constantinescu (1975) as well as Vintilescu et al. (1970). Many other data were gathered and included in unpublished reports or researches conducted for the implementation of the so-called *Cerna – Motru - Tismana* hydropower project. Key underground connections between the main surface water inflows and karst springs of Southern Vâlcan Mountains were presented by Rădulescu et al. (1987).

Based on previous data and extensive surveys conducted on the southern slope of the Vâlcan Mountains the overall hydrogeology of the karst systems of this area was thoroughly investigated and described by a Prospectiuni SA Company team (Iurkiewicz A, Slăvoacă Ruxandra and Slăvoacă D, 1991, 1992) and concluded by Iurkiewicz & Mangin (1994), Iurkiewicz et al. (1996) and Iurkiewicz (1994, 2004). A detailed analysis has been dedicated to Izvarna karst system by Iurkiewicz (2009).

Recent interpretation of the structural evolution of the western ranges of South Carpathians commonly accept a structural edifice composed by three groups of tectonic units, i.e Getic-Supragetic Units, Severin Nappe and Danubian Units (Berza, 1997). The similar tectonic pattern of the whole group including also the Vâlcan Mountains is thus dominated by the overthrust of the Getic Units over the crystalline and sedimentary formations of the Danubian Units. According to the model proposed by Pop (1973), Pop et al. (1975), Marinescu et al. (1989), Stan et al. (1979) within the *Geologic Map of Romania* (1:50.000), sheets of *Tismana*, *Peştişani* şi *Câmpu lui Neag*, the overall geological structure of Vâlcan Mountains (Figure 6) include a crystalline basement, consisting of crystalline schists and granites of Precambrian age and a sedimentary cover starting with Lias formations (sandstones, shales and conglomerates).

The limestone deposits may reach a thickness of 1000 m and are of Dogger-Aptian age. The lower sequence of these deposits is mostly layered, while the upper one is massive. The whole carbonate package is unconformly covered by a flyschoid series of Cenomanian-Senonian age. From a structural point of view the limestone mostly occupy a normal position between the Lias age sandstones and the Upper Cretaceous flysch, while some parts are thrusted over the flysch and largely occur, yet as relatively thin (<200 m) bodies (Figure 6). Still the major shafts of the region (some of which count also among the deepest in Romania, Cârca Parateilor-121 m) are located in such bodies, which occupy the summit of Mount Pleșa.

The carbonate formations are located in three distinct morpho-geologic settings:

a) In the northern part, near the main ridge, thin crystalline limestones (not indicated on the map) occur, interbedded within. However, one of this narrow (~100 m) limestone layers hosts the currently deepest cavity of the mountain range, Cartianu (-142, +23 m), inside which an underground stream of about 15-20 l/s flows.

b) In the south-eastern part, Jurassic-Cretaceous limestones with a low degree of crystallinity occur on a large and rather compact area. Deep valleys flowing from north to south and their tributaries delineate several isolated summits: Pleșa, Plescioara and Stersura-Bordul Dobriței. Devoid of surficial runoff, these areas preserve old morphologic surfaces, perched several hundred of meters above the contemporary streambeds.

c) In the south-south western part, limestones of Urgonian facies frequently display a massive, reef character, and build a low and elongated barrier, crossed by many surface streams. The existing fault systems of regional amplitude and the overall high degree of fracturing favored the organization of remarkable underground drainages.

Among the top karst phenomena from southern Vâlcan Mountains we should mention *Pârgavului Cave* (L=3600 m, D=120 m), *Râpa Vânată Cave* (L=2100 m, D=47 m), *Tismana Monastery Cave* (L=1000 m, mostly submerged), or *Gârla Vacii Cave* (1460 m in length) as well as the main potholes *Clocoticiul 1 din Scoaba Sărăturii* (L=150 m, D=98 m), *Clocoticiul din Cârca Parateilor* (149 m in depth), and the impressive *Urloi* pothole (62 m in depth).

The surface stream-network supplies the carbonate reservoir through diffuse or concentrated swallets, which may be either partial or total losses. The inflows vary between 5-200 l/s, which account for 50-100% of the total flowrate of a stream. The mean runoff displays significant variations, between 12.5 and 45 $l/s/km^2$, according to the season and to the considered elevation range. Another component of the aquifer recharge includes the rainfall on the limestone outcrops, which varies between 700 mm/year (at 200 m elevation) and 1100 mm/year (at 1500 m elevation).

Granites and granitoides of Şuşiţa and Tismana, also largely occur on the southern slopes of Vâlcan Mountains (Figure 6). These rocks have good fissural permeability, which favors the storage and circulation of the groundwater, thus contributing to the constant recharge of the carbonate aquifer however a real assessment of water volumes transferred from an aquifer to another was not possible even some attempts in this direction were made.

The upper cretaceous flyschoid deposits, with quite a different lithology, display the same hydrogeologic behavior, which includes low discharge springs (1-3 l/s), yet of permanent and constant character. The metamorphic rocks and the stack of marls and clays of Meotian-Pontian age have no significant permeability and no water.

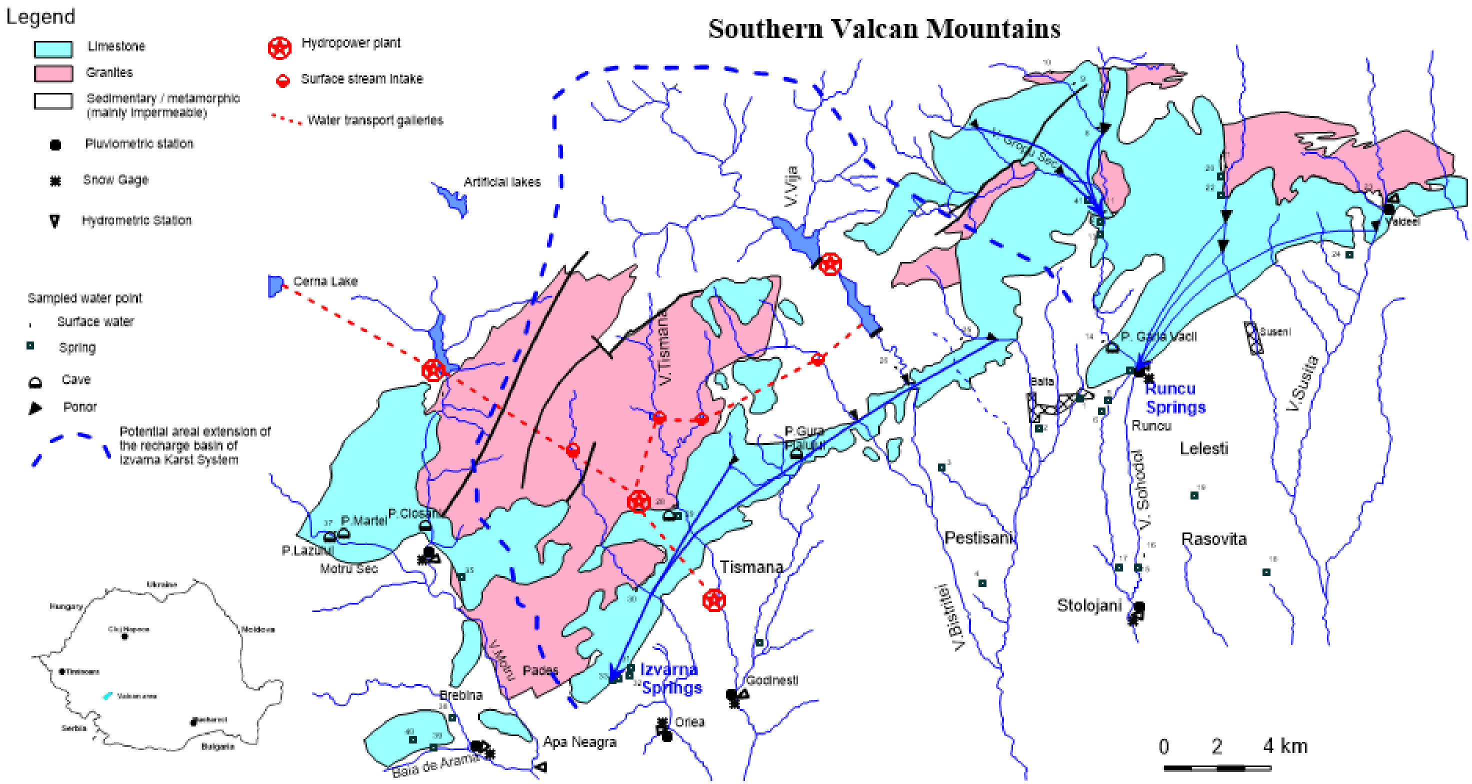

Figure 6. Sketch of Southern Vâlcan Mountains showing limestone distribution and main hydro-karst systems along with climate monitoring and isotope sampling points.

In Vâlcan Mountains three major hydrokarstic systems are organized (Figure 6), as follows:

1. The northern system (Pătrunsa-Picuiel) includes three lineaments of permanent springs, Pătrunsa, Picuiel and Valea Rea (1), with flowrates of 100-300 l/s, 100-160 l/s and 70-100 l/s respectively, as well as a lineament of temporary springs acting as an overflow, Prilejele, with flowrates of 0-200 l/s. The concentrated inflows are located in Gropu Sec valley (2), where 10-50 l/s sink, in Gropu cu Apa valley (3), where 100 -300 l/s sink, and in Sohodol valley (4), where losses of 200-300 l/s have been recorded.
2. Eight km downstream are located the resurgences of the second system, Jaleș-Vâlceaua, the main spring of which, Vâlceaua, provides one of the main water supplies to the city of Târgu Jiu (around 80,000 inhabitants).
3. The most important hydro-karstic system, flowing from north-east to the south-west, ranges among the most constant large discharge springs in Romania and discharges through the group of springs at Izvarna (Figure 7 and 8), 70% of which are tapped and piped for water supply to the city of Craiova (300,000 inhabitants).

IZVARNA SPRINGS AND WATER INTAKE STRUCTURES

The karst system of Izvarna is developed in a low and elongated limestone bar, dissected by many surface streams. The main flow-inputs to the system[1] include (from east to the west) Bâlta valley (losses of 10-30 l/s, 20 km far from the main spring Fig. 6), Bistrita valley (losses of 200-400 l/s) and Pârgavu valley (12) (losses of 10-50 l/s). Losses were also identified along the valleys of Bistricioara (50-70 l/s) and Pocruia (10-15 l/s), most probably included in the same system.

There is morphologic and hydrologic evidence (Iurkiewicz & Mangin, 1994) that an upper underground karst drainage level is overlying the main deep drainage. The main karst subsystem in this upper level is represented by the cave of Râpa Vânătă and the spring of Bolboros. It has been also inferred that the karst system receives an additional underground supply provided by a

[1] Labelled with radioactivable tracers.

fissured aquifer occupying a granitic body located to the north (Rãdulescu et al. 1985).

System discharge and water intake structures. The decision of tapping the springs of Izvarna for the public water supply of the City of Craiova (115 km far from the springs) has been taken following complex investigations carried out during 1957-1960. Results of geological studies, drilling wells, geophysics (VES) and seismic data combined with spring flow gauging have concluded the amount of water and the design of the intake structure.

Additional details on the local geology features were brought by several boreholes of different depths and vertical electric soundings (VES). This later type of surveys contributed to the identification of an important dip-slip system of faults, with an important throw of more than 150 m. To this extent the inferred fault represents the main control to the spring occurrence. Few shallow wells drilled through the overburden layer proved no lateral leakage, therefore the whole intake structure was founded to -2.5m in gravels and not in limestone.

Figure 7. Trout fishers in the former lake fed by a swarm of artesian springs

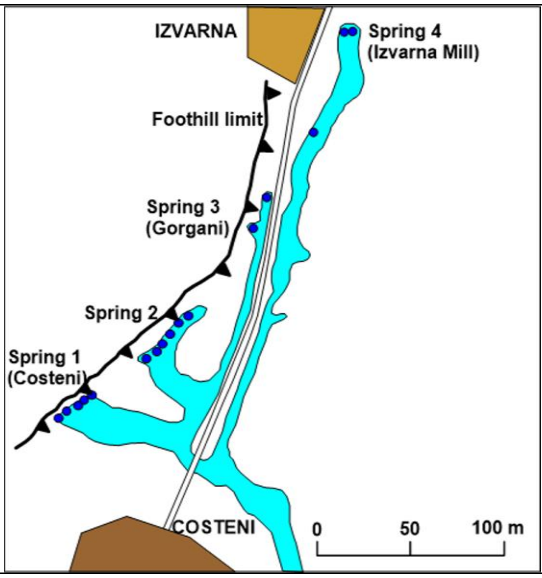

Figure 8. Line of main springs at Izvarna

During the initial recording period (1957-1960) different groups of springs were separately gaged (Table 1). Noteworthy, neither the maximum flowrates nor the minimum ones were recorded simultaneously for all the springs. The third column is representing the minimum flow rates with a probable frequency of 6.6% (1/15) based on the correlation with the time series (1921-1960) of the neighboring Tismana stream (Iurkiewicz A, 2009). The cumulated discharge from all springs was subsequently recorded for (1961-1964) period and the characteristic values for (1957-1964) period are included in Table 1.

Table 1. Characteristic values (m^3/s) for main Izvarna springs

Spring Name	Q_{max}	Q_{min} (1957-1960)	Q_{min} (6.6%)
Spring 1 Costeni	0.925	0.645	0.405
Spring 2	0.231	0.148	0.095
Spring 3 Gorgani	0.654	0.514	0.315
Spring 4 Izvarna (Mill)	0.701	0.295	0.185
Total	**2.511**	**1.602**	**1.000**

Figure 9. Intake Building


Figure 10. Main basins tapping the springs

The intake building was designed over the main spring, in fact a 35 m line of springs emerging from the base of the rocky slope but also in front of it (Figure 8) making necessary the construction of the intake structure over some 600 m^2 (Figures 9 and 10).

Interference with Hydro-Power System and trend analysis. The hydro-power system of Cerna-Motru-Tismana has been designed to convey certain less significant but perennial water courses through a network of secondary pipes, galleries and intercalated small power plants that eventually emerge to a large underground power plant. The skeleton of the system consists of four hydropower plants and five main surface water bodies (lakes) out of which four are represented on Figure 6.

Trend analysis on Izvarna springs discharges was conducted over a period of more than 15 years in order to predict the available discharge and possible anthropic influence on the tapped springs (Iurkiewicz et al. 1996). The analysis proved that due to different water supply and hydro-power projects the hydrodynamic behavior of Izvarna system particularly after 1983 has been radically changed comparing with main data series (1957-1964) previously presented. Consequently, the project of increasing the yield tapped by the Izvarna intake was cancelled.

No specific data were collected after 1992 but the overflow of Izvarna structure is continuously measured together with some nearby springs and Orlea stream at Celei.

TISMANA – MONASTERY AND CAVES

The oldest monastic settlement in historical province of Wallachia, the Tismana Monastery is an emblematic monastery sometimes also *Ban*'s (voivode, old regional ruler) *Residence* therefore frequently described as *the heart of Oltenia*. Tismana Monastery**,** together with its medieval walls and angular ramparts, is settled on the Starmina Mountain being surrounded by forests (Figure 11).

One explanation for the name is considered as originating from the Geto-Dacian word "tismena" meaning "fortress". During the archaeological works done in 1970, the foundation of a sanctuary was discovered nearly 4 m to the North of the lateral apse of the principal church. The sanctuary was built of river boulders and bricks and was dated from the time of the Roman occupation. This discovery led the archaeologists to the conclusion that an old Dacian-Roman fort had existed in this area *(http://www.romanianmonasteries.org/other-monasteries/tismana)*. A much simpler explanation stems on the material used for the building of the first church i.e. the so called *Tisa wood* (*taxus baccata*).

The settlement was founded by **Nicodim, The Pious**, a monk (Aromanian) that came here from Southern Serbia, during the rule of Radu Negru-Voda that actively supported its construction. Nicodim and his group of followers initially prayed in a small cave nearby the actual monastery until the first church was built and sanctified (1377). The building of the monastery continued under the rule of Dan I Basarab (1384-1386) and Mircea cel Batran

(1387-1418). Furthermore it was rebuilt during the rule of Radu cel Mare (Radu the Great, 1495-1508; Vlasie 1999). Ample restoring works were conducted in stages during 1970-1996 (and from time to time even nowadays) in order to highlight - and return to - the original architecture.

Figure 11. Tismana Monastery
(left: The Entrance; right: The Church of the Monastery)

Nicodim also created here a school for calligraphy. The religious book titled *Tetraevangheliarul Cuviosului Nicodim (The four gospels of Nicodim the Pious),* overlaid with gilded silver covers, was written by Nicodim himself and is considered among the oldest books in Wallachia. Nowadays the book is preserved at the National History Museum in Bucharest.

The church was originally painted in 1564 by *Dobromir (The Young*) *from Târgoviște*. His first icon is considered as the first Byzantine painting from Wallachia. The church was repainted in 1732 and 1766 but during 1955-1956 this picture was removed (and partly preserved); and subsequently the original painting was restored.

Following 1766 the whole assembly was repeatedly devastated and ruined by Turkish and Austrian armies. It is worth mentioning that subsequent to the release of his famous *Pades Proclamation*, Tudor Vladimirescu established here a camp for his army that battled during the Revolution in 1821.

The museum of the monastery is sheltering a large and rich collection of mural paintings (fragments of removed paintings from 1732), icons painted

on wood, various religious objects, old clothing, the doors of the old church and different documents.
In 1949, Tismana Monastery became a community of nuns (*maici*), that continuously preserved over decades the traditional working and daily praying.

Cave of Tismana Monastery (*Peștera de la Mănăstirea Tismana*, Vâlcan Mts.)
Synonyms: *The Treasury Cave*, *The Cave with Water of Tismana Monastery*

The cave is part of the Natura 2000 site *North of Western Gorj* (Nordul Gorjului de Vest) and as in case of the Monastery is located at the base of an impressive cliff of around 50-70 meters in high representing the eastern face of Starmina Mountain. The cave is tectonically conditioned by a system of fractures striking almost E-W contributing to the development of low galleries frequently interrupted by sumps totalizing more than 900 m in length. The transversal profile of the main passage is narrow and is also suggesting the predominance of the tectonic factors controlling cave development (Ponta et al. 2019).

The active stream of the cave has been usually quoted to 10-50 l/s, and represented the water supply source for the Monastery. However at the mid 80's the stream dried up over longer and longer periods most probably due to the Cerna-Motru-Tismana Hydropower Complex (with the exit water transport gallery designed right beneath). The increasing periods of low water in the cave almost dried up ten out of the eleven sumps and hence only the last sump (also the actual end of the cave) is nowadays a real challenge for the speleo-divers.

The recharge area for this small karst system can be related to numerous *dolines* dispersed over Cornetu Mare and Gorganu Hills. The diffuse losses along a quasi-horizontal sector of Sasa Creek, largely filled with alluvial sediments can be considered as the former concentrated input to the previously functional stream of the cave (Figure 12).

Despite of somehow impersonal appearance the cave became famous following its use as an anonymous shelter for the Romanian Bank (Gold) Treasury. The top secret operation aimed at hiding the national treasure received the code name "Neptun". Participating in the operation were the defense and finance ministries, the Romanian Orthodox Church, the Chief of Staff of the Romanian Army, the Intelligence Services and the Romanian Railway Society. Consequently between 1944-1947, 191 tons of pure gold that belonged to Romania were kept in Tismana alongside almost 2.7 tons of Polish gold that was on its way to Greece, but which was entrusted to

Romania in 1939, for safe keeping, before Warsaw occupation. Besides the aforementioned 191 tons, Romania also had 40.7 tons of gold kept in banks in Great Britain.

In respect to such successful operation, the National Bank of Romania (BNR) inaugurated on July 26, 2016 the *National Bank of Romania Treasure Museum* at Tismana Monastery (Lambru Steliu, Radio Romania International - *https://www.rri.ro/en_gb/ romanias_treasure_in_tismana-2563879)*.

The cave and the spring from Trout Nursery (*Păstrăvărie*)

It is located opposite to the monastery on the left bank of Tismana Valley (Figure 12) at a relative altitude of some 30 m above the Trout Nursery shielded by a similar cliff of some 100 m. It is genetically linked to the same fracture system controlling the cave of Tismana Monastery.

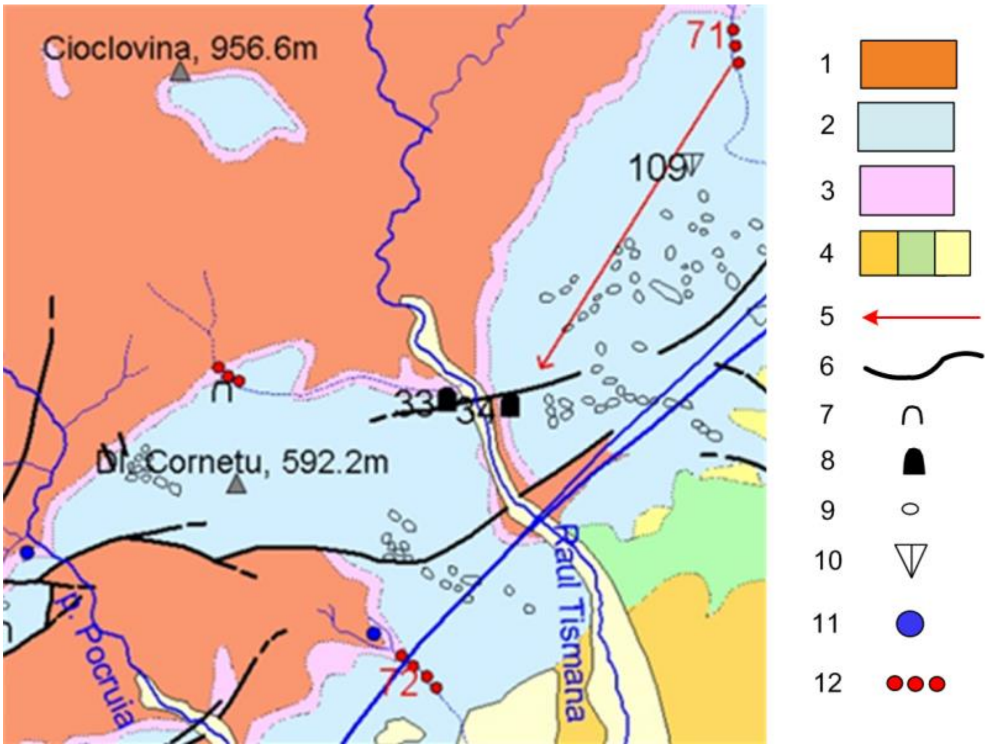

Figure 12. 1-Granites (Tismana type); 2-Limestone; 3-Impermeable rocks (metamorphic, sandstone and conglomerate); 4-Detritic rocks mainly poorly consolidated with variable hydrogeological behavior; 5-Inferred drainage connection; 6-Fault; 7-Cave, dry; 8-Cave, permanently functional; 9-Doline; 10-Sinkhole, temporary functional; 11-Spring; 12-Stream losses;

It was explored in 1984 for some 70 m and starting with the year of 2014 the length of the cave was almost doubled and even tripled by diving explorations (Focul Viu Speleo Club). The spring located 15 m downward was tapped and used for the Nursery despite of its highly variable discharge of 5-80 l/s (sometimes even totally dry). Some 50 m downstream, a smaller karst spring (3-10 l/s) also exists. The slope between the two springs is covered with calcareous tuff.

SOHODOL GORGES AND JALEȘ-VÂLCEAUA KARST SYSTEM

The gorges extend over a length of more than 12 km but the limestones occur in three separate sectors of a total length of around 10 km.

At the upstream contact with the limestones, the Sohodol stream sinks into several swallets, and then reappears in the *Pătrunsa* spring. This sector of some 6-6.5 km is highly karstified connecting several ponors to the large group of springs of Pătrunsa-Picuiel. Numerous caves and sinkholes do exists the deepest cave being *Clocoticiul din Cârca Parateilor* (149 m in depth), and the impressive *Urloi* pothole (62 m in depth) whilst the longest one i.e. *The Cave downstream to Fusteica Ponor* (*Pestera din aval de Ponorul Fusteica*), has some 2200 m.

The mid sector is shorter still also including few caves out of which *Cave from Izbucul Muschiat* is the longest one with more than 1000 m in length.

The lower (southern) sector that will be visited is extending over 2 km and is the most spectacular one. The surface karst is represented by dolines and dry valleys as well the spectacular *Lady's Ring (Inelul Doamnei)* sometimes also named *The Mirror* due to its mostly ovoid shape. The caves are very numerous and they are situated both close to the river bed and on several levels that match the terrace ones, on the valley sides. The various gorges, dolines and caves are a special attraction for tourists (Figure 13).

The first cave that can be visited is *Pestera Popii* (*The Priest Cave*) located on the right slope at some 50 m above the river bed, well known by locals and because the walls of this cave have black cave paintings with anthropomorphic silhouettes. During 1983-1985 this gorge sector has been systematically surveyed and investigated by the members of CSER (*Speleo Club Emil Racovitza*). At the end of three years of efforts they discovered and mapped more than seventy new caves that bring total number of caves to eighty; they also explored and extended the length of *Gârla Vacii Cave* from 750 m in 1971 to 1460 m in 1984.

Among the caves located close to the river bed, the most spectacular examples are *The Nostrils* and *The Furnace*, two underground meanders of Sohodol, about 60 m long (Figure 13). Downstream to *The Furnace* the river partially enters into *Gârla Vacii* Cave (1460 m long) to reappear in the Jaleş and Vâlceau springs (the tracer test in 1972 proved the connection of this cave with the two springs of Jaleș and Vâlceau with theoretical velocities of 5.5-6.5 km/day). The river also losses some 10-15% of its flowrate some 150 m upstream to the cave.

The karst springs of *Jaleş* and *Vâlceaua* have flow rates of less than 100 l/s and 100–700 l/s, respectively. They are supplied both by the sinks in Gârla Vacii cave and by the losses on Șuşiţa Seacă (6 km straight line) and Șuşiţa Verde (~11 km) valleys (Figure 6) (Iurkiewicz & Mangin, 1994).

The spring of Vâlceaua has been tapped in 1965 as the main water supply source for the city of Târgu Jiu (nowadays less than 80,000 inhabitants). The water intake structure was built above the main spring tapping also some other smaller springs. The spring of Jaleș emerging some 300 m to the West is also connected to the pipeline system conveying the water to Târgu Jiu.

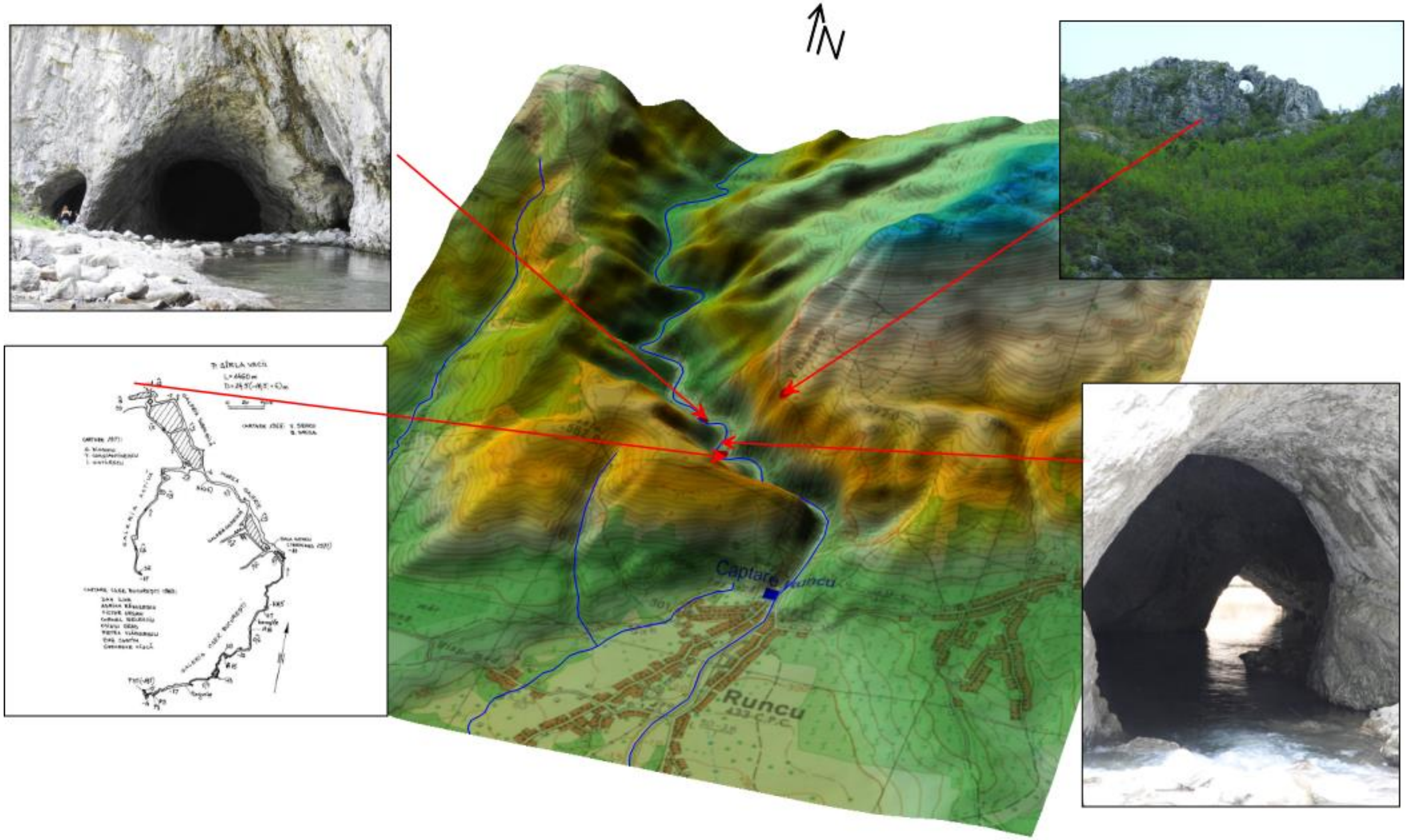

Figure 13. Sketch of the lower sector of Sohodol Gorges with location of main karst features (left upper corner – *Nostrils*; left lower corner – map of *Gârla Vacii Cave*; right upper corner *Ring of the Lady* or *Mirror*; right lower corner- *Furnace*).

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TÂRGU JIU AND *“THE HEROES PATH”* MONUMENTAL COMPLEX OF BRÂNCUȘI

compiled by Iulian POPA, *University of Bucharest*

The city of Târgu Jiu (*the Fair on Jiu River*), with a population of about 80,000 people, is the capital of Gorj County (in southwestern Romania), at about 300 km away from Bucharest. Târgu Jiu prides itself as being the city of Constantin Brâncuși, keeper of the most impressive grand monuments created by the sculptor. Nevertheless, there are also several other interesting things to see in Târgu Jiu. Lacking old monuments, most of the city center is modern. The most beautiful architecture dates from late 18th, 19th and early 20th century.

Târgu Jiu holds one of the greatest cultural treasures of Romania - the ***Heroes Path Monumental Complex,*** realized during 1937-1938 period. The *Heroes Path Complex* consists of a series of grand scale sculptures disposed on an east-west axis that cuts through the center of the city. The ensemble comprises three sculptures: *The Table of Silence*, *The Gate of the Kiss* and the *Endless Column*, on an axis 1275 m long, oriented west to east (Figure 14). The ensemble is considered to be one of the great works of 20th-century outdoor sculpture.

Right on the bank of Jiu River, the ***Table of Silence*** that is carved in travertine, marks the beginning of a symbolic journey imagined by the genius of Brancusi. Walking east towards the park’s entry, the *Chairs’ Alley* connects the Table to the second grand monument, the ***Gate of the Kiss***. Crossing the city center along the *Heroes Path Street*, you can easily reach the final monument, visible from afar. The impressive ***Endless Column*** is among the most famous monumental works of art in the world.

Table of Silence - The perfect symmetry and circularity of the table and the surrounding twelve chairs creates a space of deep contemplation. Symbolizing the silence of deep thought and meditation, the table is created by two perfect stone cylinders. Around the table, at equal distance from it and from one another, there are twelve clepsydrae chairs. For some, the monument also symbolizes the Last Supper with Jesus at the center surrounded by the twelve apostles.

Following a charming alley through the park flanked by two rows of square clepsydrae chairs, the second monument – ***Gate of the Kiss***, is visible at a short walk away. The monumental gate at the entrance of the city is a symbol of love. The stylization of the kiss symbol has been a lifelong purpose for Brâncuși. The gate, made from travertine blocks, is a sort of triumphal arch like many other around the world, but unlike others, it takes a humanly scale. Couples that pass through the gate have the custom of kissing under the arch.

On the same axis as the first two monuments but about 1 kilometre away on the other side of the city, the ***Endless Column*** is among the most famous and important monuments of the modern art of the world. The column was the only monument commissioned by the city to honor the heroes of World War I. The original name was "The Column of Endless Gratitude" and it was dedicated to the Romanian soldiers who died fighting on the shores of Jiu River, in 1916. The column is made of cast iron, has a height of 29.35 meters, weights almost 30 tons and consists of 16 overlapped octahedron modules. Brâncuşi called the modules "beads". Inspired by traditional motifs sculpted by peasants into their wooden house porches, the Endless Column has to be admired from all angles and distances, taking new forms and meanings.

Figure 14. Constantin Brâncuși (1876 – 1957) and his sculptures in Tg. Jiu
(https://www.targujiu.info/ro/.....)

The father of modern sculpture, **Brâncuși** was born (1876) a short distance from Târgu Jiu, in a peasant family of Hobita Village. Brâncuși was a Romanian sculptor**,** painter and photographer. He became famous in France, as a pioneer of modernism and one of the most influential sculptors of the 20th-century.

Considered among the great masters of modern art, with works displayed in the world's greatest museums and valued at millions, Constantin Brancusi has created some of the most famous sculptures in the world (*Bird in space, Mademoiselle Pogany, The Newborn, The Kiss, Sleeping Muse, La Sagesse de la Terre*). Although he left Romania to live and work in Paris, he never forgot his homeland. Constantly longing for home, he left in Romania his most important legacy, right here, in Târgu Jiu.

Brâncuși considered the art a source of joy and for this reason he was pretty tight with explanations about his works. On a certain occasion he concluded: *"In art what matter is the joy. Is not necessary to understand. Are you happy to see it ? It's enough!"*

KARST OF SOUTHERN CARPATHIANS BETWEEN TÂRGU JIU AND RÂMNICU VÂLCEA

compiled by Adrian IURKIEWICZ, *University of Bucharest*

This part of the trip shall focus on the karst features developed into the limestones outcropping on the southern slopes of Parâng and Căpăţânii Mountains, as well as on the southern edge of the limestone ridge of Buila-Vânturariţa. Here, the Jurassic (Tithonian) limestones have generated a well-marked karst landscape. The surface features are almost exclusively represented by deep gorges but the underground drainages have generated two of the most important cave systems in Southern Carpathians: the *Peştera Muierilor* on the *Galbenul Gorge* and the *Peştera Polovragi* on the *Olteţ Gorge*.

Parâng Mountains and the SW-part of the Căpățânii Mountains

On the way from Târgu Jiu to *Muierii Cave* the road passes through Baia de Fier, (The Iron Mine, the meaning of Romanian word *baia* also representing an archaism term for *mine*) a collectivity documented since the end of the 15th Century. However the last mining activity here was for graphite and it was closed in 1994 (after more than 40 years of exploitation) despite of the proved resources (*https://www.gorj24.com/zacamant-de-grafit-unic-in-romania-lasat-de-izbeliste-se-afla-in-judetul-gorj/*).

The geologic structure in the south-eastern section of Parâng Mountains and the south-western section of Căpățânii Mountains does not differ much to that of Vâlcan Mountains and consist of formations belonging to the Getic Domain (the Sebeș-Lotru series), a tectonic mixture strip consisting of the Tărâia Unit, and formations belonging to the Danubian Domain (the Schela Unit and the Lainici Unit).

The main aquifer formation in the area is represented by the Upper Jurassic – Early Cretaceous (Aptian) carbonate rocks (*The Oslea-Polovragi limestone formation*), occurring as an almost continuous strip of 9.23 km^2 between Gilortelul Mic stream to the south-west and Luncavăț stream to the northeast (Figure 15). Its maximum width, 1-1.5 km, is recorded in the section bounded by the streams Galbenul (to the west) and Cerna (to the east). Surface karst landforms are rather poorly developed, yet worth to be mentioned are the occurrences of grikes, natural bridges and porches, limestone escarpments, seasonal flow valleys, swallets and springs. Gorges are the most illustrative surface karst landforms in the area (ex.: the gorge sections of Valea Seacă and those of the streams Galbenul, Oltet, and Cerna).

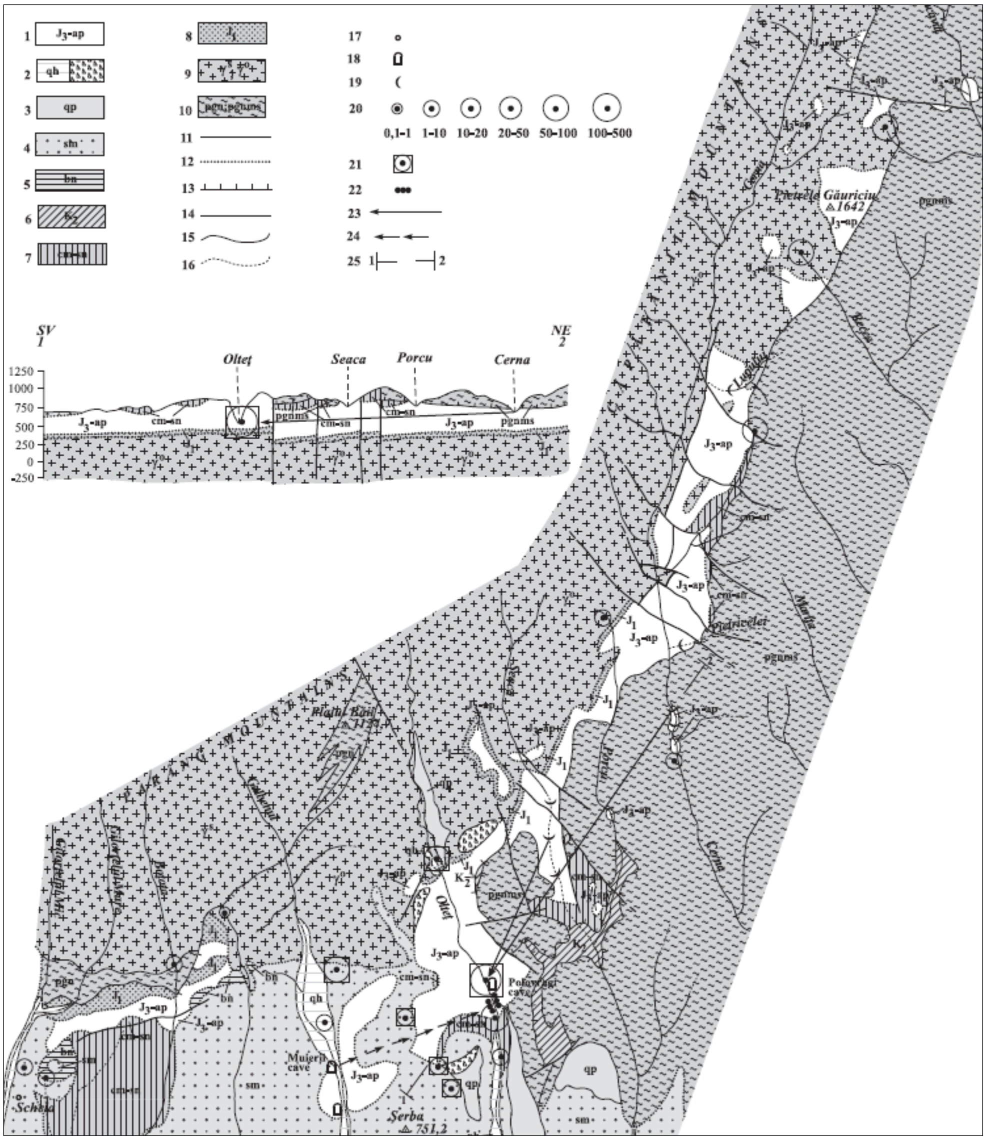

Figure 15. Hydrogeological map of the South-Eastern part of the Parâng Mts and the South-Western part of the Căpățânii Mts (Bandrabur & Bandrabur, 2010)

Legend: 1 - Mesozoic limestones (J3-ap); 2 - Alluvial deposits, colluvial deposits (qh); 3 - Boulders, gravels, sands (qp); 4 - Sands, gravels, marls (sm); 5 - Marls, limestones, sandstones, greenish breccias (bn); 6 - Carbonatic mylonites (K2 - Tãrâia Unit); 7 - Clays, arenites - Cernãdia Formation and marly limestones, clays - Nadanova Formation (cmsn); 8 - Sandstones (J1); 9 - Granites (γO -Oltet granitoids; γS – Susita granitoids); 10 - Paragneisses, gneisses, micashists (pgn - Lainici-Paius series; pgnms - Sebes-Lotru Series); 11 - Geological boundary; 12 - Unconformity boundary; 13 - Overthrust plane; 14 - Fault; 15 - Perennial surface course; 16 - Temporary surface course; 17 - Locality; 18 - Cave; 19 - Ponor; 20 - Spring discharge (l/s); 21 - Catchment; 22 - Group of springs; 23 - Underground flow direction established by tracer experiments; 24 - Presumptive underground flow direction; 25 - Hydrogeological cross-section line.

The most important endokarst phenomena are *Polovragi Cave* (10700 m length) in the Oltet Gorge, and *Muierii Cave* (3566 m length) in the Galbenul Gorge. The systematic catalogue of the caves in Romania (Goran, 1982) indicates the existence of 74 cavities characterized by various genetic and topographic features, occurring mainly clustered in the gorge sections or in their close proximity.

GALBENUL STREAM AND MUIERII CAVE (*Peștera Muierii*)

The Galbenul valley crosses through the first gorge sector within the limestone band in south Parâng Mountains. The valley is large, delimited by calcareous cliffs terminated by continuous scree deposits (Figure 17, Top). Over the 700 m long carbonate rocks section of Galbenul stream no permanent spring was identified. Yet the abundance of endokarst phenomena in the Galbenul Gorge area indicates that in the past, a rather intense hydrologic activity must have occurred there. Erosion levels are traced by cave entrances occurring on both sides of the valley.

The most important endokarst phenomenon is *Muierii Cave* at Baia de Fier. This was also the first show cave in Romania fitted with electric light. It is a large cave with a quoted length of some 4500m (Ponta et al. 2019) that apparently was explored (but not accurately mapped) to around 7000m (Goran et al. 2006). The cave develops on at least four levels in Late Jurassic - Aptian limestone out of which none is subject to perennial flow. The main part of the cave extends over levels two and three. The overall passage system strikes NNW-SSE, similarly to the fracture line on which it was developed and which additionally concerned the right side of Galbenul Gorge. The passages are a result of limestone dissolution by water infiltrated from Galbenul stream through underground flow paths along the fracture line, and they have evolved in parallel with the gorge incision that was completed by the main course of the stream (Bleahu et al. 1976). The Galbenu River bed is very close to the granitic basement overlaid by the limestone and hence most of its waters flow at surface and only the last cave system is temporary active.

The touristic track starts at upstream (northern) entrance of the cave and is following the main gallery throughout some larger halls. The longest passage, is *Galeria Electrificată* (Illuminated Passage) (570 m in length), that along with almost 1300 m of secondary lateral galleries (e.g., *Mousterian* and *Secondary* passages), situated at the same dry level, represent less than half of the entire cave network. The exit from the cave is through the downstream opening southeast oriented (Figure 16, Orghidan et al. 1984). Muierii Cave is decorated with speleothems and contains significant bone deposits, guano, and sediments.

The cave system has been known scientifically to the end of XIXth century, but the earliest sounding took place in the Main Gallery only in 1929 and this led to the discovery of many Paleolithic artifacts. Subsequent excavations in other two galleries (*Mousterian* and *Secondary* passages) were undertaken under the direction of C.S. Nicolaescu-Plopsor from 1951 to 1953 and in 1955 (Soficaru et al. 2006). They also contributed to the discovery of an abundance of Paleolithic and more recent archeological remains and a large quantity of Pleistocene faunal remains. The massive bone deposits are considered to stay at the origin of a rare phosphatic mineral: the dahlite, which makes up small stalactites, draperies and deep red crusts in this cave (Diaconu et al. 1980).

A stalagmite collected from the upper level of the cave system was dated by U-series method to a time interval corresponding to MIS 5e (~121±5 to ~90±6 ka, Constantin 2003). The results of a complex dating of fossil samples (mostly bones of *Ursus Spelaeus*) had been published by Doboș et al. (2009). The applied methodology yielded ages from 30,000 to more than 50,000 (^{14}C, years BP).

The conclusions of Soficaru et al. (2006) on the 30,000 (^{14}C, years BP) human remains from Muierii Cave refers to a basically modern human derived morphological pattern that joins the sample of human remains from the sites of *Peștera cu Oase* and *Peștera Cioclovina* in S-E Europe, *Mladecˇ* in Central Europe, and *Brassempouy*, *La Quina Aval*, and *Les Rois* in Western Europe in filling out the morphological pattern of the earliest of modern humans in Europe.

A rehabilitation project is about to start targeting a modern (and ecological) approach for the design and implementation of the touristic facilities outside and particularly inside the cave.

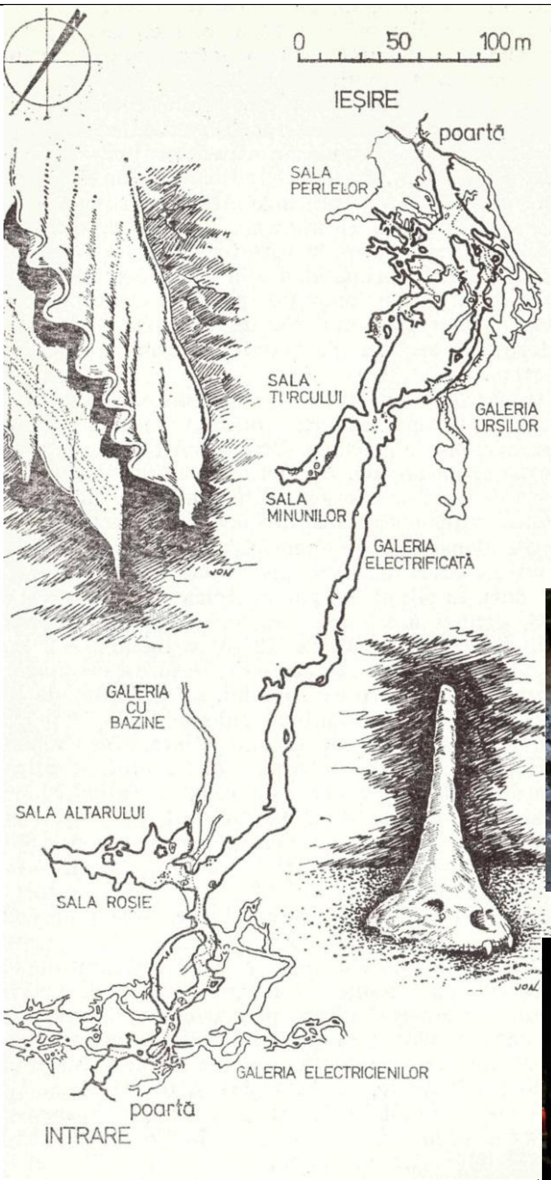

Figure 16. Sketch-map of Muierii Cave (from Orghidan et al. 1984)	Figure 17. Top: Galbenul Gorge; Middle: Muierii Cave entrance; Bottom: Sampling stalagmites; photo courtesy of *Ionut Mirea*

POLOVRAGI MONASTERY AND OLTEȚ STREAM

The name of the nearby locality and the whole area is considered as coming from a miraculous and quite rare plant used by local therapists used as a remedy against different disease. The name of this real panacea is *polovraga*, a plant considered somehow similar to *ginseng*, from which only the root can be used for a naturist therapy.

The chronicles attest the monastery at the beginning of the 16th century (1505), by two local rulers *Radu Comisul* and *Petre Spătarul* (Ciocioi et al. 2013). Two centuries later (1693) the ruler Constantin Brâncoveanu restores the church in the byzantine style adding also the surrounding wall. The significant inside painting of the church has been completed by the disciples of the painting school of Hurezi Monastery. The paintings have been preserved intact, as the coloring, with sober and harmonious nuances stands out on a blue background. The iconostasis is remarkable, richly ornamented with floral interlaces, a masterpiece of old Romanian sculpting. The icon depicting "The protection of the Mother of God" is at the exterior, and it is said that it punishes the ones with evil thoughts. The legends say that a young man chased by a Turk was looking for a shelter inside the monastery. The chaser, angry with his own inability, shot the icon; short after he fell off his horse and was fatally injured. Starting with 1968 the monastery is administrated by nouns.

The monastery has a museum that accommodates a collection of 650 glass and wooden icons, manuscripts with psalm chants, items donated by Matei Basarab and Constantin Brâncoveanu and an old book deposit of over 3,000 volumes in Romanian, Slavic and Greek.

The Olteț Gorge starts behind the Polovragi Monastery. Before reaching the depression located in front of the Carpathians (the «Oltenia section of the Subcarpathian Depression»), Olteț stream cuts through the E-W striking limestone bar a gorge whose vertical extension is in excess of hundred meters, marking the geomorphologic limit between Căpățânii and Parâng Mountains (Figure 19, two upper photos).

The nature has created a great, overwhelming and unmistakable landscape extending over some two kilometers. At a certain point an abrupt path can be seen on the right side of the forest road. After approximately one hour of walking on foot on the marked trail, passing "Cornet" and "Sub Cruce" layovers, you reach "Crucea lui Ursache", where there is the Dacian Fortress of Polovragi. Built in the 2nd and 1st centuries B.C, it was the only fortification with a stone wall in Oltenia, used as a refuge by the Dacians and for the defense of the road leading to Sarmizegetusa Regia. Legends say that the Dacians reached the fortress in Orăștiei Mountains through the galleries of Polovragi Cave, covering a distance of 40 kilometers.

In spite of being located just 5 km east of Galbenul gorge, the Oltet gorge displays a completely different appearance. The high walls of the valley are tightly spaced one to another: the distance between them varies from 4-5 m next to the stream-bed, to 10-20 m in the upper part. Several erosion levels can be traced within the walls, more prominent being the levels highlighted by the cave-entrances lineaments occurring at 25 m and at 60 m above the streambed. The most important cavity is Polovragi Cave, a former underground meander of Oltet stream; the cave entrance is located 20 m above the streambed and some 200 m upstream the place where the stream exits from the gorge.

POLOVRAGI CAVE

Polovragi Cave is situated in Gorj County, at 1.2 kilometres from Polovragi village. In terms of geographic location, the cave is situated in Căpățânii Mountains, on the left side of the Olteț Gorges, at about 200 m from the entrance of the gorges downstream, at an elevation of 650 masl. The summarized statistical data on the cavern refers to 10,793 m of passages and 91m vertical range (−62 m, +29 m) with a branching index of 6.81 and an extension of 1520 m (Ponta et al. 2019).

Polovragi Cave was declared Natural Reserve by the Government of Romania by Law 5/2000 concerning the approval of the national territory arrangement plan - Section III - Protected areas, according to which it is part of the "protected natural areas of national interest". The Polovragi Cave–Oltețului Gorge karst area is part of the Protected Natural Area 2440 located in the Natura 2000 ROSCI0128- ”Nordul Gorjului de Est” site. It is classified according to Law 462 as a natural reserve, IUCN category IV, Class B.

The main entrance of the cave was known for a long time, as *Cave of Pahomie* from Polovragi. A brief description of the cave was made by Joannes in 1868, followed by another description made by Alexandru Vlahuță in his well-known volume of *România Pitoreasca* (1901). The first data regarding the location of the cave were published in 1929 by P. Jeannel and E. G. Racoviță (Orghidan et al. 1984).

The cave was extensively explored and mapped by the members of Focul Viu Speo-Club that in only two years (starting with 1974) mapped some 9300 m (Orghidan et al. 1984). More recently i.e. subsequent to the year of 2000, the same club resumed the exploration concluding in a total length slightly less than 11 km of galleries, thus ranking the cave on the eleventh place among Romanian caves.

For description purposes, Ponta & Aldica (2009) divided the whole network of galleries in three sectors as i.e. the Access Section (1), the Upstream Section (2) and the Downstream Section (3):

(1) The *Access* Passage (*Zona de Acces*), with 1224 m of passages, extends between the upstream entrance and the Wonder Hall (Sala Minunilor). The passages are in general small, formed along E–W and NE–SW oriented fractures, and developed on three different levels, most of them being formed by surface sinking streams. It has an average height of 1 m, and in time most probably was completely submerged as suggested by cave morphology (horizontal ceiling, narrow passages), and large argillaceous deposits.

(2) The *Upstream* Section (*Zona Amonte*) is of maze type, specific to phreatic caves, with many narrow passages, frequently less than 1–1.5 m high. This sector cumulates a total length of 2,880 m of galleries, where fractures striking N-S or E-W were identified. Occasionally, at faults crossings, the passages widen into large chambers, with breakdown blocks and flowstone domes (Goran, Constantin and Horoi 2006)

(3) The *Downstream* Section (*Zona Aval*) (partly shown in Figure 18), includes the 2–7 m wide and 1.3–10 m high main passage extending between the Wonders Passage and the downstream, main entrance, over more than 5000 m of passages. Side passages are between 50 and 200 m long, and they are either abundantly decorated (the Wonders Passage, the Soda Straws Passage), or very tight (Constantin & Goran 2006).

Electric lighting and tourist facilities have been installed along some 900 m of the main passage, although in that section most of the decorations had been vandalized since long. This sector also includes the functional stream (lower) section of the cave with active passages and chambers that amounts to 850 m total length.

The black painting of Death on cave walls has probably been done by one of the monks who inhabited the cave between the 16^{th} and the 20^{th} centuries. As in case of *Women Cave* a modern (and ecological) rehabilitation project has been designed for *Polovragi Cave* but it's still before the feasibility-tendering stages.

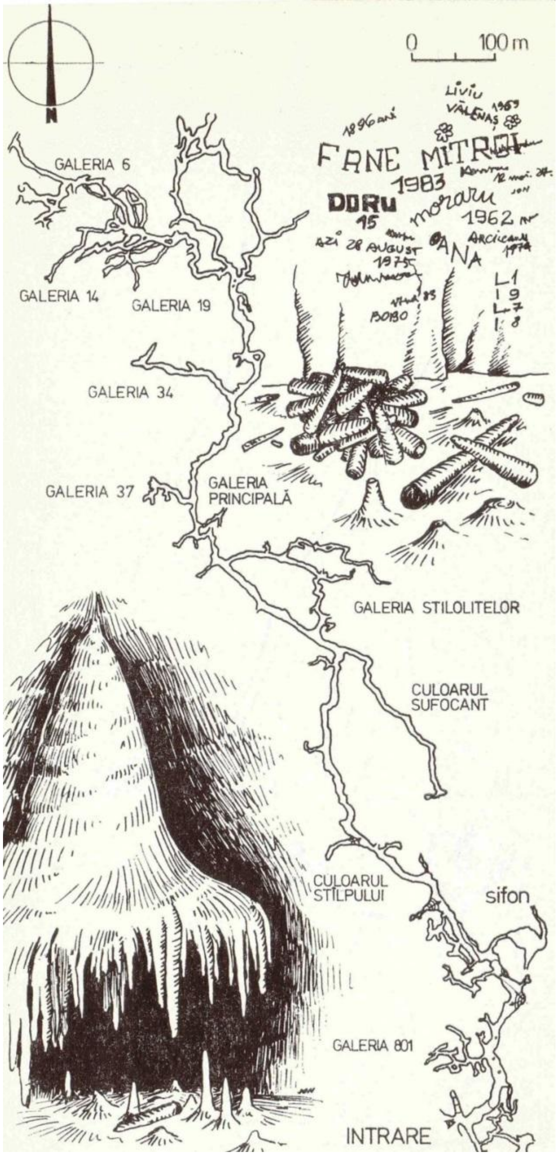

Figure 18. Sketch map of Polovragi cave (Orghidan et al. 1984)

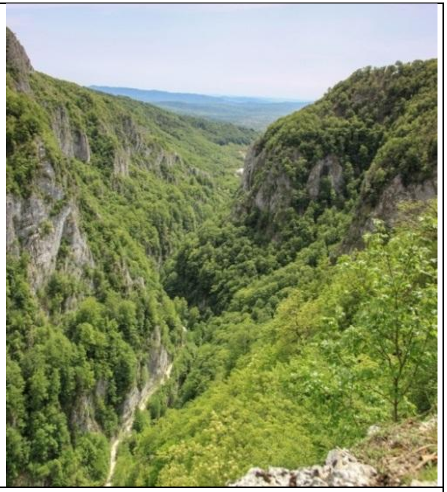

Figure 19. Outside (the upper two photos, courtesy of *Iulian Mirea*) and Inside Polovragi Cave (the lower two photos, courtesy of *Iulian Popa*)

HUREZI (HOREZU) MONASTERY

compiled by Adrian IURKIEWICZ, *University of Bucharest*

The Hurezi Monastery, the most important monastery founded by the martyr Voivode, Constantin Brâncoveanu (1688–1714), was built between 1690 and 1693, the great church of the complex being consecrated on 8th September 1693. Being considered the most representative edifice built in the "Brâncovenesc" style in the country, the Hurezi Monastery is, perhaps, the largest monastic complex in Romania and is considered to be a masterpiece of this style characterized by its architectural purity and balance, the richness of its sculpted detail, its treatment of religious compositions, its votive portraits, and its painted decorative works. It extends on more than 3 ha, including the monastery itself, the Infirmary Church, the "Sfinţii Apostoli" Hermitage and the "Sfântul Ştefan" Hermitage, as well as the "Sfinţii Îngeri" Church, also built by one of the abbots of the monastery, a church lying southwards of the precinct of the monastery. In 1993, the Hurezi Monastery was included in the UNESCO World Heritage List.

Hurezi Monastery mainly consists of two precincts: the inner one is delimited by brick walls including the core complex of five churches. The entrance has a wide vault, with a massive, wooden gate. Apart from the main church of the complex, the other four were built from 1693 to 1700 and slightly after (Figure 20).

The outer one has buildings on three sides and a high wall to the sunrise, thus completing the image of a real fortification assembly. In the belfry tower there are four bells, weighing between 300 and 1000 kilos. The name of ruler *Brâncoveanu* is inscribed on three of them. The *Brâncovenesc* style, which can be found at several other churches and monasteries in Wallachia, is the only true and original Romanian style and is honoring the name of the ruler who, in a period of constant battles between the world powers of that time, put cultural development of the country above everything and made it the goal of his life. The some extent the church can be considered an approximate replica of the famous *Curtea de Argeș Monastery*.

Built on a three-cusped plan, the "Sfinţii Împăraţi Constantin și mama sa Elena" (*Saints Constantine and His Mother Helena)* Church is of 32 meters long and 14 meters high and develops the model of the Episcopal Church of the Curtea de Argeș Monastery, in the sense of more elongated shapes and by adding a veranda typical of the "Brâncoveanu" style, with arcades supported by ten stone columns, decorated with ornaments characteristic of the late Renaissance. Rectangular panes and ornamental niches with circles decorate its façade. The frame of the entrance door is made of carved marble, the inscription including the emblem of Wallachia and that of the Cantacuzino family. Here, in the Church of *Saints Constantine and Helena* is where Constantin Brâncoveanu prepared his burial sarcophagus; this remained empty following the martyrdom of the voivode and his four sons on August 15, 1714 in Constantinople (Gabriel Herea, 2009).

Figure 20. Images from the core complex of churches

All the churches have been preserved in their original shape. The coherence of the programme is coupled with the unity of the architectural style: the churches, rectangular in plan, have high slender turrets whose heights equal the length of the edifice. The porches opening to the court by arched vaults within the dome are supported by ten stone piers adorned with late Renaissance motifs (Corina Popa, 1995).

The constructions and the churches were endowed with carved wood furniture: pews, high back chairs, iconostases that borrow the adornment of the door frames where the foliage is in relief or flat, suggesting its connection to the *Baroque* metal work. For ten years a number of artists, masons, stone cutters and wood sculptors, icon and wall painters had been working earnestly to perfect this remarkable monastic masterpiece.

The churches preserve most of the original wall paintings. Painted between 1692 and 1702 by twelve painters led by Greek painters Constantinos and John, they represent the early *Brâncovan* (or *Brâncovenesc)* style in wall painting. The two Greek masters, who also painted the Lady's Church (*Biserica Doamnei*) in Bucharest, built in 1683, were outstanding promoters of *Byzantine Renaissance*, both as regards icon and wall painting. Alongside the religious scenes shown, in the pronaos there is a portrait gallery of the Brâncoveanu, Basarab and Cantacuzino families.

The prince, several boyars and priests made of Hurezi the main artistic centre of the Râmnic bishopric, so that *Polovragi, Mamu, Surpatele, Cozia* and *Govora* monasteries, were either built or restored and painted by the same artists who at Hurezi established a very unique style and a real school of painting.

Initially Hurezi (Horezu) was a monk monastery, but in 1872 it became a monastery of nuns. Several rehabilitation stages occurred during 1827, 1872, 1907-1912, and 1954. The last rehabilitation works were conducted during 1960-1978, concluding in the full restauration of the monastic assembly.

OLARI, STRET OF THE CERAMISTS

compiled by Adrian IURKIEWICZ, *University of Bucharest*

Horezu ceramics is a unique type of Romanian pottery that is traditionally produced by hand around the town of Horezu in northern Oltenia (Vâlcea County), close to the famous Horezu Monastery. It reflects the development of knowledge and skills in the branch of pottery of many generations working and leaving in this area which is why the craftsmanship of Horezu pottery was inscribed on UNESCO Intangible Cultural Heritage Lists in December 2012 (*https://en.wikipedia.org/wiki/Horezu_ceramics).*

The craft of working the clay was transmitted through the ages by the families of ceramists who managed to keep it alive in the ancestral village hearth, now known as "Olari street". On the main street of the village there are 18 ceramists' workshops, where the artisans work the clay with the same unparalleled craftsmanship as their ancestors ***(****http://www.horezu-infoturism.ro/EN/olari-village-of-the-ceramists).*

Each potter has his own technique of shaping, but each respects the sequence of the process. Men select and extract the local (very specific) type of clay, which is then cleaned, cut, watered, kneaded, trampled and mixed – eventually transformed into a body from which they produce a red pottery. The potters then shape each object with a special finger technique requiring concentration, strength and agility. Usually the women decorate the shaped ceramics before firing with special techniques and tools in order to draw traditional motifs. Their skills in combining decoration and color determine the personality and uniqueness of these pieces. Colors are bright shades of brown, red, green, blue and so called "Horezu ivory". Horezu potters use many traditional tools like a mixer for cleaning the earth, a *pottery wheel (roata olarului*) and comb for shaping, a hollowed-out bull's horn and a fine wire-tipped stick for decoration, and a wood-burning stove for firing (*https://ich.unesco.org/en/RL/craftsmanship-of-horezu-ceramics-00610).*

Horezu is a singular historical Romanian ceramic center in which this trade remained the main source of income for many families of potters out of which the most known are Ogrezeanu, Vicsoreanu, Iorga, Frigura, Bascu or Tambrea (*http://www.horezu-infoturism.ro/satul-de-ceramisti-din-olari*). Today this craftsmanship is transmitted as always in the family circle, but also in workshops from master to apprentice, and pottery festivals and exhibitions. The Olari centre produces a type of pottery having its own unitary character, well-defined through its shape, decorations, technique and colours (bowls, plates, pots, pitchers, cups of various sizes, for home or decorative use - Figure 21).

The village of Olari from Horezu commune has always been recognized as a specialized center in ceramics. The potters from Horezu realized in the beginning regular vessels that they would sell at the fairs organized in the vicinity of their village or they would give to the waggoners who would sell them in some other villages. Usually, the trade was made outdoors (several vessels in exchange for maize, poultry or animals). The notion of "regular vessels" comes from the fact that these vessels were used in everyday usage. The vessels were not decorated, but there were only a few enameled stains of color on them.

Figure 21. Images from Olari Street

TROVANTS MUSEUM NATURAL RESERVE AT COSTEȘTI

compiled by Adrian IURKIEWICZ, *University of Bucharest*

The *Trovants Museum Natural Reserve*, is located at 8 km from Horezu, nearby the village of Costesti and is the only one of this kind in Romania and in Europe. It was created in 2004 and subsequently was declared UNESCO monument. Nowadays is managed/administrated by "Kogayon Association", a non-governmental organization of environment protection.

The term *"Trovant"* is usual in Romanian geology and denominates sandy concretions, representing local cementations in a sand layer. The trovants represent local cementation in the reservoir of sand that contains them, some of the very strange shape. The diameter of the trovants is from centimetric to metric. This term has been used for the first time by Murgoci (1907) with respect to indurated blocks inside a largely unconsolidated formation. The origin of the term could be ascribed to the Italian *trovànte* (*erratic boulder*, Țicleanu 2011). Noteworthy, in a previous note in English, Murgoci used the term *concretion* for the same type of rock (Jean-Paul Saint Martin et al.).

One of the most important places of Romania where the trovants occur is the sand quarry from the Costesti village on the route from Horezu to Râmnicu Vâlcea (Figure 22). The cemented elements can be found in sand formation of Upper Miocene (around 6.5Ma) displaying a deltaic environment. Local exploitation of sand and weathering (erosion) make new trovants to appear continuously from the (Upper Miocene) sand formation (Figure 23). The main outcrop (the quarry) was integrated and arranged in an open-air museum of trovants, covering a total surface of 2500 m^2.

As regards the origin of trovants, several hypotheses are mentioned by Tita (2002) i.e. wind erosion and the variations of temperature (1), water infiltration in a sand deposit generating triggering the creation of some concretions by cementation (2) or by seismic shocks (3). However according to Țicleanu et al. (2008) the epigenetic origin as hypothesized by (1) and (2) is out of discussion and in fact *the trovants* represent diagenetic textures reflecting paleodynamic (paleoseismic) conditions and correspond to specific compactions of the sandy sediments containing locally solutions (especially carbonate) accumulated in the sand, which during important seismic shocks and under the influence of the internal cohesion forces tended to spherical forms. In the process are involved: gravitation force, seismic shocks, solution cohesion forces (particularly surface tension) and the adhesion strength between the sand grains and the liquid (Țicleanu, 2011).

The two essential conditions for the trovants formation are the occurrence of sand sediments and conservation of a significant porosity, despite the normal compression caused by the pressure and segregation of specific minerals from secondary components dispersed in the host rock.

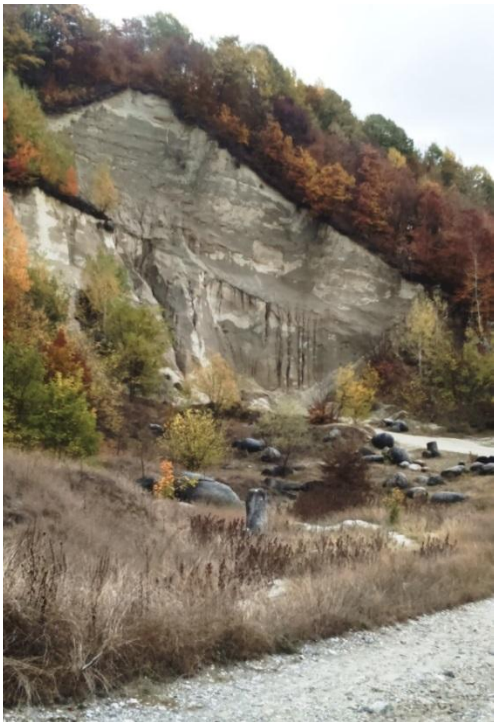

Figure 22. General view of the sand quarry

Figure 23. Trovants still buried in sand

Complex aggregates of two or more trovants can often be found (Figure 24). The large trovants found in the thick sand beds reflect great initial amounts of solutions in the bulk of the sandy sediment. The perfect spherical shapes (Figure 25) which sometimes can be found suggest great magnitudes and durations of the paleo-earthquakes (Țicleanu 2011). Noteworthy, there is no mineralogical difference between these pseudo-concretions and the surrounding sands. Their cement is often carbonate-type and no distinct nucleus can be found inside them.

 

Figure 24. Aggregates of trovants

Figure 25. Exhumed spherical trovant

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A BRIEF GEO-CULTURAL TOUR OF RÂMNICU VÂLCEA AND ITS SUROUNDINGS

compiled by Adrian IURKIEWICZ, *University of Bucharest*

The city of Râmnicu Vâlcea is set at the foothills of the Southern Carpathians being located at about 12 km from the Cozia Mountains and about 40 kilometers from Făgăraş and Lotrului Mountains.

Due to its geographical position, Râmnicu Vâlcea was on the access route of the roman legions led by Trajan, in the second war between the Roman Empire and Dacia (105 - 106 AD). In order to strengthen the advancement to the Dacian fortresses from the mountains of Orăştie, Traian built an access road along the Olt Valley, endowed with strong fortifications. (*http://www.turismlaramnicuvalcea.ro/en/Pagini/3-0-4-history.html*)

The first documented mention of Râmnicu Vâlcea, is a charter issued at Cozia Monastery (Point **M** on Figures 26, 27) that dates back to 1388, during the significant rule of Mircea cel Bătrân (1386-1418). The town became the seat of a Vâlcea County in 1392, and was a temporary residence for many of the subsequent rulers, *Pătraşcu cel Bun*, Mihai Pătrașcu (furthermore known as *Mihai Viteazul*) or *Matei Basarab,* being the prominent ones.

In 1640, at *Govora Monastery* ((Point **H** on Figures 26, 27) one of the oldest in Romania), nearby the City of Râmnicu Vâlcea, it was printed "Pravila de la Govora" – the oldest collection of laws printed in Wallachia (Ţara Românească). The printing activity intensified during the rule of Constantin Brâncoveanu (1688-1714). Thus, the city becomes, in the 18th century, one of the largest printing centers in *Ţara Românească*.

The Romanian anthem *Desteaptă-te Române* with lyrics written by Andrei Mureşanu and music composed by Anton Pann (his memorial house is located in the center of the town), has been played for the first time in Râmnicu Vâlcea during the revolutionary year of 1848 making the City an important benchmark in the Romanian History.

Noteworthy, the setup of *Zăvoi* Park as recreation area is due to Barbu Dimitrie Ştirbei (1849 – 1853) officially mentioned in 1850 as a place for "townsfolk promenade", being as such one of the oldest parks in Romania. Starting with 1980s, the city has been completely rebuilt maintaining however some of the characteristics of the local architecture.

The geology around Râmnicu Vâlcea and to the north of it is dominated by the successive overthrust of *Getic* and *Supragetic* Domain over *Danubian D*omain. The main lithological units as extracted from Geologic Map of Romania 1:200000 are presented in Figure 26 together with the location of some important places already mentioned or that will be mentioned in the following pages.

The north - western limit (as included in the map) is represented by the metamorphic formations of *Getic Nappe* (Sebes-Lotru series) whilst to the north-eastern one the metamorphic Cumpana – Cozia series that belongs to *Supragetic Nappe* occur.

Again toward the north-western corner of the map the sedimentary deposits of the Getic Domain represented here by Middle Jurassic–Oxfordian detrital and siliciclastic rocks, overlain by Kimmeridgian – Lowermost Cretaceous reef limestones (Ples et al. 2016*)* built up the impressive Buila-Vânturarița Massif that spreads from the west of the Bistrita Gorges to the east of Olănești Gorges (Point **A**). The peaks in the central sector exceed 1800 maMN (*Vânturariţa Peak*: 1885 m). The whole ridge has a linear type of extension and consists of 14 km long, and 0.5 - 2.5 km wide, calcareous crest, with a NNE–SSW orientation.

Buila-Vânturarița National Park (BVNP) has been established in 2004 and it is part of the Network European Ecological Natura 2000 (as Site of Community Interest: ROSCI0015 Buila - Vânturarița, and Special Protected Area: Cozia-Buila-Vânturarița ROSPA0025 (Muntean et al. 2010). Extending over 4186 ha, BVNP is the smallest one, out of 13 National Parks of Romania but still include about 120 caves and four narrow gorge sectors amongst which the Bistrița Gorges is the southmost one (Points **B** and **C**) .

At the SW corner of Buila-Vânturarița National Park, two other important monasteries i.e. *Bistrita Monastery* **(**Point **D)** and *Arnota Monastery* (Point **E**) contributed to the rich cultural history of Râmnicu Vâlcea and its surroundings.

The *Peştera Liliecilor* (Bats Cave) from *Bistriţa Monastery* is also known as the Cave of St. Gregoire (or *Grigore Decapolitul)* since it was used to shelter the relicts of the Saint. It is a small cave carved into the right side of Bistriţa valley, approximately 80 m above the stream. It has three entrances and an overall maze appearance due to several pillars and large breakdown blocks. Under the northern (largest) entrance a small church has been built around 1635 AD. In the deeper part of the cave, a small chamber has been also used as a chapel where the relics, exposed at the monastery during the day, were sheltered overnight (Bleahu *et al*, 1975).

The cave does not bear spectacular features but, together with the other sites described above is part of the cultural landscape of northern Oltenia, which typically associates the monasteries to remote karst areas, their gorges and their caves.

To the east, along the Oltului Valley, the chain of rich areas in cold mineral and thermo-mineral water of *Călimănești-Căciulata-Cozia* (Points **J, K, L**) is considered as a single aquifer unit genetically linked to the favorable litho-structural features of the region. The systematic exploitation of mineral springs started in 1854 in Căciulata area, and in 1887 in Călimănești area (Pricăjan, 1985) the latter being taped, bottled and exported in France (Antics and Roșca, 2005). The aquifer is represented by a sedimentary complex of *Getic* and *Supragetic* Nappes subsequently covered by deposits of Eocene (Ypresian – Luthetian) age, including mainly sandstone and conglomerate.

The interpretation of the hydrogeological parameters of the thermo-mineral water reservoir conducted by Slăvoacă & Slăvoacă (1991) lead to a conceptual model suggesting the existence of complex blending process in which three types of water are mixed in different ratios:

- Karstic water that supplies the deep groundwater reservoir from beneath of it; the recharge area of this type of water is hypothetically related to Buila-Vânturarița Massif.
- Mineralized water similar to *formation water* of petroleum reservoirs (with a rich content in Iodine, Bromide, Boron, NH_4, H_2S, but also CH_4);
- Infiltration water from local precipitations.

More or less similar geo-structural conditions occur in *Băile Olănești* area (Olănești Spa, Point **I,** central part of Figure 26) and here too, a large number of springs and wells (including a geothermal one exceeding 3000 m in depth) are used for internal and external (balneation) cures for therapeutic and recreation purposes. To the South, the mineral water from *Băile Govora* (Point **G**) and the *salt mining area* of Ocnele Mari adds to the geo-diversity of this region.

*

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Vâlcea County is known to Romanian pilgrims as the Romanian *Mount Athos* because here, in the *Northern Oltenia* near to the mountains, are no less than 29 monasteries, some of them of inestimable value recognized even beyond Romania's borders (i.e. Horezu, a UNESCO World Heritage site). At one point Vâlcea had 60 monastic centers, being one of the largest eparchies, founded in 1503. It was here that some of the first books printed ever in Wallachia , libraries built, it was here that *Brâncovenesc*-style painting and architecture found a large home, the Vâlcea cultural patrimony including several important monuments of the Brâncovenesc style (*https://www.agerpres.ro/engleza-destinatie-romania/2014/08/13/destination-romania-valcea-county-romanian-athos-10-38-38T)*.

Practically, the entire north-central area of Vâlcea County can be seen as a unit of monastic settlements, starting from the foothills and mountains, on valleys or peaks, to the rocky cliffs of high heights. Each settlement has its own history, monuments and specificity.

Specific details for each point are offered in the captions of the selected images (Figures 27), whilst the *Ocnele Mari* area including the touristic part of the *Salt Mine* (that will be visited) is presented in a subsequent chapter. Most information regarding the mineral water areas shall be referenced to Pricajan (1985) and despite of possible changes in terms of number of sources in use, they are even now a realistic image of the surveys and activities performed along the years for the hydrogeologic knowledge of the region.

Figure 26
Simplified Legend: 1-7, gravel, sand and loessoid deposits; 8-12, clay, marl and sand; 13-14, sand, marl, clay and tuff; 15, mainly tuff, salt, marl and clay; 16-18, Conglomerate, sandstone and sandy marl; 19, megabreccias and megaconglomerate, sandstone and marl; 20-22 conglomerate, sandstone and marl; 23-24, sandstone, marl and clay; 25, conglomerate, sandstone and marl; 26, massive limestone; 27, conglomerate, sandstone and argillaceous limestone; 28, Valea lui Stan and Leaota metamorphic series; 29, Sebeș-Lotru and Cumpăna-Cozia metamorphic series.

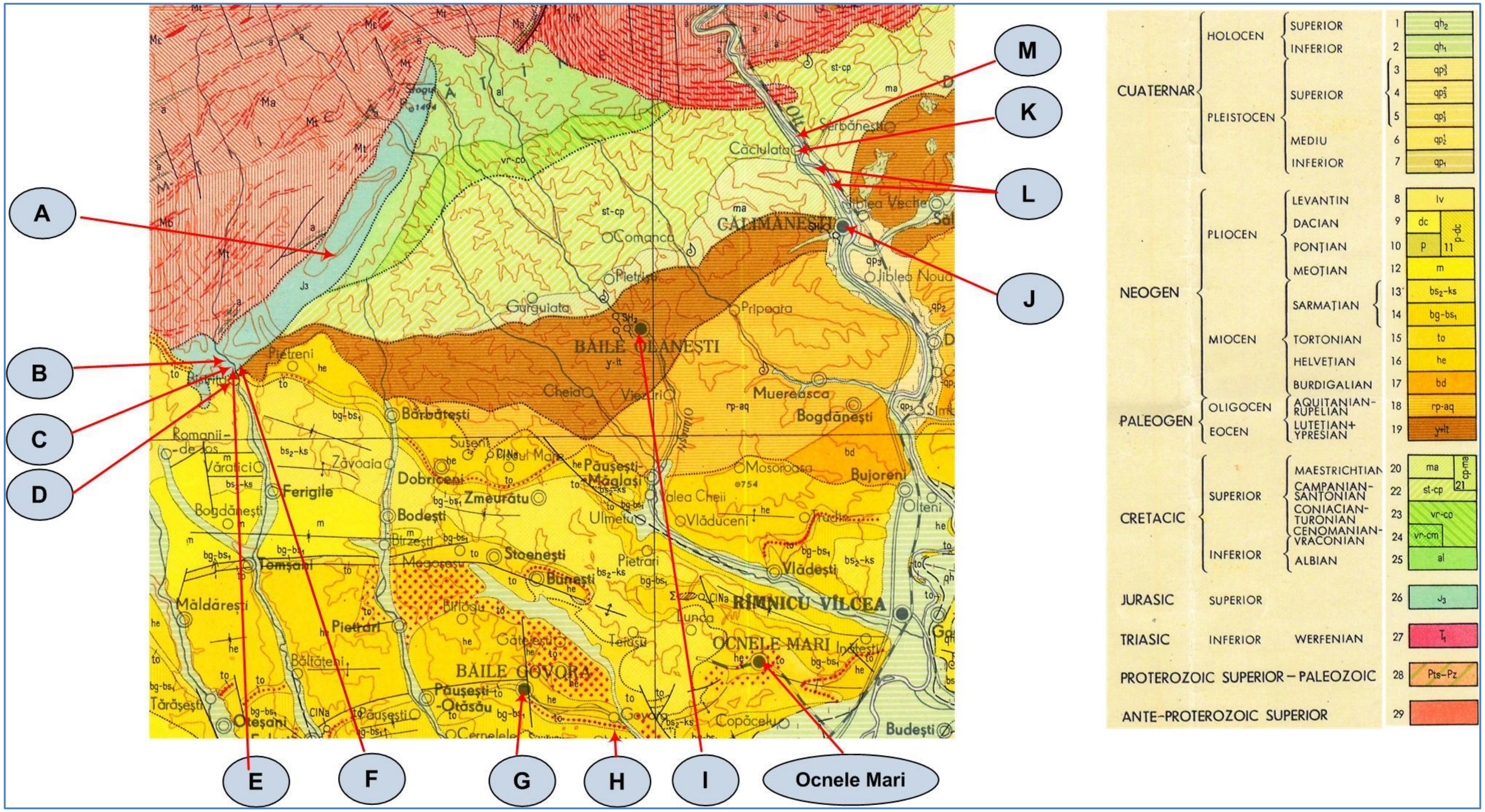


Figure 26. Geologic map of Râmnicu Vâlcea area with significant geo-cultural points of interest (extracted from Geologic Map of Romania, 1:200,000 sheet 34-Pitesti);

Figures 27

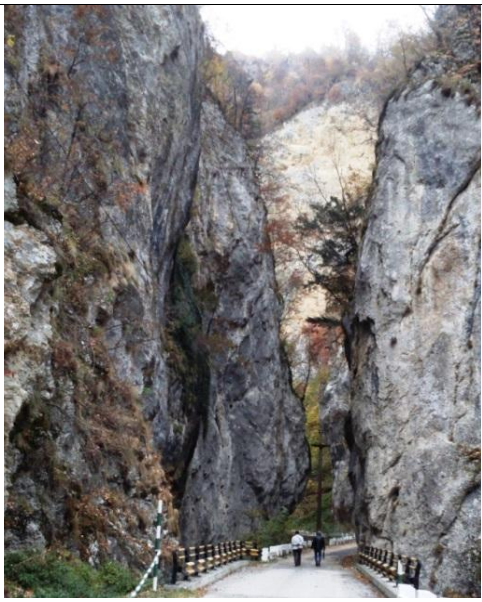
A (upper left)

National Park Buila-Vânturarița (left)

- Impressive calcareous ridge developed in Upper Jurassic-Lower Cretaceous limestone
- About 120 caves
- Four gorge sectors

B (lower left)

Bistrita Gorges at SW limit of Buila-Vânturarița; extending over some 600 m but said to be the narrowest one in Romania.



C (lower right)

Bear Cave – the entrance is located 30 m above the river bed. The cave is represented by a main gallery (35m high and 20 m large at the entrance sector) and some secondary ones. It is accessible for around 400 m of galleries. *(http://www.focus-oltenia.ro/resources/pdf/Cheile_Bistritei.pdf)*

The name of the cave is related to the numerous fossils of *Ursus Spelaeus* found inside, together with some prehistoric artefacts dating from Neolithic but also more recent from Dacian or medieval times. The cave is not electrified nor fitted for visits and tours.

D

Bistrița Monastery

First mention is in document dated 1494 but few years later in 1509 the assembly was complete destroyed by Mihnea Vodă. It was rebuilt during 1515-1519 by *Craiovești* boyars under the rule of Neagoe Basarab.

The most important treasure is represented by holy relics of *Saint Gregory of Decapolis*, which had been brought over here by Barbu Craiovescu in 1497.

Following the earthquake of 1810, the monastery was substantially restored including the internal painting done in 1850 by famous Romanian painter *Gheorghe Tatarescu*.

E

Arnota Monastery was erected by Matei Basarab during 1633-1634 and firstly documented in 1636.

It was frequently renovated and repainted mainly during 1705-1706 under the rule of Constantin Brâncoveanu (1689-1714), or between 1852-1856, under the rule of Barbu Dimitrie Ştirbei who ordered its walls to be repainted. Important restorations were also carried out in 1907, 1935 and 1954-1958, when the construction was consolidated.

The tombs of Matei Basarab (whose remains were moved here from Târgovişte) and his father can be seen in the narthex (pronaos).

Initially it was a monastery for monks, but since 2000 has been converted for nuns.

	**F** Limestone exploitation: Open Pit at Bistrita – Pietreni (Costesti) Extraction started in 1960. Administrated by SALROM since 1965. Mining area: around 1.2 km^2 Used for salt processing industry (Oltchim, Govora). Conflicting aspects – the boundary with B-V Natural Park.

	**G** Govora Spa (*Băile Govora*) Sulphur water in a mainly sandy aquifer of Sarmatian age; TDS=1.4 - 44.4g/L. Maximum content in H_2S is of around 26mg/L. Chloride-sodium type of water in a complex sand-tuff-conglomerate aquifer of Helvetian age; TDS= 31-87g/L; maximum content of iodine is 57.9 mg/L; including two wells of 1170-1350 mbGL, T=31-37°C. Different external therapeutic procedures.

<table>
<tr><td></td><td>H
<u>Govora Monastery</u> - built during XIV-XVth centuries; a 250 kg bell, cast during 1456-1457 (during the reign of Vlad Țepeș) is host inside.
The icon of Virgin Mary - Hodighitria dates back to 1530. The second typography in Walachia is installed here in 1637.
The Monastery was repaired and enriched during 1640-1645, under the rule of Matei Basarab.
The actual painting of the church dates back to 1711-1712; Brâncovenesc-Hurezi school of painting.
In 1959 become a nouns Monastery.</td></tr>
<tr><td></td><td>I
<u>Olănești Spa</u> (Băile Olănești)

30 cold mineral springs (15 taped and used);
four wells (only two used) of around 400 and 750 mbGL; internal cure for digestive and urinary tract diseases.

One deep geothermal well (drilled 1995):
Depth: 3313 mbGL
Temperature: 50 °C
Q (artesian): 5 L/s</td></tr>
</table>

	**J** Călimănești (Hotel Central) <u>Cold mineral water (8-10 °C)</u> from the 12 natural springs used in internal cures for the treatment of kidney, liver, bladder, and stomach diseases and decrease the pathologically high glycaemia. <u>Shallow thermo-mineral water</u> (nine wells) are of the sulphate-sodium-chlorine-brome-iodine type, with calcium, having a TDS up to 18 g/l and T= 43-47°C.
	<u>Deep thermo-mineral waters</u> (produced by 3 wells, see below). Water of sodium-chloride type, with calcium and iodine. Used in external cures for the treatment of rheumatism (inflammatory and degenerative), articulation diseases, peripheral neural diseases or for the treatment of some respiratory system diseases. **K** Căciulata – Cozia area (Complex of hotels and treatment facilities)

L

Geothermal Wellfield Foradex SA
No. of wells: 3
Depth range: 2640-3250 mbGL
Temperature range: 91-96 °C
Q range (artesian): 9-20 L/s
TDS: around 2g/L

Main purposes: external cure, balneation, heating.

M

Cozia Monastery – Initially known as Nucet (translated in cuman as *Cozia*). Built during 1386-1391 by a Serbian constructor under the rule of *Mircea cel Bătrân*, and painted firstly during 1390-1391 it was largely improved in 1706-1707.

Paintings were restored during 1704 - 1705 and 1984 - 1985.

The tombs of *Mircea cel Bătrân* and mother of *Mihai Viteazul* can be seen in the narthex (pronaos).

The monastery hosts a rich museum and presently is one of the most visited cultural and religious sites in Romania.

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OCNELE MARI – SALT ENGINEERING AND TOURISM (*THE SALINA*)

Iulian POPA, Marius MOCUȚA, *University of Bucharest*

The Ocnele Mari salt deposit is located in the sub-Carpathian hills of Southern Romania (Oltenia region, Vâlcea county), at 12 km westward from Rm. Vâlcea town – Figure 26. About 8 km long, it runs east to west, with a width of 3.5 km and a thickness of up to 400 m, dipping about 20° to the north (Figure 28). It is bounded by the Olt River at East and by Govora River at West. It crosses the territory of Ocnele Mari town and surrounding villages with a population of about 5000 inhabitants.

From the geologic point of view the Ocnele Mari area belongs to the Getic Depression, the most external unit of Southern Carpathians. The salt deposit is located on the faulted Northern flank of the Ocnele Mari - Govora anticline, being delimited by faults: Teiuș (westward), Copăcelu (eastward), Stoenești (to the north) and Bisericii (to the south). The salt deposit has a stratified lenticular shape and is of Badenian age (Miocene). Along a north-south cross section (Figure 28) the lithological sequence is as following: the salt deposit of Badenian age underlined by tuffs of the same age. The overburden is made up by marls, sandy marls, sand and sandstones.

Currently the exploitation takes place in two mining areas:

- Coceneşti mine, traditional dry mining;
- Ocnele Mari-Ocniţa wellfields, were salt is extracted by dissolution.

The classic extraction of salt in actual **Cocenești mine** started in 1993. The exploitation develops downward in two horizons, +226 and +210 m, using the most modern method - small rooms with square pillars *(http://www.salrom.ro/ocnele-mari.php)*.

After completing the exploitation, the west wing of +226 m horizon was designed as touristic area (*Salina*) – Figure 29. On around 40,000 m^2 you can find entertainment facilities and playground areas, a museum devoted to salt exploitation in the region, a restaurant and last but not least the biggest underground church.

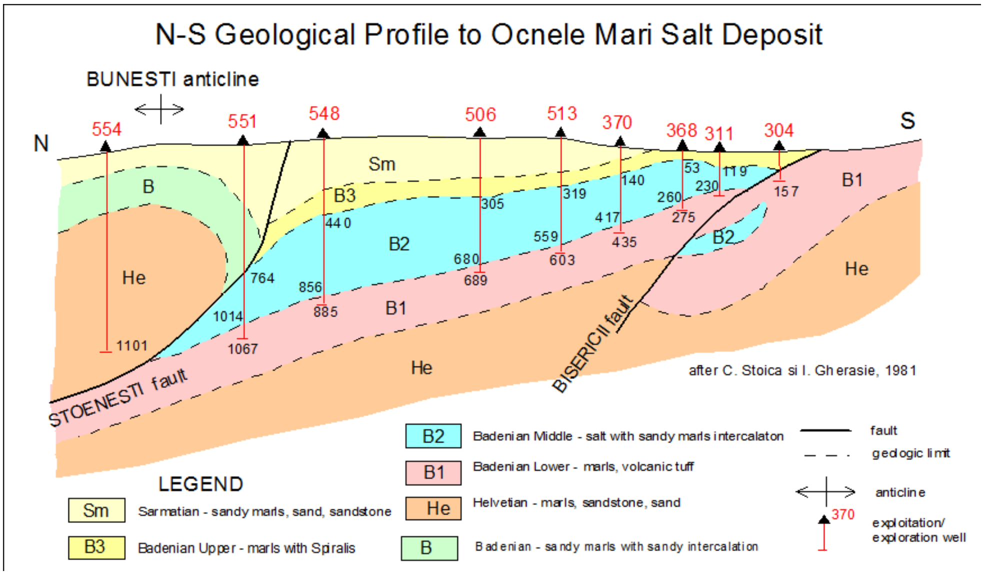

Figure 28. Geological cross-section

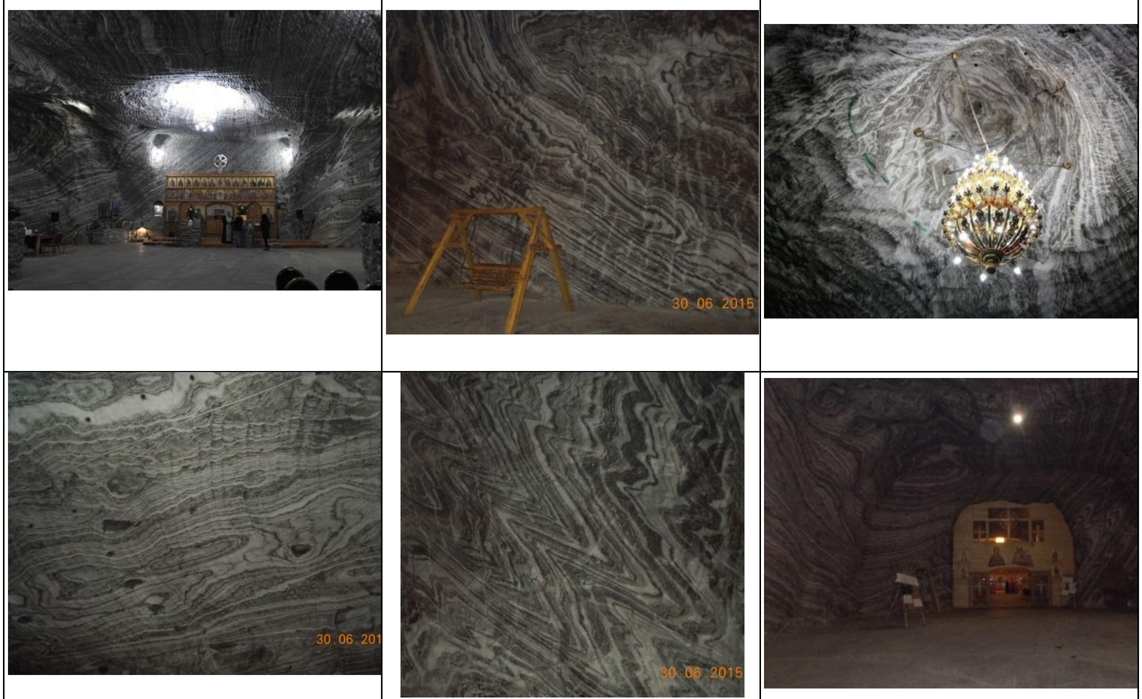

Fig. 29 Touristic zone (*Salina*); *photos by Iulian Popa*

Salt has been actively extracted through **dissolution** in four exploitation fields which started sequentially, beginning with 1954. Operations in *Field 2* were initiated in 1969 and led to the extraction of 13.5 million tons of salt until a major collapse occurred in March 1991. This event underscored the risks associated with the presence of large dissolution caverns close to a densely populated area, prompting the decision to shut-down the exploitation in this field (Zamfirescu et al. 2007). However the hazards associated with the presence of a large volume of confined brine near to a densely inhabited region remained real.

Cavernometry measurements carried out in 1993 outlined the presence of a massive cavern formed by the complete dissolution of the inter-chamber pillars of 6 of the 15 wells, containing 5.5 million m^3 of confined brine - the world's largest artificial underground cavern.

One major collapse took place towards the northern edge of the cavern in September 2001, when a part of the roof caved in, forming a quasi-circular crater of almost 200 m in diameter and leading to the spill of 1.7 million m^3 of brine. Furthermore a second major event occurred in July 2004, during which the original sinkhole was enlarged, accelerating thus the demand for a solution to this mechanical instability problem.

To eliminate this huge hazard in a densely inhabited area, a technical solution developed by the team of University of Bucharest was implemented i.e. reaching the stability state through the triggered (controlled) collapse of the roof while pumping the brine out and filling the cavern with sterile material. A complex monitoring system was installed to provide information about micro-seismic activity related to stress re-distribution during the controlled/triggered collapse of the cavern roof.

The collapse of the **Field 2** occurred in December 24/2005 without human victims/injuries, with minimum environmental impact and largely in line with the technical project particularly in terms of position and magnitude of the collapse – Figure 30.

Figure 30. **Field 2**, The collapse lake and the affected areas; Left – view from the southern side; Right – view from the northern side; *photos by Iulian Popa*

Four years later a similar technical solution has been adopted by DCGGA team of the Bucharest University at around 250 m westward in the area of the **Field 1,** where a cavern of about 1 million m^3 has been identified. The collapse of the cavern roof started on 8^{th} of August 2009, the volume of the evacuated brine was about 840,000 m^3 and the crater on the ground surface it was around 39,000 m^2 – Figure 31.

Figure 31
Field 1, The collapse lake and the affected areas; *photos by Iulian Popa*

Top: View from the northern side

Bottom: View from the southern side

The brine was stored in the reservoirs of the Pârâul Sărat dam and further on completely processed by the Govora chemical plant (Zamfirescu *et al*. 2010).

Noteworthy, the controlled collapse of the cavern in the *Field 1* has progressed in good agreement with the proposed project. The safety concerning the economic, social and environmental conditions was completely fulfilled.

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http://www.salrom.ro/ocnele-mari.php

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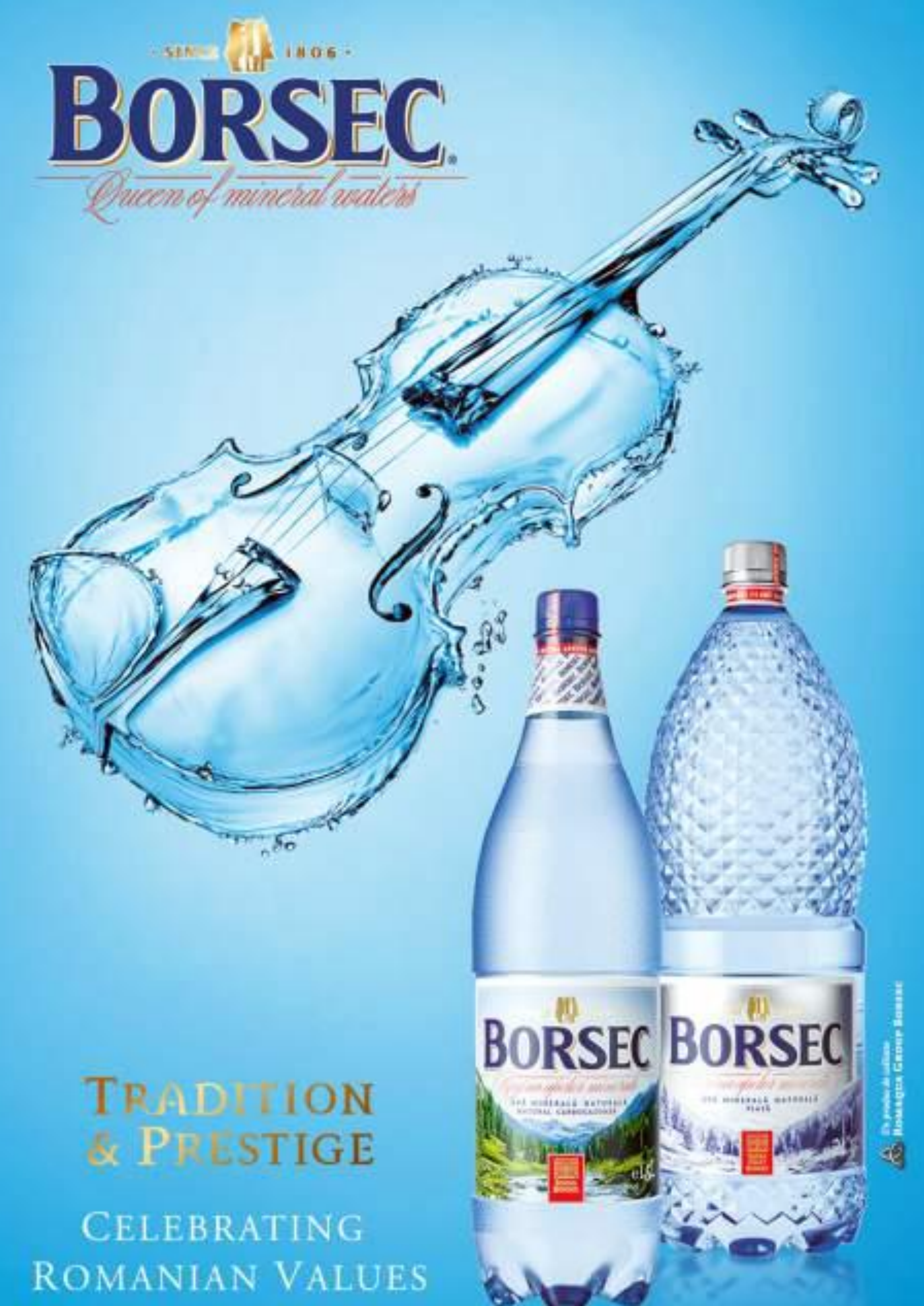
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