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TRADITIO ET EXCELLENTIA



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## ***Geomorphology in the Anthropocene***

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**&**

**BABES-BOLYAI UNIVERSITY, CLUJ-NAPOCA  
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## **FIELD TRIP GUIDE**

### **APUSENI MOUNTAINS**

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## APUSENI MOUNTAINS – GENERAL FEATURES

### Physical characteristics

The Apuseni Mountains represents the highest (1848 m) and the largest ( 10.750 km<sup>2</sup>) sector of the Western Carpathians, bordered to the north by the Someș Corridor ( through some of its tributary rivers) and to the south by the Mureș Corridor.



Fig. 1. Geographical setting of Apuseni Mountains

The central core (the highest area in the Apuseni Mountains) is represented by the Biharia Massif (1848 m), around which the other mountain massifs stretch out radially: to the south: Zărand and Metaliferi Mountains; to the east: Trascău Mountains, Gilău-Muntele Mare Mountains;



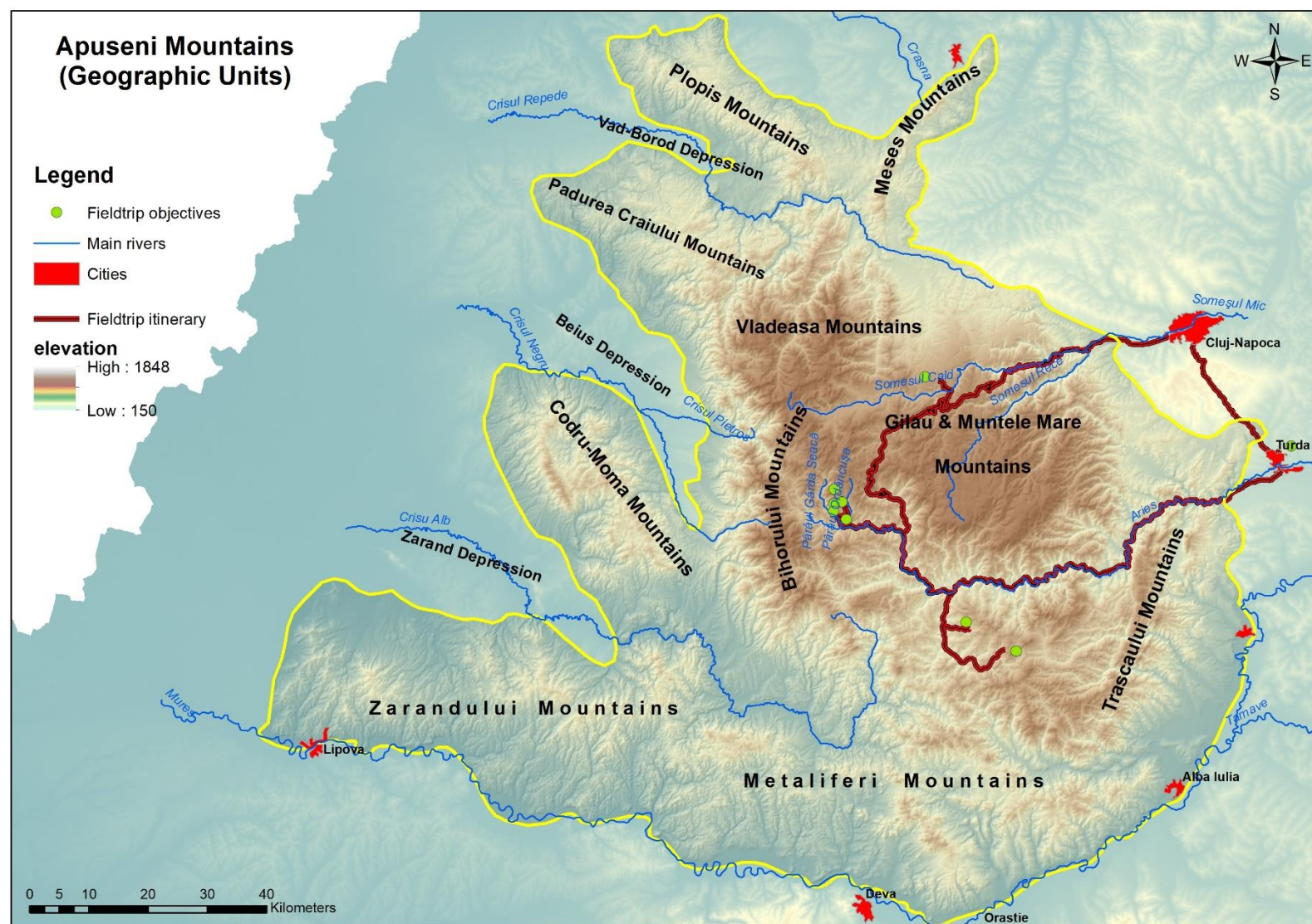


Fig. 2. Geographical Units of Apuseni Mountains

to the west and north-west: Codru Moma and Pădurea Craiului Mountains; to the north: the massifs of Vlădeasa, Plopiș and Meseș (Gf. României, 1987).

The geographic individuality of the Apuseni Mountains is defined by some features as:

- Altitudinal zonation - the presence of the three erosion surfaces/platforms: Fărcașa-Cârligatele platform (between 1600-1800 m.), Măguri-Mărișel platform (between 800-1200 m.) and Feneș - Deva platform (500-800 m.);
- Increased development of Triassic, Jurassic and Cretaceous carbonate rocks (limestones, dolomites, conglomerates with calcareous cement etc.) that favoured the development of some karst landforms with important scientific, landscape and touristic value;
- The presence of some picturesque sectors of gorges and canyons, carved either in limestones or in other types of rocks;
- The central disposal of the Bihor Mountains (the highest area) determines a radial development of the watercourses. The watercourses orientation is also influenced by the presence of some fault lines.

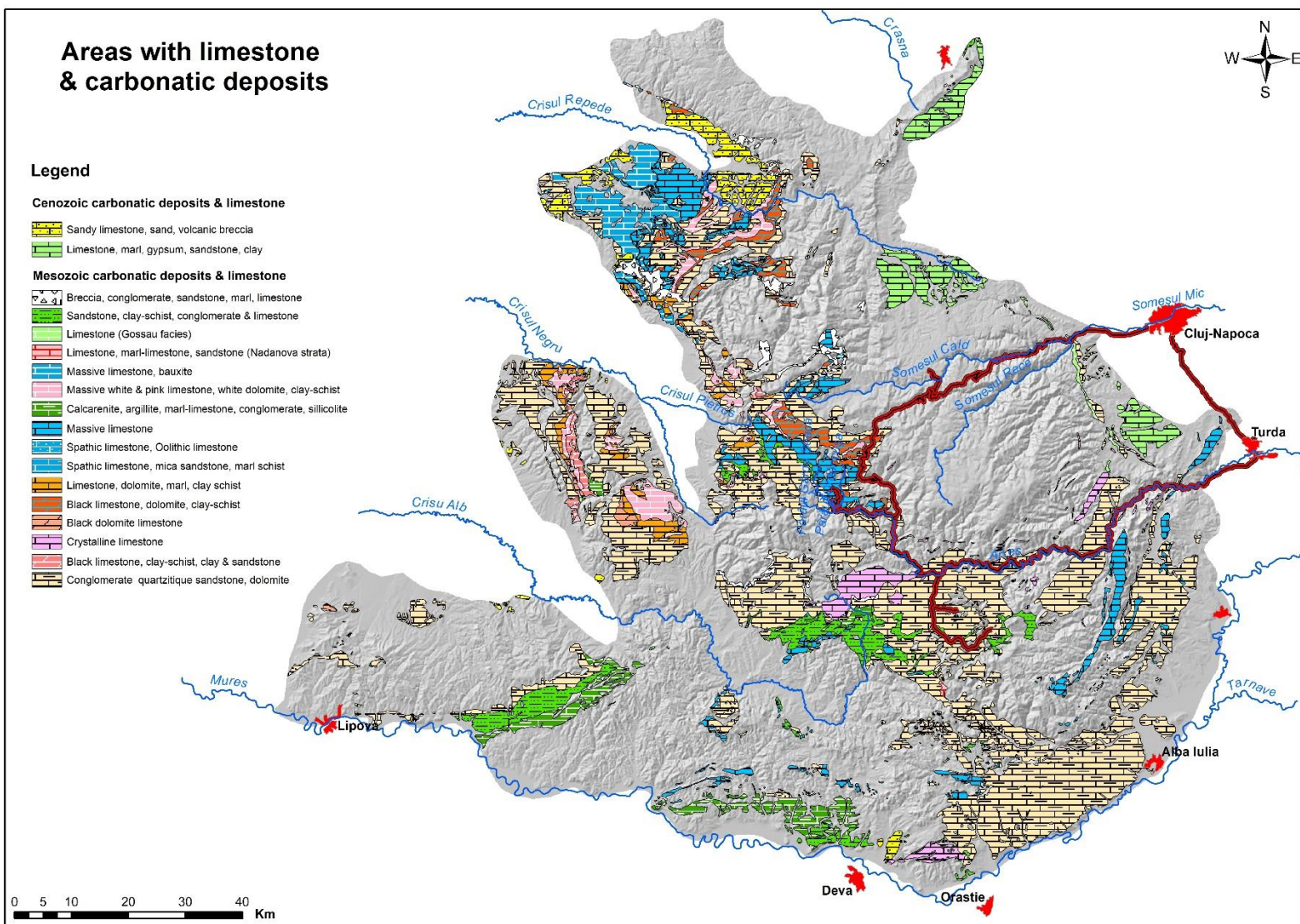


Fig. 3



## **Geology**

The general physiognomy of the landscape mirrors a rather recent age for the Apuseni Mountains. The Apuseni Mountains were largely affected by the tectonic events in the Cretaceous that made the preceding morphology hard to be revealed. The long period throughout which the massif was subaerial allowed the development of three erosion surfaces, each of them with other two subsequent levels (Ianovici et al., 1976).

The Apuseni Mountains appeared as a result of the evolution of a rift within the Pannonian Transylvanian block that split into the Pannonian block and the Transylvanian block.

Consequently, two units were individualized: a crystalline Mesozoic area (Northern Apuseni Mountains) and a flysch area (Southern Apuseni Mountains).

The deformations that affected the Apuseni Mountains induced major faults along two main directions: NE-SW and NW-SE. The magma from the inner core migrated to the surface along these directions, either insularly or well-developed bodies.

Within the alpine cycle, the Transylvanian-Pannonian block was formed that was further immersed by the epicontinental Mesozoic Sea. The analysis of the Apuseni Mountains structure reveals the existence of three important geostructural units: Bihor Autochthonous, Codru nappe system and Biharia nappe system. Simultaneously, in late Cretaceous (the Laramide orogeny - the magmatic rocks called banatites - in Vlădeasa Massif) and in Neozoic in Metaliferi Mountains (Gold Quadrilateral) an intense magmatic activity took place.

The splitting of the Apuseni mountainous block increased in early Sarmatian, allowing the advance of the sea within the mountains up to Roșia Montană, the upper Arieș River basin or to Gurahonț Depression along Crișul Alb. In mid- and late-Sarmatian, the immersed regions narrowed down to the regions, bordering the Apuseni Mountains block in the graben-type depressions in the west (along the three Criș Rivers), in the east, in Zlatna basin and in the north-east, the Almaș-Agrij basin.

The early Sarmatian had a transgressive character, especially in the western part of the Apuseni Mountains. The Pannonian Sea invaded the western gulfs, thus Zărand and Codru Moma Mountains become islands, while Pădurea Craiului and Plopiș, peninsulas. As a result of the raised base level, Beiușului Gulf on Crișul Negru was linked to Hălmagiu Gulf, on Crișul Alb over the Criștior saddle.



In late Sarmatian-early Pontian, a continuous retreat of the sea is reported, thus larger and larger areas became subject to sub-aerial modelling. In late Pontian, a new important transgression took place. The reconstitution of the level reached by the new transgression is difficult, as compromised by the followed-up processes that rubbed up its traces in many areas.

In the following Dacian-Levantine period, the major part of the Transylvanian Basin became sub-aerial, excepting some lakes in the marginal depressions. The hydrographic network in the Apuseni Mountains advance slowly, meandering across the post-Piacenzian littoral plains, towards the constantly lowering Pannonian Basin. Some remnants of these plains, strongly eroded, are still to be found in the western part of the Apuseni Mountains. In late Pliocene and early Quaternary, the Apuseni Mountains became subaerial totally. From this point on, Paucă and Ilie (1935) indicate the existence of an uplift movement that could have determined the asymmetry in altitude between the eastern and western parts of the Apuseni. The hypothesis is also sustained by the morphology of the valleys in the Bihor massif, which in the upper sectors have large transversal profiles, modelled in earlier phases, while in the lower sectors, the profiles are V-shaped, as a result of the rivers' effort towards profile, balancing within the context of the base level lowering in the Pannonian Basin.

On the other hand, Ficheux (1996) asserts that in Pliocene the Apuseni Mountains were described by tectonic stability and that the mountains came out of water because of the gradual lowering of the base level in the Pannonian Depression.

From tectonic point of view, the structural units that build up the substrate of the Bihor Mountains are: the Bihor Autochthonous, on the top of which the Codru nappe system and the Biharia nappe system thrust in a discordant and transgressive manner (Bleahu et al. 1976, Săndulescu, 1984, Mutihac, 1990, Balintoni, 1996).

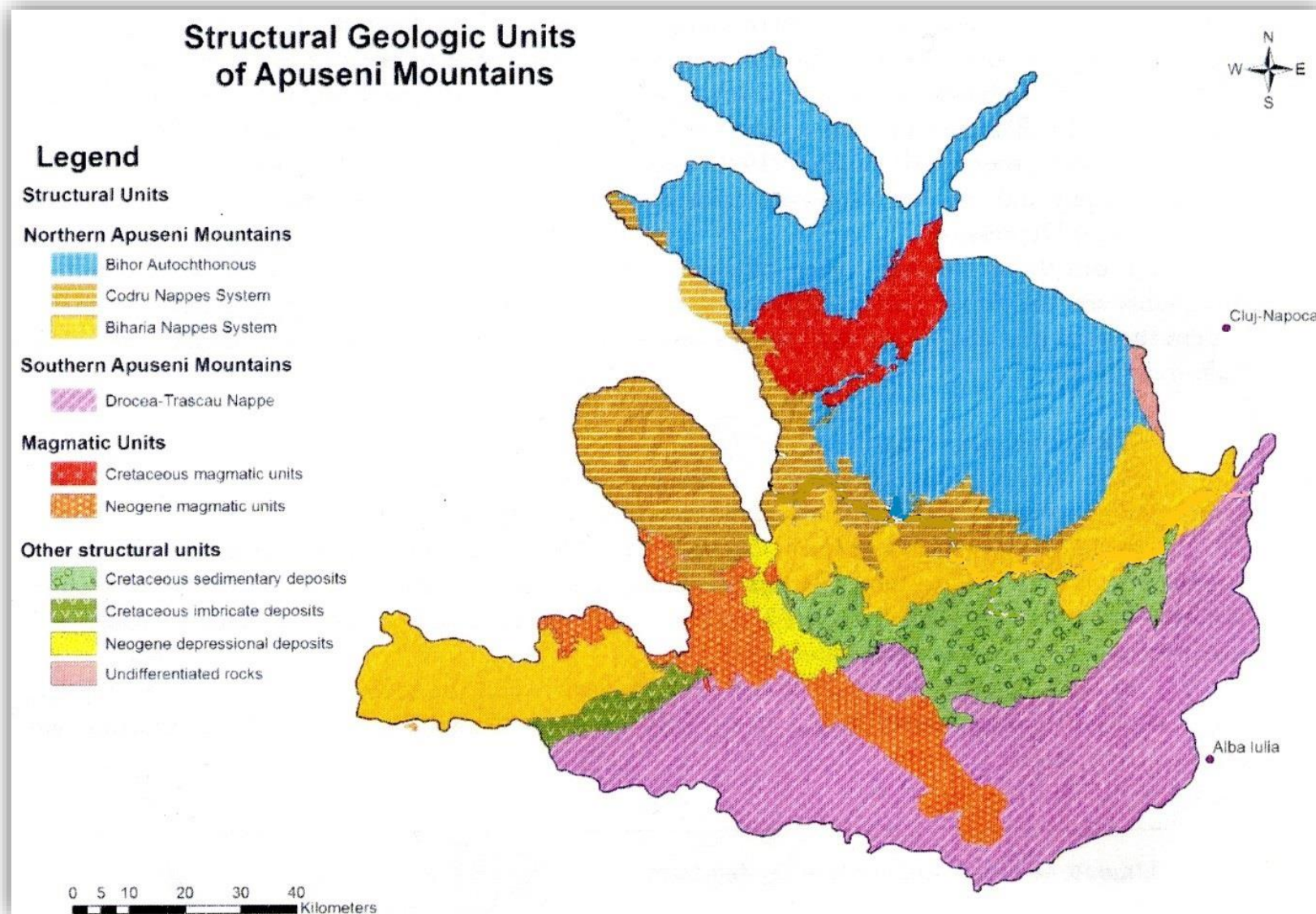


Fig.4

### **The banatites rocks**

The intrusive granite rocks are sin-tectonic to the Hercynian orogeny, together with the Banatitic eruptions. Starting with the Permian, on the top of these rocks, a sedimentary layer laid down.

In late Cretaceous and early Paleogene, the Northern Apuseni Mountains were affected by an intense magmatic activity, related to the Laramide orogeny event that generated a new set of magmatic nappes, known as the Banatites. Another hypothesis asserts that the Laramide magmatic activity would belong to two paroxysmal phases: Sub-Hercynian and Laramide.

By analysing the relation between the magmatic rocks and the sedimentary formations, the hypothesis of a single major magmatic events taking place between late Senonian and early Eocene arises, with three well distinguished stages:

1. *The early effusive-explosive Laramide vulcanism*, when large lava flows and andesite, dacites and rhyolites were laid down. For the Biharia Massif, rocks as rhyolites, andesite, dacites, rhyolites dacites, microgranite rhyolites, micro diorites andesite.

2. *The intrusive Laramide vulcanism* that generated blocks of diorites and tonalites, quartz-diorites, granodiorites, monzogranite and granite. The following rocks outcrop in Bihor Mountains: granodiorites, diorites.

3. *The final Laramide vulcanism*, when some dykes of aplite, micro granite, micro diorite, basalt and porphyry. Among the characteristic rocks, in Bihor, are basalt, porphyry micro granites, micro diorites, porphyry micro granodiorites, lamprophyre and undifferentiated basalts.

The crystalline schist and the Permian, Triassic and Jurassic deposits in the Bihor Mountains are penetrated by numerous seams, dykes, sills and unregulated rock bodies of various composition. A very important Banatite rock body that determined the formation of a large contact area is located in Băița-Bihor. The majority of these rock bodies are directed northwest-southeast and northeast-southwest, along the main fault systems that affected the Bihor Mountains.



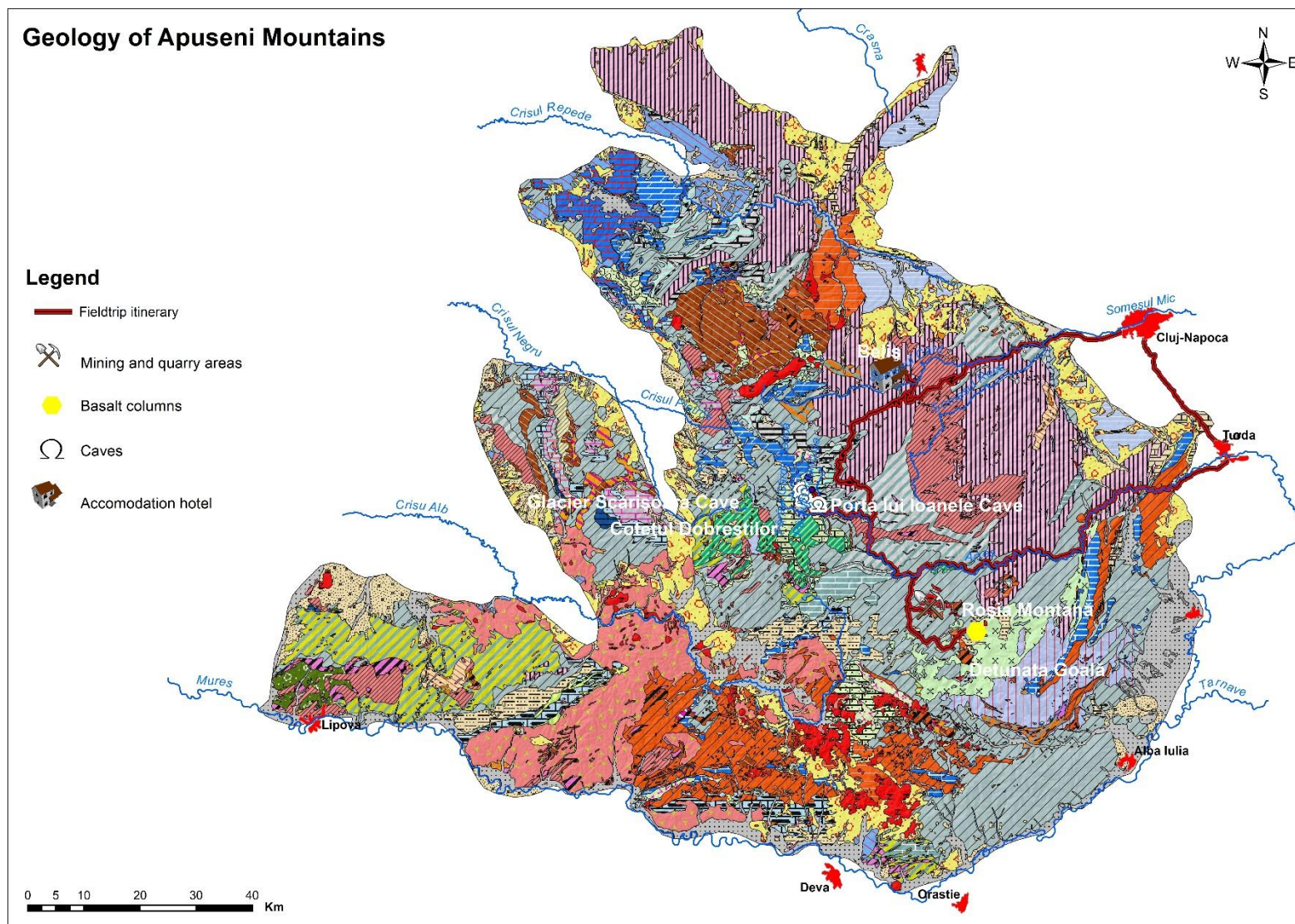


Fig. 5

## Legend of geologic map

### Types of rocks & deposits

#### Cenozoic rocks & deposits

	Present alluvial deposits
	Clay, sand, sandstone, marl-limestone, bituminous marl-limestone
	Gravels, pebbles, sand
	Marl, gypsum, clays
	Gravels, pebbles
	Gravel, sand and clay-sand
	Hillslope deposits

#### Mesozoic rocks & deposits

	Quartzite sandstone and conglomerate
	Bauxite, limestone, marl-limestone
	breccia, conglomerate, sandstone, marl, limestone
	Massive white limestone
	Massive white limestone, massive dolomite
	Crystalline limestone
	Rudist limestone
	Limestone, dolomite, marl, clay schist
	Limestone, marl, gypsum, clay
	Limestone, marl-limestone, sandstone
	Massive limestone
	Massive limestone white and pink, massive dolomite
	Massive limestone, bauxite
	Massive limestone, stratified limestone
	Black limestone, dolomite, clay schist
	Fossiliferous black limestone, clay schist
	Saby limestone, sand, volcanic breccia
	Black limestone and dolomite
	Oolitic limestone
	Spathic limestone, micaceous sandstone, marl schist
	Calcarene, argilite, marl-limestone, conglomerate
	Conglomerate, quartzitic sandstone, dolomite
	Flysch
	Sandstone, clay sandstone, conglomerate
	Jasper, clay schist
	Microconglomerate and quartzitic sandstone
	Clay schist, calcarenite
	Clay schist, sandstone, conglomerate

#### Precambrian & Paleozoic rocks and deposits

	Amphibolite
	Quartzite
	2. Metaconglomerate
	2. Micasisturi paragneiss
	Porphyry
	Green tufa rocks
	Skarn
	Arada, Biharia and Muncel series
	Tulisa and Varmaga series
	Syenite
	Crystalline schist
	Quartzite-sericite schist, chlorite-sericite schist
	Chlorite sericite schist
	Green schist
	Spilite
	Stromatolite, clay schist

#### Magmatic & volcanic rocks

	Andesite and pyroxene
	Basalt
	Dacite
	Diorite
	Diabase flows, tufa & phyllite
	Gabro
	Granitoid
	Peridotite
	Rhyolite
	Pyroclastic rocks

Fig. 6



The eruptive formations in the Roşia Montană-Bucium area were born in the last stage of alpine magmatism in the Apuseni Mountains, through a volcanic activity carried out in several episodes from the Miocene (early Tortonian) to the late Pliocene-early Quaternary.

An explanation of the Neogene volcanism suggests that it was triggered as a result of the subduction of the ophiolites from the Metalliferous Mountains considered remnants of the oceanic plate from the Mures trench. Added to this is the opinion that the volcanism here is a result of the ascent of magmas from the mantle level, through a series of successive magmatic chambers to the surface. From a geochemical point of view, the magmas are predominantly andesitic (Mutihac, 1990, Ianovici et al., 1969, 1976).

### **Neotectonics**

Within the Romanian territory, the neotectonics movements occurred in the Quaternary and determined a deformation of the Piacenzian deposits and the newer ones.

They also induced a diversification, fragmentation and deformation of the Quaternary relief, as well as some changes in the altitude distribution. It is considered that in late Pliocene and Quaternary, the Carpathians uplifted with around 1000 m, with variations within the component massifs.

The intensity of the negative movements was considered in relation to the Quaternary deposits thickness, while that of the positive ones, in relation to the altitude of the Piacenzian deposits or to the absolute height of the landforms correlated to the morphogenetic stages.

In the northern sector of the Western Carpathians, the recent tectonic movements were less intense. The uplift values in the Apuseni Mountains do not exceed 1-2 mm/ an. On the map of the recent tectonic movements in the Atlas of the Soc. Rep. Rom. from 1979, the Apuseni Mountains is registered as a region with reduced tectonic movements (Mutihac, 1990, Ianovici et al., 1969, 1976).

## FIELDTRIP ITINERARY

Objectives – Rosia Montana, Poarta lui Ioanele Cave, Scarisoara Ice Cave

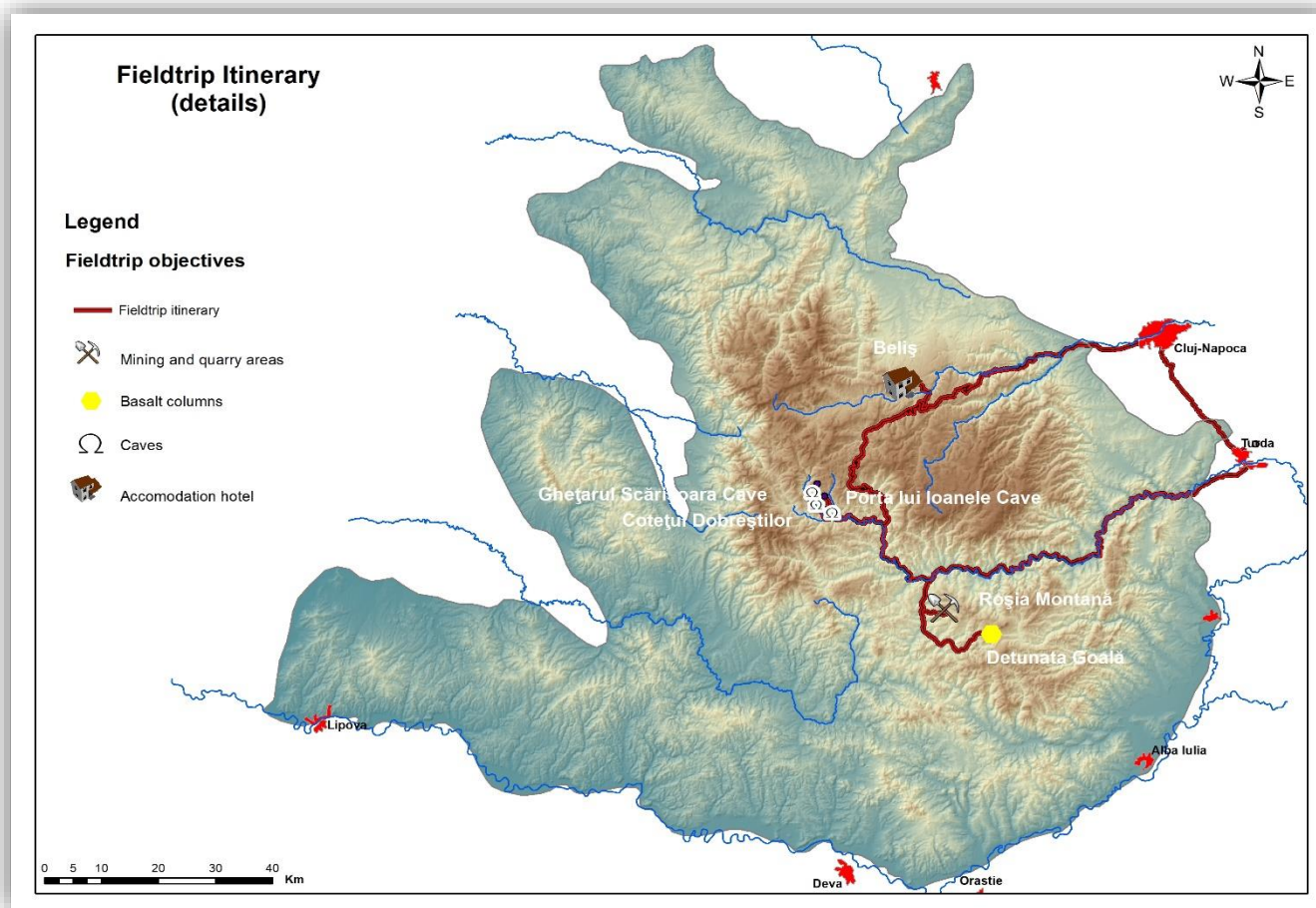


Fig. 7

**ROȘIA MONTANA** is a settlement in Țara Moților (The Land of Moți), located in the north-eastern part of the Metaliferi Mountains and of the Gold Quadrilateral, placed in a small geologic basin, close to the towns of Abrud and Câmpeni. It is very well known today, due to its famous golden and silver deposits, the largest in the country and in Europe, known and exploited for over 2000 years (Gf. României, 1987).

Roșia Montana is a part of what is known as "Gold Quadrilateral", a large mountainous area of about 2500 km<sup>2</sup> that, since more than 2000 years, was mentioned in historical documents as being mined for gold. This quadrilateral includes *three metallogenetic districts* (**Brad-Săcărâmb District, Stănița-Zlatna District and Roșia Montană-Baia de Arieș District**) and several, hierarchically inferior, metallogenetic fields.

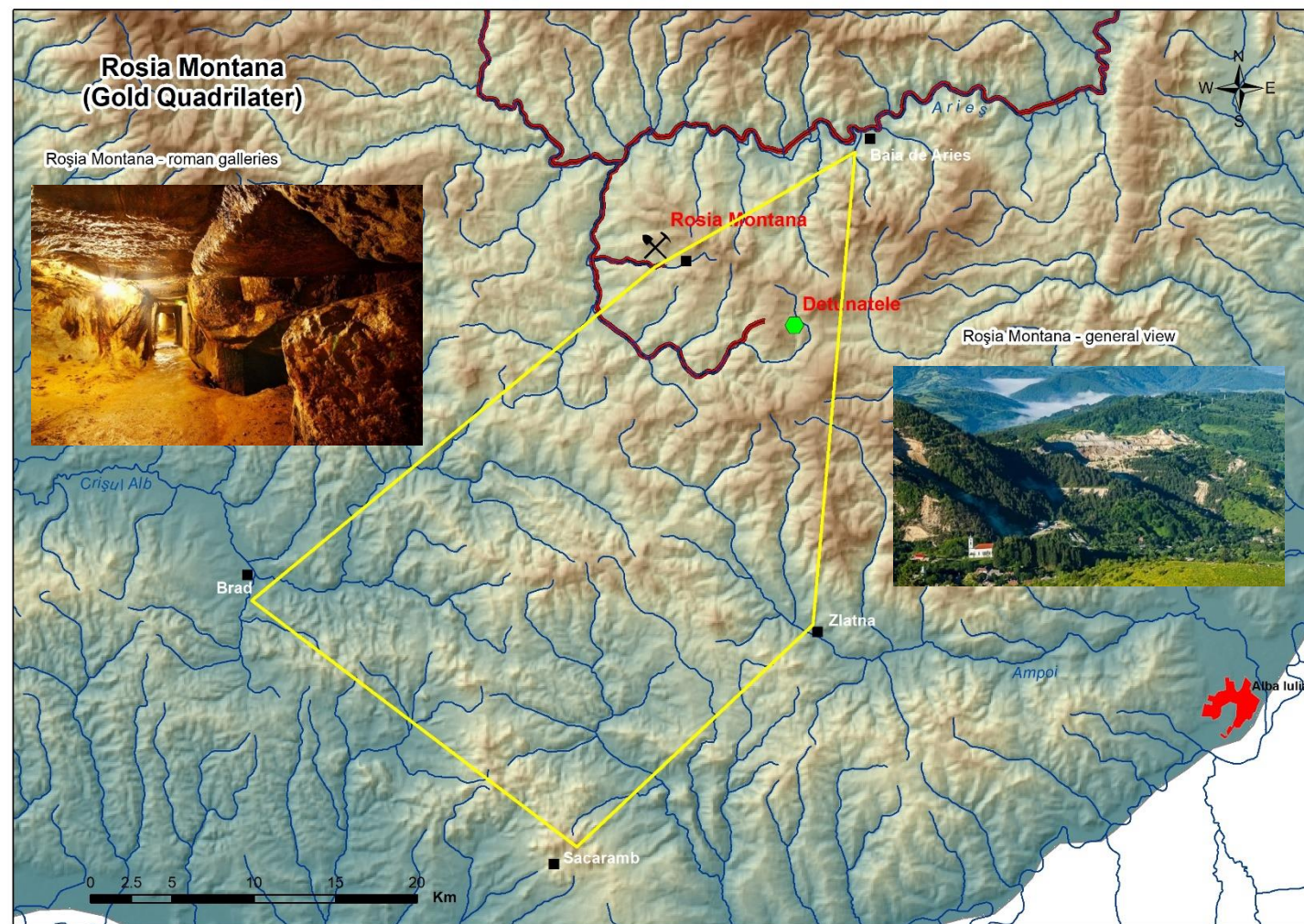


Fig. 8 Photo sources:

[https://images.search.yahoo.com/search/images;\\_ylt=Awrhbmzc2Rk\\_a0IjiIXNyoA;\\_ylu=Y29sbwNiZjEEcG9zAzEEdnRpZANDQ0FEU1IDVF8xBHNlYwNwaXZz?p=rosia+montana&fr2=piv-web&type=E210US885G0&fr=mcafee](https://images.search.yahoo.com/search/images;_ylt=Awrhbmzc2Rk_a0IjiIXNyoA;_ylu=Y29sbwNiZjEEcG9zAzEEdnRpZANDQ0FEU1IDVF8xBHNlYwNwaXZz?p=rosia+montana&fr2=piv-web&type=E210US885G0&fr=mcafee)



The geologic makeup of this area includes, among others, Neogene volcanic structures. Not only the gold-silver mineralization and ore are genetically related to these rocks, but also metallic accumulations (tellurium, lead, zinc, mercury, copper, etc.).

Volcanism in the Roșia Montană-Bucium-Detunatele area was facilitated by the existence of two fault directions arranged NW-SE and N-S.

Neogene volcanic activity took place during three eruptive cycles, the first two more intense and the third, weaker in terms of duration and intensity.

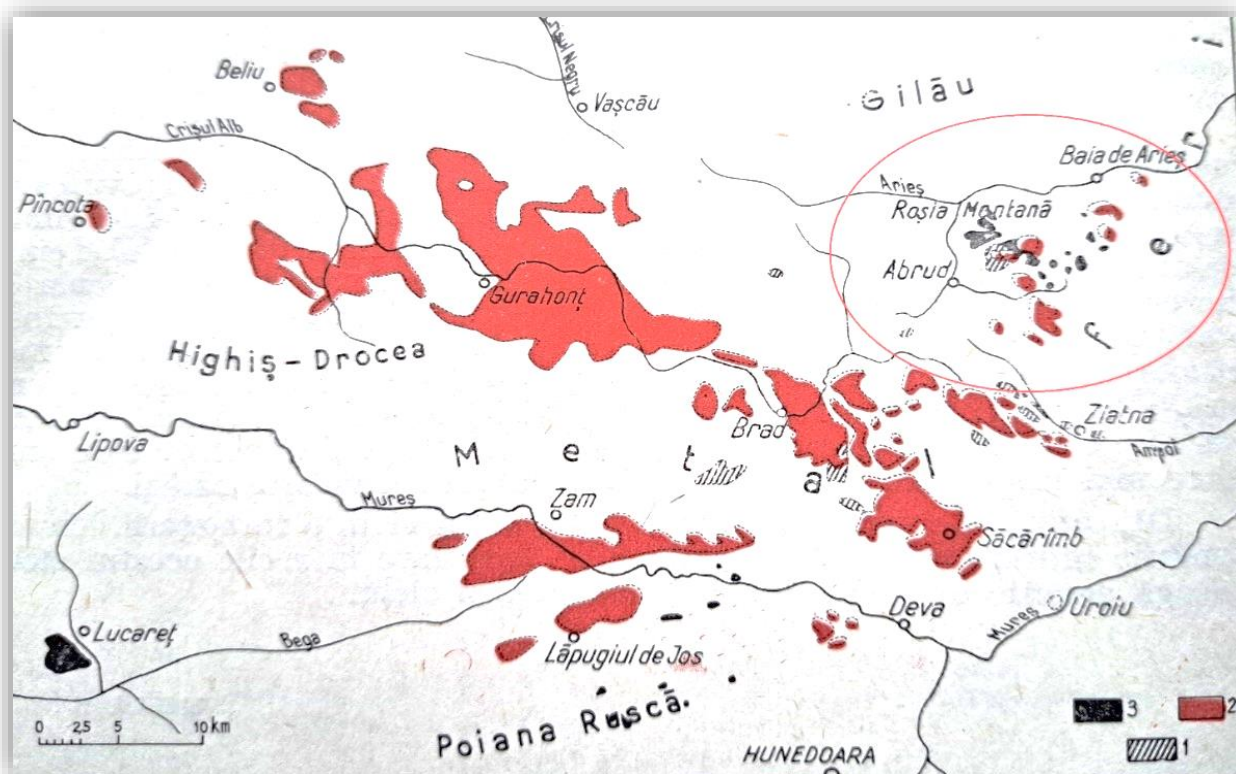


Fig. 9. The distribution of Neogene volcanism products in Apuseni Mountains. 1. First cycle of eruptions; 2. second cycle of eruptions; 3. third cycle of eruptions, (after Ianovici et al., 1969).

The first cycle that marked the beginning of volcanic activity in the Apuseni Mountains took place from the early Tortonian to the late Tortonian. Volcanic activity had a rhythmic and pulsating character, the highest intensity of volcanic activity being recorded in the early Tortonian. The volcanism of this period had an explosive character, with a great variety of rocks.

The second cycle had the highest intensity and the highest volume of volcanic products. It took place during the late Tortonian and early Pliocene periods. In the first phase of this cycle,



dacites were expelled, in the second phase the eruption products were quartz andesites, and in the third phase, dacites were expelled again. The third cycle took place during the late Pliocene and early Quaternary period. Volcanic activity in this cycle was less intense compared to the first two and represents the end of magmatic-volcanic activity in the Apuseni Mountains. This cycle manifested itself as weakly explosive effusive volcanism, generating flared bodies or small pillars



Fig. 10. Tectono-volcanic map of the area of Roșia Montană – Bucium. 2. Crystalline deposits; 2. Cretaceous sedimentary deposits; 3. Neogene sedimentary deposits; 4. Pre-Tertiary faults; 5. Tertiary tectono-volcanic faults; 6. Volcanic apparatus; 7. Centres of polygenic volcanic activity; 8. Subvolcanic bodies; 9. Under surface volcanic structures, (after Ianovici et al., 1976).

(columns). The volcanic products erupted in this cycle were basaltoid andesites and amphibolic andesites, and in the last phase, basalts.

The volcanic products of the third cycle have a restricted distribution in the territory. They have the greatest development in the Roșia Montană sector, with volcanoes made of basaltoid andesites and the two Detunates which have the shape of rooted columns composed of basalts with nepheline (Mutihac, 1990, Ianovici et al., 1969, 1976).

The Roșia Montană deposits are located in a basin between mountains, generated by the tectonic movement, at the beginning of tertiary era, completely isolated in the mid of early Cretaceous, pierced by a series of dacitic and andesitic eruptions. The dacitic volcanic bodies pierced the tertiary foundation and deposits, forming two tall mountains, with many minerals near the surface. In the area of the basin, there are volcanic rocks made up of dacites, breccia, tuffs and sedimentary rocks, formed of tuffs and conglomerate, known as volcano-sedimentary rocks ("local deposits").

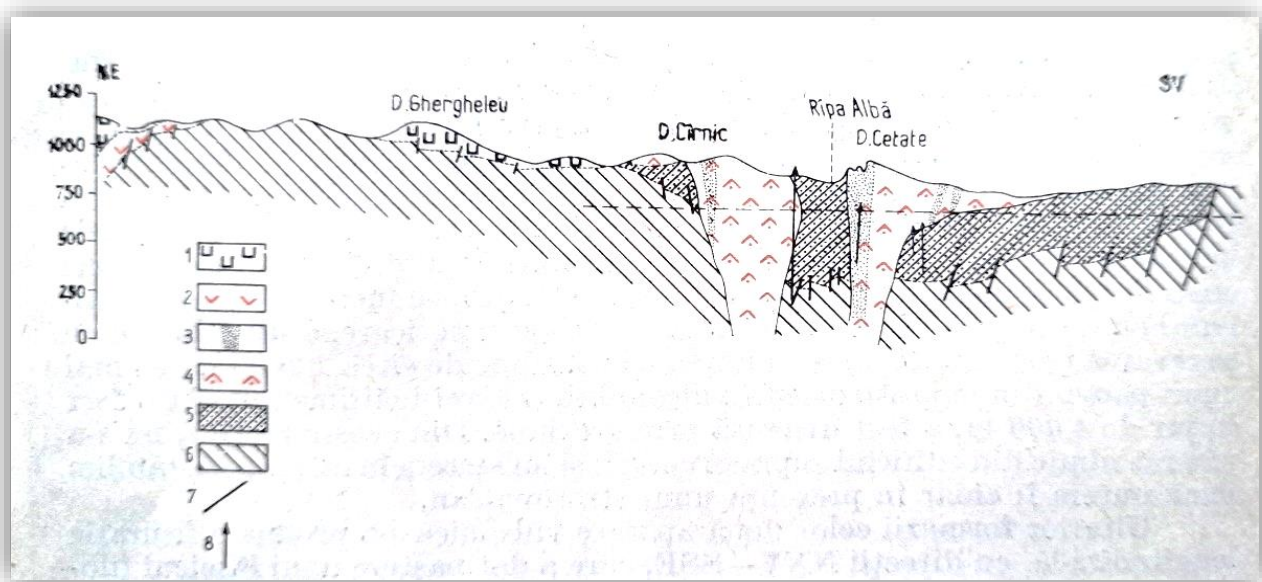


Fig. 11. Geological section of volcanic structure from Roșia Montană. 1. Basaltic andesite; 2. Cuartiferous andesite; 3. Eruption columns; 4. Dacite; 5. Volcanic sedimentary deposits; 6. Cretaceous deposits; 7. Fault; 8. Borehole, (after Ianovici et al., 1969).

One of the main geologic features of these deposits is that gold mainly occurs in mineralized vein (fracture in the host rock) and to a lesser extent in brecciated rock bodies - the latter being locally the case in Roșia Montana and Baia de Arieș deposits.

Gold is present as native (free), visible, sometimes locally condensed in "nests", weighting several kg and, exceptionally, tens of kg. Other forms of gold occurrence are micrometre-sized grains, disseminated in the rocks. The texture of the gold deposits is extremely important: it determines the most suitable processing methods, treatment with cyanide in the case of the finely impregnated gold, or respectively amalgamation, in the case of free gold.

The vein infilling is represented by a wide range of metallic and non-metallic associated minerals that were formed from hydrothermal solutions: Pb-Zn, Cu, Fe, In, Te, As, Ge, W.

To summarize, the known and partly mined gold-silver deposits from the Apuseni Mountains are low-grade ores (2 grams/ t), the gold being widely distributed in large rock volumes. These two genetic characteristics impose that large volumes are mined (at the surface, in open air quarries) on the one hand and cyanides are used for chemical processing of the "chemically-bound" gold, on the other hand. These are the main challenges for any mining company; they need to open mega-quarries and to use cyanides for gold processing (Mârza, 1. 2012).

### **Human indicators**

Roşia Montana town is part of Alba County and comprises 16 villages. The inhabitant population of the administrative area of Roşia Montana has decreased by 28.77% (1192 people), in 14 years, from 4142 in 1992, to 2950 in 2006. This depopulation is both a result of the migration and of the ageing of the population, 15% being over 65 years old in 2002. The town is characterized by a certain degree of ethnic and religious diversity, as a result of 2000 years of mining, by comparison with the ethnic and religious homogeneity of the Land of the Moţi, the historical region to which it also belongs. In 2002, the ethnic composition was as follows: 3.518 Romanians, 289 Gypsies, 55 Hungarians, 6 Germans, and 4 other nationalities, while the religious one was: 85.5 Orthodox, 4% Roman Catholics, 3.3% Pentecostals, 2.6% Greek Catholics, 1.8% Calvinist and Unitarians, 1.5% Baptists and 2.1% other cults (Erchedi Nicoleta, 2012).

### **History**

The history of Roşia Montana is closely related to the exploitation of gold resources and has undergone three significant periods: Antiquity with the vast system of Roman exploitations, Middle Age, with the traditional exploitation type and the modern period, characterized by the technological development.

In Antiquity, at Roşia Montana (Alburnus Maior), mining work started in 131 AD. 24 km of galleries and mining spaces have remained since the Romans times. Hard rock ore extraction was made by using fire (fire +cold water), chisel, holes filled with water and covered with a wooden plug, which was hammered, so eventually the pressure caused the cracking of the ore.

Mining is mentioned in the Middle Ages in 1238 and is said to have been organized by German colonists. By then, the place was called Rubeo Flumine (Red River) and afterward was called Rotseifen and Rotbach. The holes were still made by chisel, but the rocks were removed with back powder techniques that lasted until the Modern Age.

During the Modern Age, characterized by Industrial Revolution, the State (The Hasburg Empire) and the private owners started major mining ores. Artificial lake system was created for grinding the gold ore. At the end of 19<sup>th</sup> century, gold mining develops significantly and Roşia Montana evolves economically and becomes a separate territory with its own administration.

During the communist period, planned mining develops in order to pay for the war damages and then in order to pay for the debts of the State. This period is characterized by using out-of-date technologies and frequent flux interruptions in the preparation plant led to significant losses, therefore that gold can be found today in the separation ponds for the plant waste (Erchedi Nicoleta, 2012).

## DETUNATELE

The volcanic apparatus from Detunatele are made of basaltic andesitic lavas and have a simple tubular flared (inflated) root near the surface. The tendency to escape is noticeable in the arched nature of the prismatic columns which form a 15 m overhang at 150 m high. The volcanic manifestations here were not explosive.



*Photo 3. Detunata Goală*

*Photos source:*

[https://images.search.yahoo.com/search/images;\\_ylt=AwrFPCrdfGRkMPsIsmtXNyoA;\\_ylu=Y29sbwNiZjEEcG9zAzEEdnRpZANDQ0FEU11DVF8xBHNIYwNwaXZz?p=detunatele&fr2=piv-web&type=E210US885G0&fr=mcafee](https://images.search.yahoo.com/search/images;_ylt=AwrFPCrdfGRkMPsIsmtXNyoA;_ylu=Y29sbwNiZjEEcG9zAzEEdnRpZANDQ0FEU11DVF8xBHNIYwNwaXZz?p=detunatele&fr2=piv-web&type=E210US885G0&fr=mcafee)



*Photo 4. Detunata Flocoasă*

The appearance of the fractures that outline the basaltic columns show that the magma cooled very close to the surface, or even on the surface. A.Koch 1900 and M. Palfy 1912 (quoted by Ianovici et al., 1976) classified the basaltic columns from Detunate in the Staukuppen or Qullkuppen type – inflated forms with a tholoid appearance. It is considered that the appearance of the magmas here is related to the N-S oriented fracture system. The high alkalinity of the products compare to other neighbourhood areas affected by the third cycle, shows that basalts occurred at the final volcanic cycle. The chemical composition of the basaltic andesites from Detunate includes olivine, pyroxene and nepheline. Sub-centimetric vacuoles containing chlorite and carbonates are frequently found. Comparing the basalt columns from Detunatele with those found at “*The basalt Columns from Racoș*” (Brasov County) we will notice that the rocks here have a squared shape, which means only 4 corners instead of 6 how the columns from Racoș are.



The explanation for hexagonal shape at Racos consists in different amount of time required to cool the lava.

Detunata Goală is an isolated ridge with a maximum altitude of 1158 m asl, derived from a volcanic neck (Pécskay et al., 1995). In the absence of a crater morphology and of pyroclastic materials accumulated around the site (Maxim, 1944), the lava emerged at the surface from a monogenetic fissure vent (Ianovici et al., 1976) about 7.4 Ma ago (Pécskay et al., 1995, Roşu et al., 1997) creating a basaltic andesite intrusion in Cretaceous flysch with micaceous sandstone and schistose sediments (Bordea et al., 1979). The ridge is composed of prismatic columns of basaltic andesite rocks feeding two debris deposits accumulated on its western and southern sides, the first being considerably larger

Recently, the permafrost occurrence has been found at the Detunata Goala, this site hosting a permafrost at the lowest altitude in Romania (Popescu et al., 2017).

Due to its morphological features of volcanic origin, the presence of low-altitude permafrost (at 1020–1110 m asl), the existence of talus slopes on both sides of the ridge, Detunata Goala may be considered as one of the most emblematic geomorphosites in Romania.

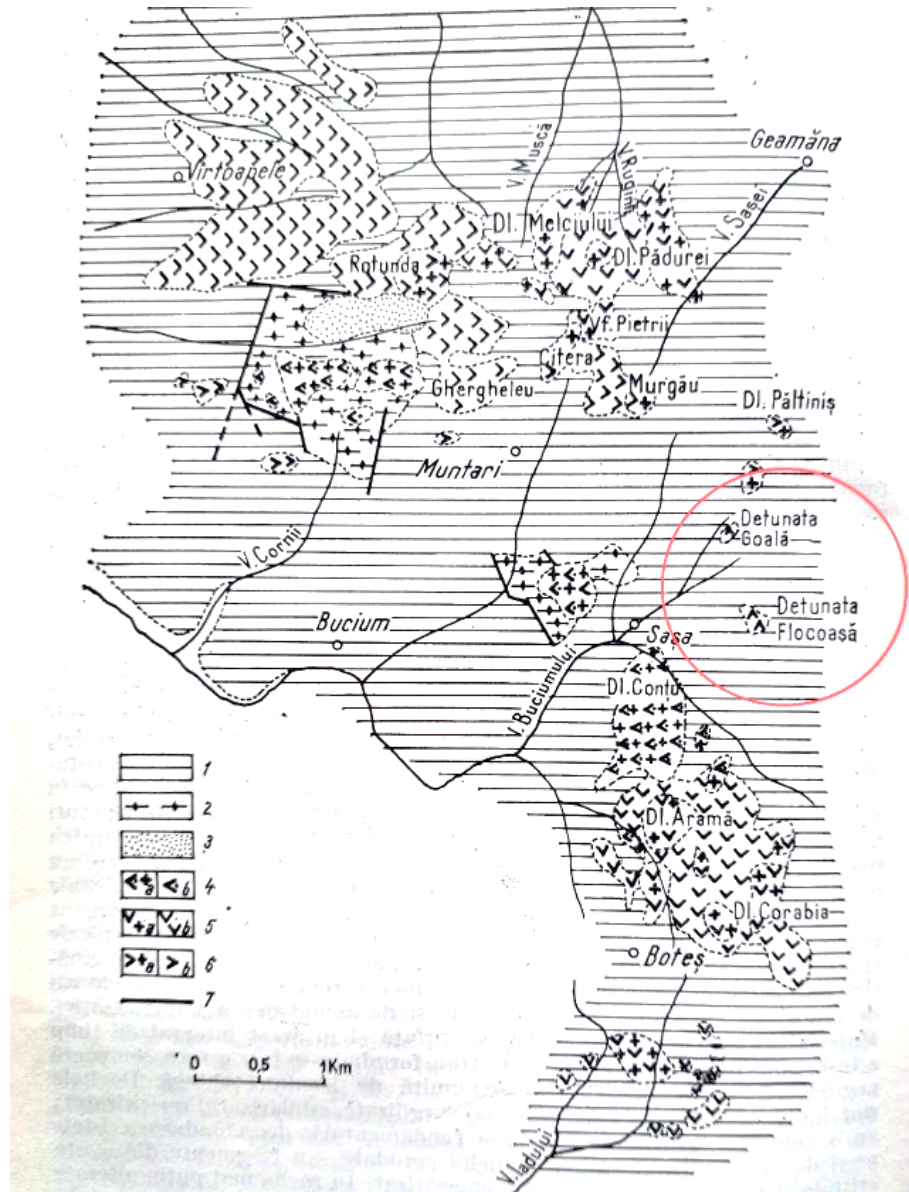


Fig. 12. Geological setting of Detunatele within Roșia Montană-Bucium area. 1. Cretaceous sedimentary deposits; 2. Pre Tortonian volcanic sedimentary deposits; 3 Tortonian sedimentary deposits; 4. Cuartiferous andesite of Roșia; 5. Cuartiferous andesite of Barza; 6. Andesite of Rotunda; 4, 5, 6, a. Sub volcanic bodies; 4, 5, 6, b. Lava flows; 7. Faults, (after Ianovici et al., 1976).

**POARTA LUI IOANELE CAVE (IOANELE'S GATE)** is one of the many karst forms that are located in Valley Ordancusei, right tributary of the Dry River Garda.

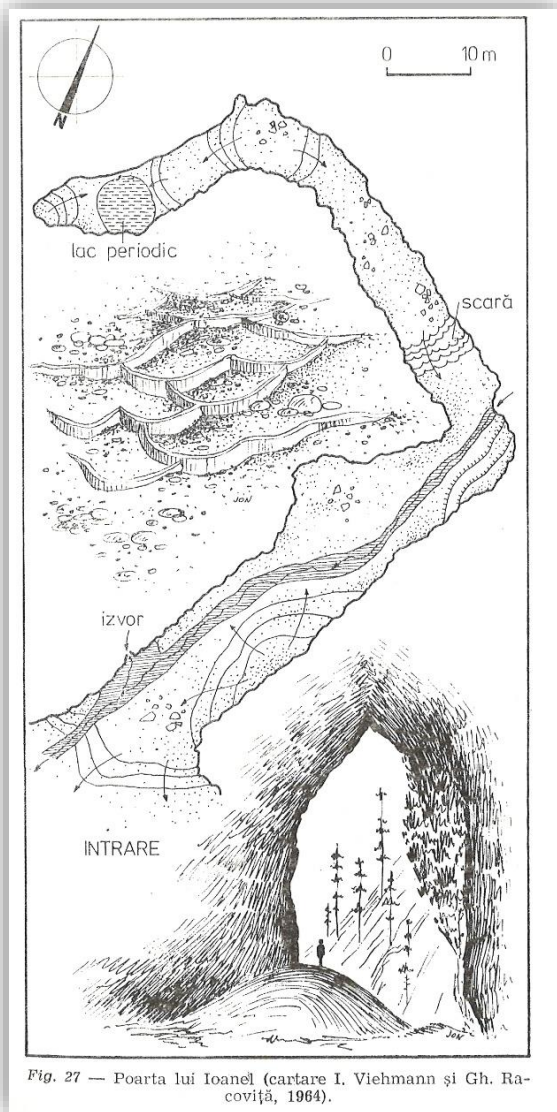


Fig. 27 — Poarta lui Ioanel (cartare I. Viehmann și Gh. Racoviță, 1964).



Photo. 5. Poarta lui Ioanele Cave, Photo source: [https://images.search.yahoo.com/search/images;\\_ylt=AwrFPCrdfGRkMPsIsmtXNyoA;\\_ylu=Y29sbwNiZjEEcG9zAzEEdnRpZANDQ0FEU1IDVF8xBHNlYwNwaXZz?p=detunatele&fr2=piv-web&type=E210US885G0&fr=mcafee](https://images.search.yahoo.com/search/images;_ylt=AwrFPCrdfGRkMPsIsmtXNyoA;_ylu=Y29sbwNiZjEEcG9zAzEEdnRpZANDQ0FEU1IDVF8xBHNlYwNwaXZz?p=detunatele&fr2=piv-web&type=E210US885G0&fr=mcafee)

Fig. 13. Poarta lui Ioanele Cave (after Orghidan et al., 1984)

The cave entrance is 1.5 km upstream of the confluence point for the rivers Ordancusa and Dry Garda, on the right side of the valley at elevation 810 m. Its presence can be seen from the road because of the successive steps of a travertine cascade formed by the river exiting the cave. The cave was first detected by E.A. Bielz in 1857 and then J. Vass mentioned it in literature in

1884. Subsequently cave fauna was investigated by E. Racovitza and his collaborators in 1921, and in 1964 was measured entirely by I Viehmann and Gh. Racovita.

The appellative "Gate" comes undoubtedly from the appearance of the entrance of the cave that has 15 m. height. The entrance is the most spectacular as the rest of the cavity consists of a modest passage, only 130 m. long, turning two times toward left. The passage lacks speleothem except for a stalagmite that is necessary to be escalated for a height of 6 m. There is a circular excavation, a funnel of 5 m. in diameter, which was filled with rain water. Underground water course has a route indefinitely, depending on the amount of rainfall; it can follow one path or another. The stream that crosses the cave comes from the top of the massive limestone from the cave Glacier Zgurasti which is located about a few tens of meters above the cave Poarta lui Ioanele. In fact, origin of the water that passes through these two caves must be searched in the upper basin of the river Ordancusa in water losses there. Currently the cave is decorated for tourism and a part of it can be visited (Orghidan et al., 1984).

## SCĂRIȘOARA – OCOALE AREA

*Racovita and Onac*

The Ocoale - Ghețar - Dobrești karst system is part of the Scărișoara karst complex, located in the central area of the Bihor Massif, the core unit of the Apuseni Mountains. The area is a karst plateau, bounded on the east and west by Ordâncușa and Gârda Seacă valleys, respectively.

The landscape around the Scărișoara Glacier Cave generally consists of rolling summits or isolated massifs, separated one another by several saddles and small karst depressions (dolinas, uvalas). These morphological features give the region a chaotic appearance.

Two different hydrographic networks are located within this karst complex. These are the Ocoale Valley –Polița, along which the Ocoale –Ghețar –Dobrești karst system develop and the Ordâncușa Valley, transformed in its lower third part into an impressive canyon (Rusu & al., 1970).

Sinkholes and cave entrances provide moist microclimates for plant species that are different from those found in other parts of this massif. Most of the terrain is densely wooded, providing a home to a variety of wildlife. Bears, lynxes, boars and deer are the most common wild mammals.

The traditional architecture and the folklore of the population living on the Ocoale –Ghețar Plateau is worth noting. Wood processing is the primary occupation of the inhabitants of this region.

With a surface area of 3.6 km, the Ocoale Depression is a classic example of the formation and evolution of a closed karst depression, created by a subterranean stream piracy, through a series of stream sinks and sinkholes that migrated upstream, close to the spring area. It is bordered by Ocoale Hill to the north, Comărnicele and Bocului Hills to the west, Culmea Pârjolii to the south (where Scărișoara Glacier Cave is located) and in the east, a series of limestone hills separates it from the basin of the Ordâncușa Valley.

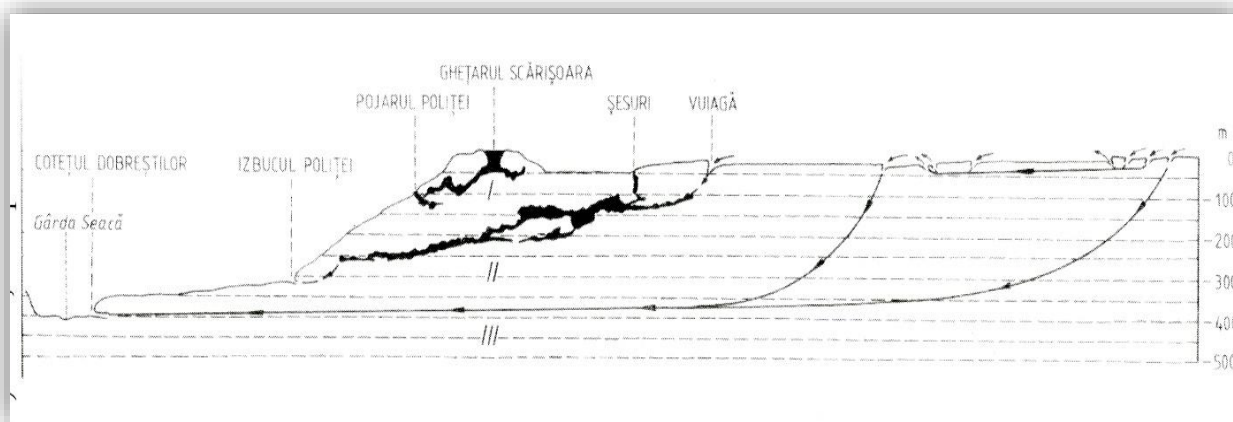
The heart of the depression shelters the Ocoale Hamlet, which is crossed by the Gârda de Sus-Ordâncușa-Ocoale-Ghețar tourist road (18 km) and is situated at 260 m below the highest altitude of the surrounding hills. A permanent stream in the upper (northern) sector and a temporarily active stream in the middle sector drains it. The southern partially forested sector is



without surface drainage but has a blind sinkhole valley, along which there are some temporarily active swallets and two permanent springs in the Vuiagă area.

In the southern extremity, the steep side of Culmea Pârjolii Hill (30-45 m in height) borders the Ocoale Depression. Its base is almost horizontal and is punched by several uvalas, dolinas and a short gorge section between the Ponorul de la Vuiagă and the close depression in which the Avenul din Șesuri (Șesuri Pit) opens.

All of the streams in this depression migrate underground, where they form two important subterranean drains. One is temporarily active with a karstic spring in the Polița Izbuc, through which the water caught in the southern sector reappears. The other is the permanent and inaccessible karst spring of Izbucul Cotețul Dobreștilor. It drains the surface water from the middle and upper sectors of the depression.



*Figure 14. The speleogenesis of the Scărișoara karst complex (source: Rusu et al., 1970)*

The geological setting of the Ocoale –Ghețar Plateau is rather simple. The entire plateau is developed on Mesozoic sedimentary rocks belonging to the *Bihor Unit* (autochthonous). To the west, the autochthonous is over thrust by the Permian detrital formation, developed in a typical Verrucano facies (purplish-red colored quartzite sandstone, conglomerates, and shales). This latter one is part of the Gârda Nappe.

The Scărișoara Glacier Cave was believed to develop in massive reef limestone of Ladinian (Middle Triassic) age (Ianovici et al., 1976). The authors estimated the age of the limestone by using paleontological and structural elements.

Bucur & Onac (2000) have recently sampled the limestone in different point of the cave and studied by means of thin section. They found the following algae (*Salpingoporella pygmaea* (GUEMBEL), *Salpingoporella annulata* (CAROZZI), *Linoporella capriotica* (OPENHEIMER), *Petrascula* sp., *Nipponoplycus ramosus* YABE & TOYAMA, *Solenopora jurassica* NICHOLSON, *Thaumatoporella parvovesiculifera* RAINERI) and foraminifera (*Laryrinthina mirabilis* WEYNSCHENK, *Andersenolina alpina* (LEUPOLD), *Troglotella incrustans* WERNLI & FOOKES).

This association is characteristic for the Upper Jurassic, most probably Lower Tithonic. Therefore, the limestones in which the cave is cut are equivalent to the Cornet Limestone in the Pădurea Craiului Mountains.

The existence of the Scărișoara Glacier has stimulated many speleological investigations in the area. In particular, the water divides between Gârda Seacă and Ordâncușa valleys, dominated by the Ocoale – Scărișoara close catchment basin, was the object of many groundwater observations. Among these, groundwater flow directions and flow rate values were measured in combination with fluoresceine tracer tests (Orășeanu, 1996).

The Mununa –Ghețar Fault is of crucial importance in the hydrogeology of this region, as it divides two distinct tectonic blocks. Each block contains its own karst aquifer and resurgent spring. Waters entering the aquifer on the eastern side of the fault (Munună –Hănășești Block) resurge out in Poarta lui Ioanele spring (average flow rate 90 l/s). On the western side of the fault (Ocoale Block), waters entering the aquifer are drained by the Cotețul Dobreștilor spring. This latter drainage is the longest (2800 m) and it has the largest relief (390 m) recorded in the Upper Arieșul Mare Basin. It drains the waters of Ocoale stream that sink within the Ocoale –Scărișoara close catchment basin (Orășeanu, 1996). The average flow rate recorded for the Cotețul Dobreștilor spring over the observation period (October 1984 -September 1985) was 280 l/ s. A flow volume of 1.06 m<sup>3</sup>/ s was the monthly maximum. During periods of prolong draught, the spring flow rate declines progressively until complete dry. The outlet is actually an overflow spring of the system. The perennial outlet is Izbucul Morii, located some 100 m downstream from Cotețul Dobreștilor, as well as a number of springs that occur at stream level or below over the same distance. These springs including the Izbucul Morii have occasionally been gauged (during periods when Cotețul Dobreștilor outlet dried up), giving resulting values of approximately 85 l/s

(Orăşeanu, 2000). Parameters measured from the correlative and spectral analysis of Coteţul Dobreştilor indicates the karst system has relatively important groundwater reserve.

Avenul din Şesuri (Şesuri Pothole) – Poliţei spring (mean average flow -5 l/s) is another hydro-karstic system. Much of the water is derived from sinking of temporarily surface streams in the southern pan of the Ocoale –Scărişoara close catchment basin.

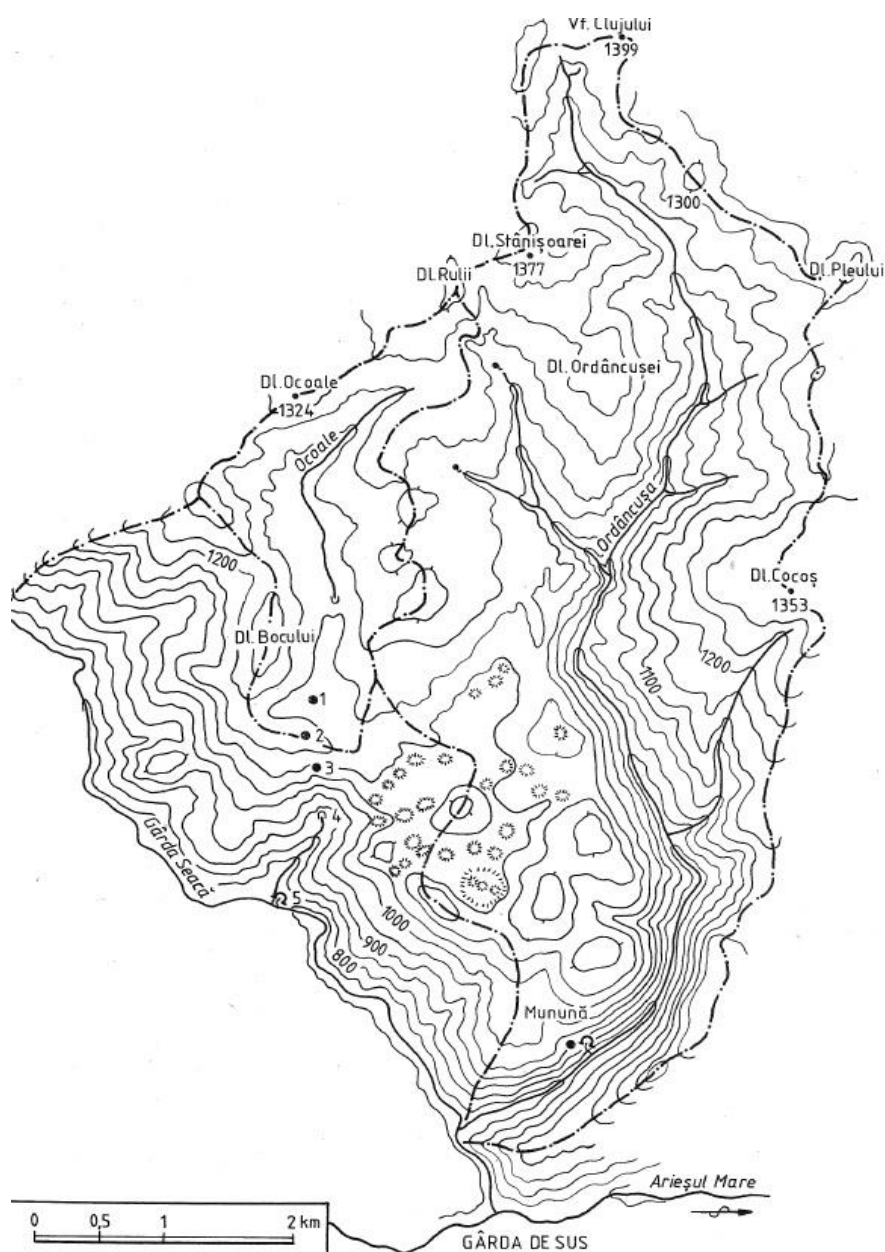


Figure 15. Morphohydrographic map of the Scărişoara-Ocoale karst plateau. 1. Şesuri shaft; 2. Scărişoara Glacier Cave; 3. Pojarul Poliţei Cave; 4. Poliţei spring; 5. Coteţul Dobreştilor Cave, (source: Racoviţă & Onac, 2000).

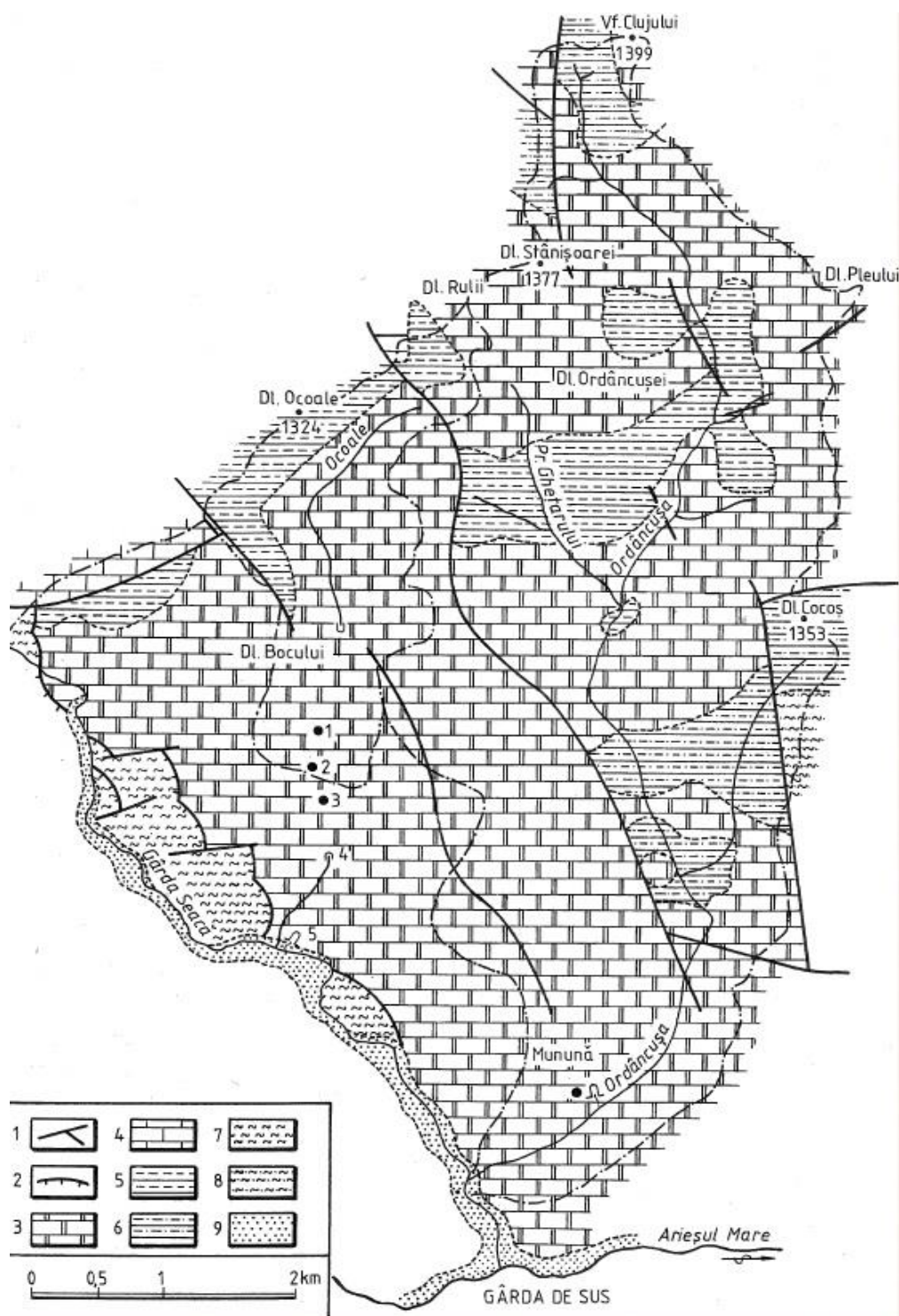


Figure 16. Geologic map of the Scărișoara-Ocoale karst plateau. 1. Fault lines; 2. Overthrust lines; 3. Upper Jurassic limestone; 4. Limestones; 5. Jurassic quartzites and shales; 6. Triassic quartzites and shales; 7-8 Crystalline basement; 9 Alluvial deposits, (source: Racoviță & Onac, 2000).



## SCĂRIȘOARA ICE CAVE

The Scarisoara Ice Cave (Scărișoara Glacier Cave) is a scientific and touristic asset of Apuseni Natural Park area and from administrative point of view the cave is located on the territory of Ghetari Hamlet.



Fig. 17, Photo sources:

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The cave opens with an elliptical, funnel shaped shaft of impressive dimensions: up to 60 m in diameter and 48 m in depth. The bottom of the shaft is covered with a thick layer of perennial snow. The cave entrance is located in the western wall of the shaft and has an imposing arch 24 m high and 17 m wide. Beyond is the "Sala Mare's" (Big Room's) ice floor, a 3,000 m<sup>2</sup> perfectly horizontal surface, with just four massive conic ice formations. One is on the left side and the other

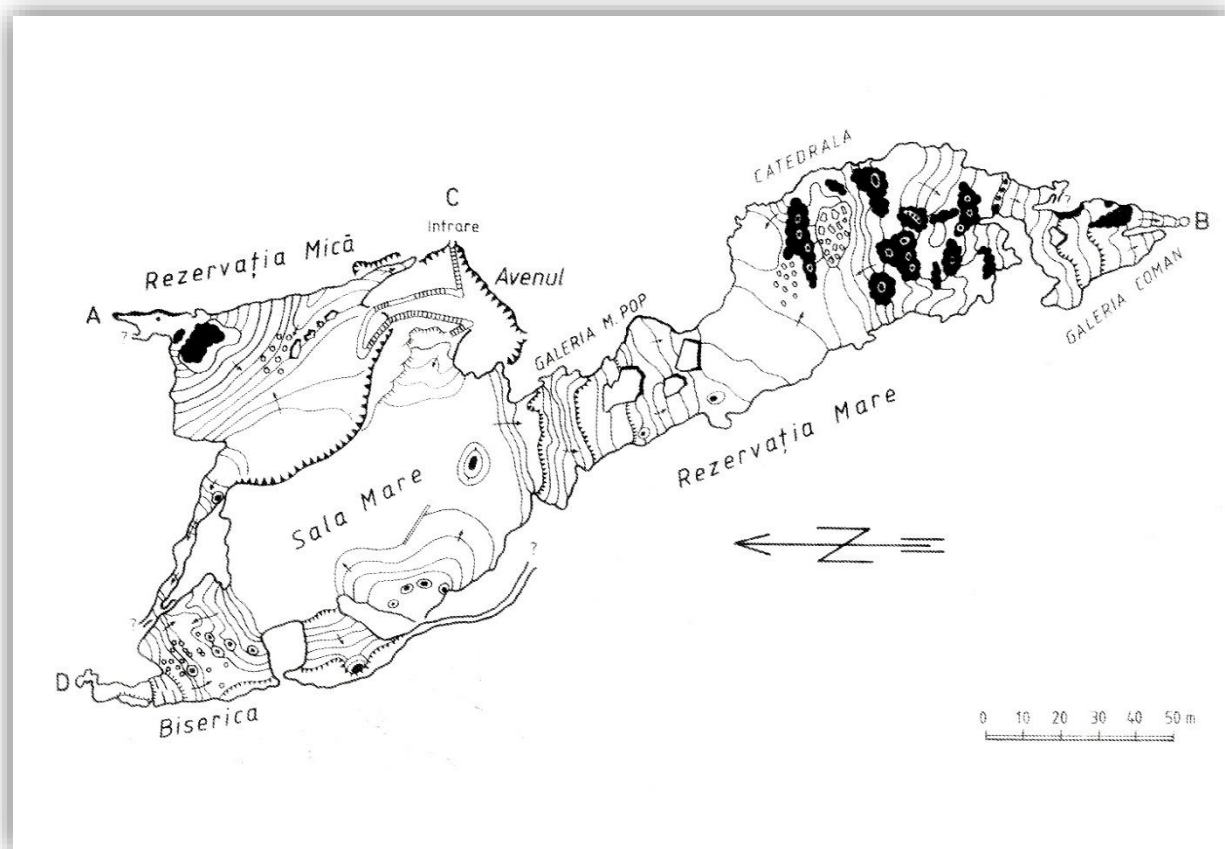


Figure 18. Map of Scărișoara Ice Cave (source: Rusu et al., 1970)

three (*Both Schmidl, 1863, and Racoviță, 1927, noted the presence of only two stalagmitic formations in this place*) are attached to each other near the wall opposite to the cave entrance. Usually, these form large ice columns. During springtime, ice stalactites form on the room's ceiling, but their existence is ephemeral.

To the north, there is a second opening towards the surface, a progressively narrowing chimney linked to the ceiling of Sala Mare by a slanting tunnel approximately 3m in diameter.

Towards the northwest, the horizontal floor ends with a steep slope dipping 8 m that can be descended by steps carved into the ice leading into a second room. Local residents have named this area "Biserica" (The Church). Here, ice speleothems dominate the underground scenery. On

sunny days, the tips of the stalagmites shine in the reflected light from the snow accumulated at the bottom of the shaft, creating the impression of gigantic lighted candles.

The "Biserica" continues with a narrow side passage lacking ice formations. At its end is a succession of three small circular-shaped cavities (Figure 3, profiles C-D), with walls bearing traces of water flow.

Another ice slope can be descended on the left side of the Sala Mare before entering the "Biserica". At its base, a narrow space between the glacier and the cave's limestone wall (crevice) formed due to wall's higher temperature.

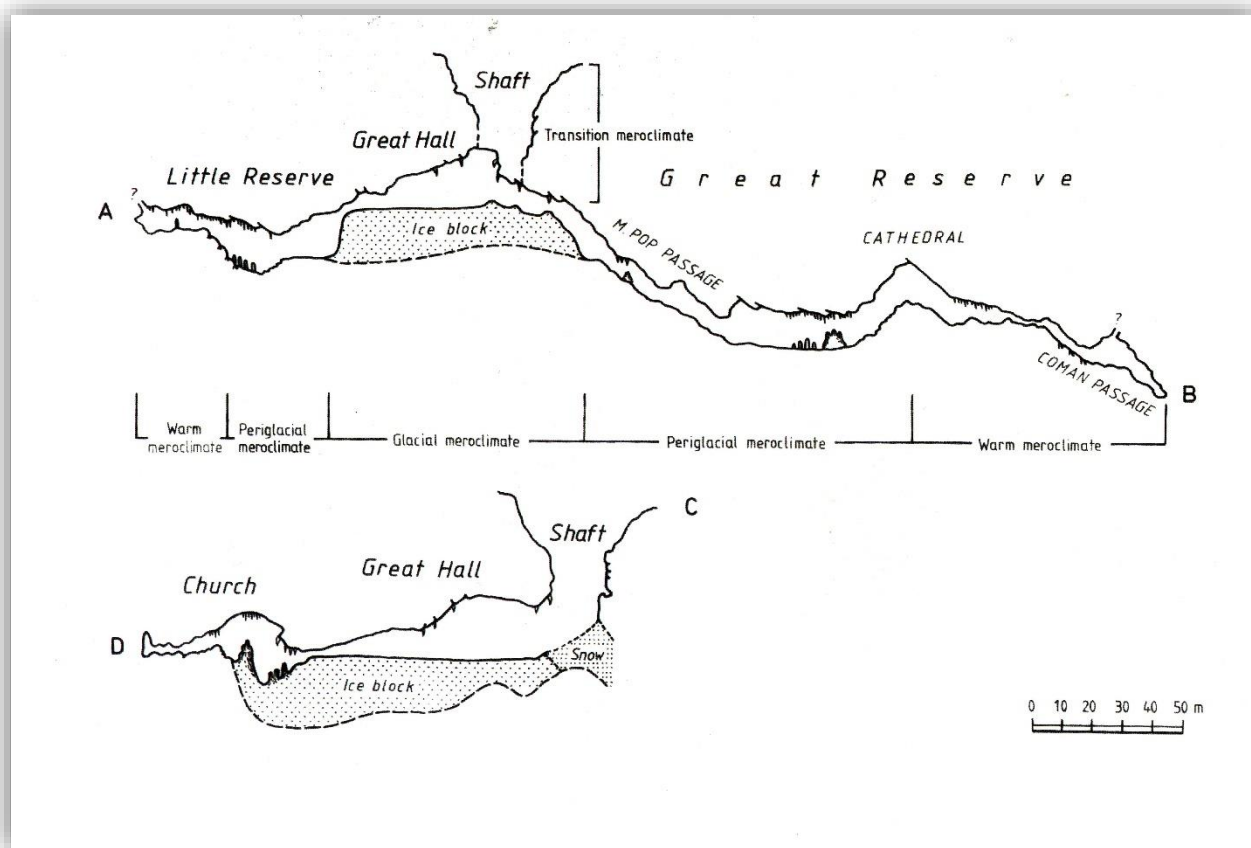


Figure 19. Profile sections of Scărișoara Ice Cave (source: Rusu et al., 1970)

The shaft, the Sala Mare, and the "Biserica" are parts of the tourist section of the cave and are toured without caving gear. On the other two sides of the Sala Mare, the space between the ice and the limestone walls allows access into the deep parts of the cave that have been declared scientific reserves. Visiting these areas requires a minimum of underground climbing experience, as both passages are either vertical or almost vertical cliffs.

The Rezervația Mica (*Little Reserve*) is on the northern side of the Sala Mare and can be entered by descending a 15 m vertical cliff (Fig. 16, profile section A-B), along which the ice stratification is visible.

Two other crevices form at the side edges of the ice cliff near the limestone walls, which both descend steeply and almost reach the base of the ice block. In the central part of the room, not far from the ice block, a field of ice stalagmites forms. They differ from the ice stalagmites found in the "Biserica" in that they do not appear as massifs but as isolated stalagmites. Beyond these, the cave floor is partly covered by a calcite crust and rises abruptly towards a short passage called "Palatul Sânzienelor" ("*Sânziana*" is the name of a fairy in the Romanian tales) (Sanziana's Palace), in which there are only calcite speleothems. There are still two unexplored chimneys at its end which could be very important in the depicting the genesis of the Scărișoara Glacier Cave.

The entrance to the Rezervația Mare (*Great Reserve*) is much larger than the previous one and is located on the southern side of the Sala Mare. Within this part of the cave, the largest rooms are found (20 to 45 m wide and up to 20 m high). Here, the ice forms a steep slope to a depth of 90 m below the surface. This passage was named Galeria "Maxim Pop" (the Maxim Pop Passage), in the memory of the leader of the 1947 expedition. On the horizontal bedrock floor, in the central part of the Rezervația Mare, is another field of ice stalagmites, similar to the ones in the Rezervația Mică. Beyond this area, the cave floor rises abruptly and is covered by huge collapsed limestone blocks. On top of these, large calcite domes have formed. Thus, this part of the Rezervația Mare is called "Catedrala" (*The Cathedral*). At the end of "Catedrala", a narrow passage opens through a grate of stalagmites and enters the Coman Passage. Besides being well decorated, this passage reaches the cave's maximum depth of -105 m (Racoviță & Onac, 2000).

Based on topographic surveys performed on 1965, the total length of the Scărișoara Glacier Cave is 700 m.

The climatic conditions with very low temperature, even in those parts of the cave that do not have ice, are probably the explanation for the scarcity of the underground fauna. Some very rare bats and an important population of *Pholeuon proserpinae glaciale*, endemic for this area is present in this cave. Individuals can sometimes be observed also on the ice. Racoviță Gh. (1980, 2000) has performed thorough studies on ecology of this cave during several years. He obtained



interesting results with respect to the dynamic of underground populations and their climatic requirements.

From scientific point of view, the importance of the glacier consists in its role as recorder of the climatic evolution of the last part of the Holocene.

Following the topographic surveys carried out in 1969, the area of the block was determined to be 3000 square meters with an average thickness of 20 m. The estimated volume of the ice is 75,000 m<sup>3</sup>, in which the climatic oscillations produced since its formation are stored. As a result of the studies carried out, it was found that the age of the glacier is about 3000 years. Because the study was conducted in an area where the ice block does not reach its maximum thickness, it is believed that the oldest ice layers of the block, at the bottom, were formed at least 4000 years ago.

The glacier has been studied continuously since Emil Racovită discover it until now. During this entire period, the level of the ice block decreased by 2 m. Between 1947-1980 the glacier underwent the most intense melting, with a value of 1.50 m.

The temperature in the cave is influenced by the ventilation regime and consequently by the seasons outside. In winter, due to air exchanges with the outside, the temperature can drop indefinitely. The lowest temperature recorded was -20<sup>0</sup> C. During the summer, when the aerodynamic exchanges fade, the temperature in the cave is about 0.5<sup>0</sup> C.

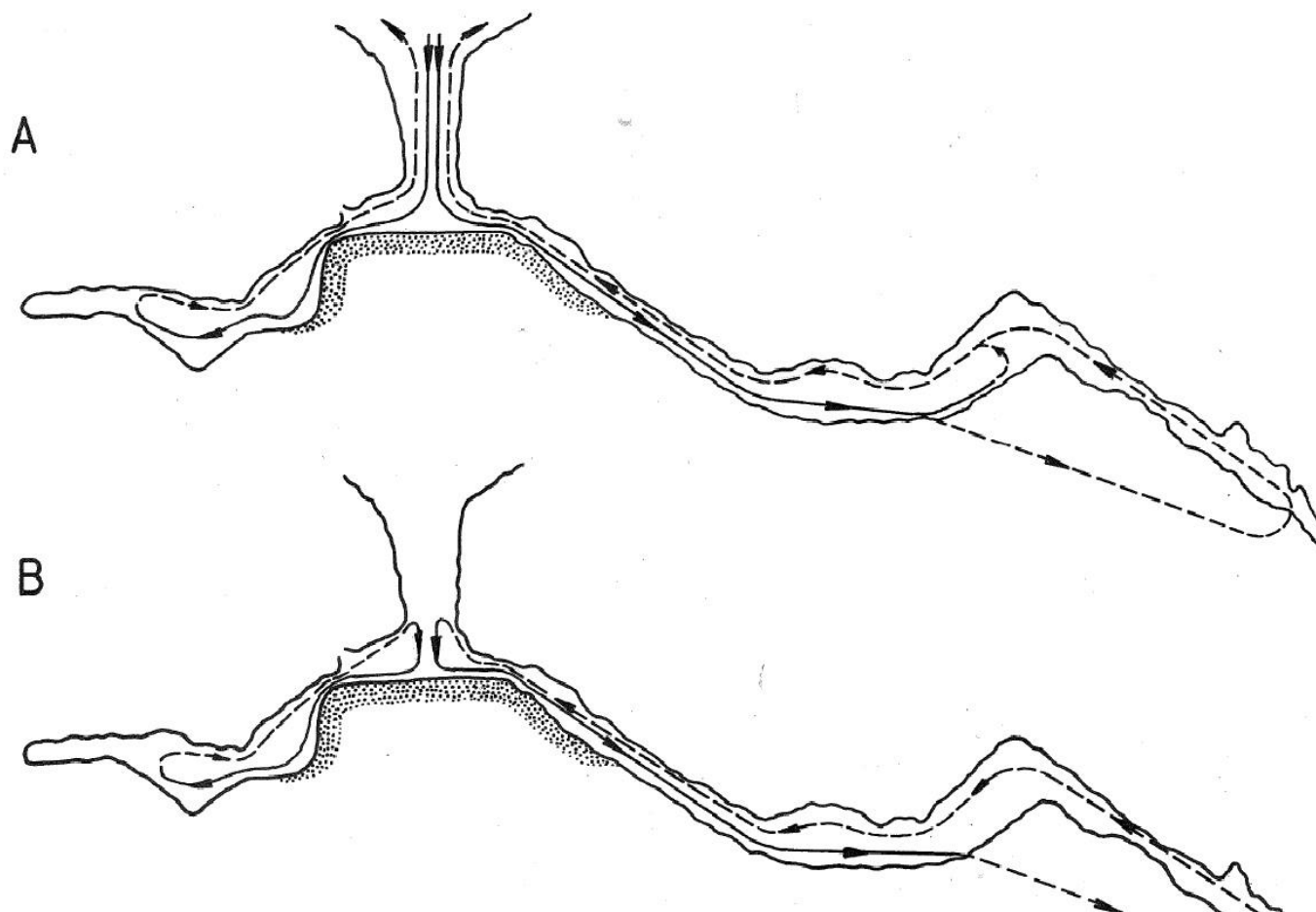


Figure 20 The air circulation in Scarisoara Glacier Cave in winter (A) and in summer (B), (source: Racoviță & Onac, 2000).

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