GEOLOGY AND KARST GEOMORPHOLOGY OF THE IZVORUL IZEI AREA (MARAMUREŞ, ROMANIA)

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ABSTRACT

Karst landscape in the Izvorul Izei area (NW Rodnei Mountains) developed on an approximately 40 m thick Upper Eocene limestone succession, which was deposited over the Upper Precambrian crystalline rocks of the Rebra series and is overlain by Oligocene black shales and sandstones. Uplift of the Rodnei Mountains and subsequent erosion have exposed the carbonate rocks over a large part of our study area. However, these extensive exposures of limestone appear to be relatively poor in exokarst landforms, which are restricted to few gorge sectors, cliffs, several isolated occurrences of karren and alignments of karst depressions in the vicinity of lithologic contacts. The presence of impervious rocks above and below the limestones appears to be the main controlling factor behind the distribution of karst landforms in the area. Karst depressions are concentrated along the contact between the carbonate rocks and the overlying Oligocene units and generally drain small allogenic streams. The main underground drainage, the Iza - Izvorul Izei karst system, developed close to the contact between the limestones and the underlying crystalline rocks. It is believed that this underground drainage also collects most of the water drained through the depressions identified at the surface. The upper and lower ends of the Iza - Izvorul Izei system are accessible through two caves that have been the object of intense exploration and surveying during the past 12 years. Their collective length is now over 5 km, however a direct connection between the two caves is yet to be discovered. Izvorul Izei area appears to be a typical contact karst. On one hand, the juxtaposition of permeable and impermeable lithologies has facilitated the development of an extensive underground drainage and corresponding surface landforms, and on the other hand the distribution of karst depressions and the caves themselves provide and ideal opportunity to study tectonic and lithologic features that are otherwise not detectable in the surface outcrops available in the area.

RÉSUMÉ: La géologie et la géomorphologie du karst de la zone Izvorul Izei (Maramureş, NO des Monts Rodnei, Roumanie).

Le terrain karstique de la zone Izvorul Izei (Nord-Ouest Monts Rodnei) a été formé sur une séquence calcaire d'âge Eocène supérieur, d'environ 40 m d'épaisseur. Les calcaires sont déposés sur les roches cristallines du Précambrien supérieur de la série de Rebra et sont partiellement couverts par des argiles noires et des grès Oligocène. Bien que des roches carbonatées sont exposés sur une grande superficie de la zone étudiée, les phénomènes exokarstiques sont relativement rares. Ils sont limités à un secteur de gorges et des murs de calcaire, des apparitions sporadiques de lapiés et des alignements de dolines et ponors le long des contacts lithologiques. La présence de roches imperméables près de calcaires est le principal facteur de contrôle de la distribution des phénomènes karstiques. Les dépressions karstiques sont concentrés le long du contact entre les calcaires et les roches Oligocènes, et ils drainent des petits ruisseaux d'eaux allogéniques. Le drainage souterrain principale de la zone, le système karstique Iza - Izvorul Izei, a été formée principalement au niveau du contact entre les calcaires et les roches cristallines du Précambrien supérieur. Même si les deux grottes, situées à l'extrémités du système karstique, explorées et cartographiées les 12 dernières années, ont une longueur totale de plus 5 km, le lien entre eux n'a pas encore été trouvé. Nous supposons que ce système karstique collecte l'eau de ruisseau Sterpu et aussi l'eau infiltrée a travers les dépressions karstiques (ponors et dolines) de la surface du bassin d'alimentation. La zone Izvorul Izei se caractérise par un karst de contact typique. D'une part, le chevauchement des roches karstifiables et roches imperméables a facilité le développement des formes exokarstiques et d'un important drainage souterrain. D'autre part, la localisation et la distribution de dépressions karstiques et des grottes sont idéales pour l'étude des caractéristiques de la structure, la tectonique et la lithologie, qui ne peuvent pas être observés dans les affleurements de surface.

REZUMAT: Geologia şi geomorfologia carstului din zona Izvorul Izei (jud. Maramureş, NV Munţilor Rodnei, România).

Relieful carstic din zona Izvorul Izei (NV Munţilor Rodnei) s-a format pe o secvenţă calcaroasă de aproximativ 40 m grosime, de vârstă Eocenă superioară. Calcarele sunt depuse peste rocile cristaline de vârstă Precambriană superioară ale seriei de Rebra şi sunt parţial acoperite de argile negre şi gresii Oligocene. Deşi rocile carbonatice sunt expuse la suprafaţă pe arii extinse din zona studiată, aceasta este relativ săracă în fenomene exocarstice, care se restrâng la un sector de chei şi câtiva pereţi calcaroşi, la apariţii sporadice de lapiezuri şi la aliniamente de doline şi ponoare de-a lungul contactelor litologice. Prezenţa rocilor necarstificabile în apropierea calcarelor este principalul factor de control al distribuţiei fenomenelor carstice. Depresiunile carstice se concentrează de-a lungul contactului dintre calcare şi rocile Oligocene şi drenează mici cursuri de apă alogenă. Principalul drenaj subteran al zonei, sistemul carstic Peştera Iza - Peştera Izvorul Izei s-a format în mare parte la contactul dintre calcare şi rocile cristaline. Cu toate că cele două peşteri de la capetele sistemului carstic, explorate şi cartate în ultimii 12 ani, au o lungime cumulată de peste 5 km, legătura dintre ele nu a fost încă găsită. Presupunem că acest sistem carstic colectează, în afară de apele pârâului Sterpu, şi apa infiltrată prin depresiunile carstice (ponoare şi doline) de la suprafaţa bazinului de alimentare. Zona Izvorul Izei se caracterizează printr-un carst de contact tipic. Pe de o parte, suprapunerea rocilor carstificabile şi necarstificabile a facilitat dezvoltarea formelor exocarstice şi a unui important drenaj subteran. Pe de altă parte, localizarea şi distribuţia depresiunilor carstice şi a peşterilor sunt ideale pentru studiul unor caracteristici de structură, tectonică şi litologie care nu pot fi observate în aflorimentele de la suprafaţă.

INTRODUCTION

The Rodnei Mountains National Park is the largest national park in the northern Eastern Carpathians. The main purpose of the park is the conservation of natural habitats and biological diversity (APNMR, 2010), but it also includes several isolated karst areas classified as nature reserves. Two of these, the "*Ponorul Izei Nature Reserve*" and the "*Peştera şi Izbucul Izei Nature Reserve*" (APNMR, 2010) are situated in the NW corner of the Rodnei Mountains and include a significant proportion of the karst landscape in our study area. 33 of the ca. 50 caves discovered so far in the Izvorul Izei karst area are included in the two nature reserves.

The karst rocks from the area, consisting mostly of Upper Eocene (Priabonian) limestones, form a continuous band, approximately 10 km long and up to 3 km wide (Fig. 1), oriented SW - NE, from Săcel (Maramureş county) to the northern slopes of Bătrâna (1710 m) and Tarniţa Bătrânei (1762 m) summits at the western part of the Rodnei Mountains ridge.

Hydrographically, the whole area is tributary to the Tisa River Basin, through two main water courses: the Iza River, draining most of the karst area, and the Dragoş Valley, which collects waters from the south-eastern corner of the study area. (Fig. 1). One of the tributaries of the Dragoş Valley, the Sterpu stream, originates under the Bătrâna summit and is captured underground at "Ponorul Bătrânei", the entrance to the Iza Cave (Fig. 1, 2). The water resurfaces at Izvorul Albastru al Izei (*The Blue Spring of Iza*), or shortly Izvorul Izei (*Iza spring*) in the hydrographic basin of the Iza river.

The Iza - Izvorul Izei system is the main underground drainage of the area. The drainage is about 2.2 km long as the crow flies and collects most of the surface water of the studied perimeter through ponors and caves. Two longest caves in the area belong to this underground drainage: Iza Cave (4.4 km), and Izvorul Izei Cave (0.9 km), near the Izvorul Izei spring. So, it is not surprising that previous studies were mostly concerned with exploration, survey and scientific documentation of these two caves (Viehmann et al., 1979; Sârbu, 1985). However, their possible links with the outside morphology, lithology and hydrology were marginally addressed (Viehmann et al., 1979, 1981; Silvestru and Viehmann, 1982; Iurkiewicz, 2010).

The present paper compiles published and unpublished data obtained in the last 12 years on the Izvorul Izei karst and adds a detailed survey of both karst and lithology at the surface and in the caves. At the beginning of our studies, the only maps we were aware of were the one of Viehmann et al. (1979) and the geologic map 1:50000 (Kräutner et al, 1982). We have mapped all karst features (karren, dolines, ponors, gorges, karst tunnels, caves and potholes), and their possible connections with bedrock lithology.

The surface mapping was done during two summer camps, each one week long (2008-2009). The survey, comprising over 600 stations, was done with a Garmin 60 SX GPS and in parallel, when necessary, with the classic method, using compass and clinometer (Tandem Suunto) and fiberglass tape. GPS data were processed with DNR Garmin 5.03, available online at Minnesota Dept. of Natural Resources (*http://www.dnr.state.mn.us/ mis/gis/tools/arcview/ extensions/DNRGarmin/DNRGarmin.html*). The topographic map of the area was developed using Quantum GIS (*http://www.qgis.org/*) based on topographic charts at scale 1:25000 (1984 edition), and the geologic map 1:50000, Pietrosul Rodnei (Kräutner et al., 1982).

Cave survey is an ongoing process: it took so far over 30 trips from 2001 to present, and involved over 40 people. Underground mapping was done using a Bosch DLE 50 laser telemeter with 0.2 mm/50 m precision and a Tandem Suunto optical instrument which includes a compass and a clinometer, with precisions of 0.5 degrees. Field data (geologic contacts, karst phenomena, cave maps) were drawn using Adobe Illustrator.

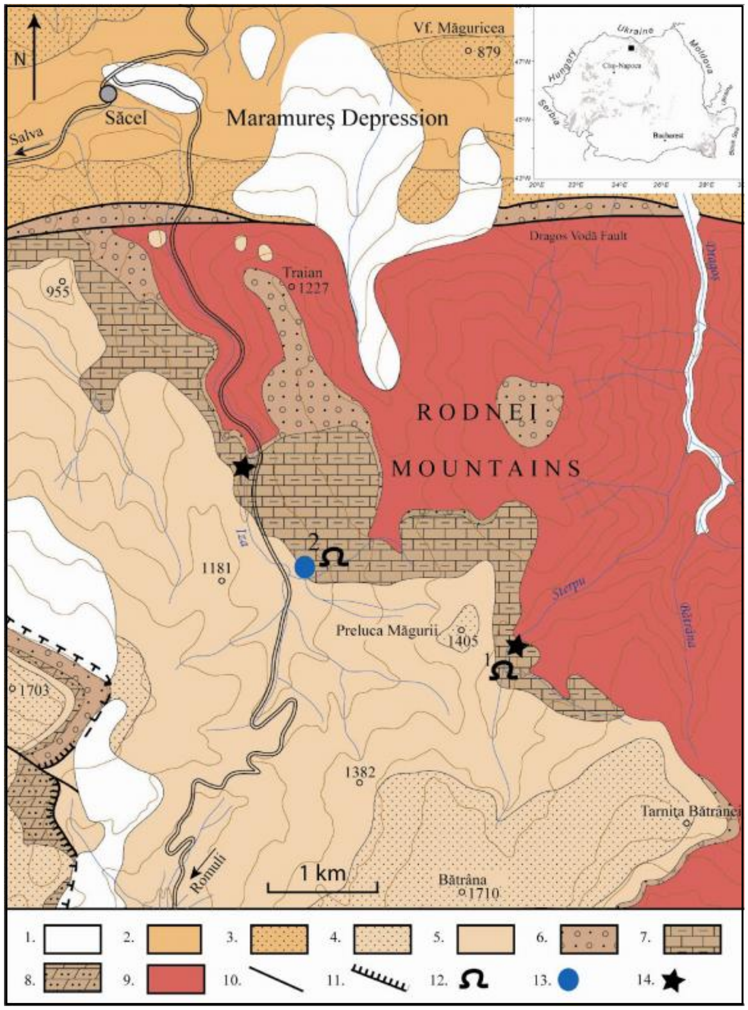

Figure 1: Geological map of the NW part of the Rodnei Mountains (after Kräutner et al., 1982) 1 – Quaternary deposits, 2 – Upper Oligocene flysch, 3 - Borşa sandstone, 4 - Birţu sandstone (Lower Oligocene), 5 - black shales (Valea Carelor Formation, Lower Oligocene, 6 - Lutetian conglomerates, 7 – Priabonian limestone, 8 – Eocene marls, 9 – metamorphic rocks, 10 – fault, 11 – nappe, 12 – entrances to Iza (1) and Izvorul Izei (2) caves, 13 – Izvorul Albastru al Izei, 14 – location of the two limestone profiles studied by Sahy et al (2008).

PREVIOUS WORK

Knowledge of the Iza Cave dates from back in ‘50s, but the first exploration was done only in 1976 (*Buletin FRTA - CCSS*, 1977; Viehmann *et al*., 1979). The first survey was done in 1977 and the paper describing the cave was published in 1979 by Viehmann *et al*. At that time the explored and mapped length of the cave was 2300 m (-170 m) (Viehmann et al., 1979). Three years later, the cave length reached 2440 m (*Speotelex* 1982). Silvestru and Viehmann (1982) and the Romanian Cave Systematic Catalogue (Goran, 1982) mention a length of 2500 m. A diving trip in 1986 attempted to pass the Iza Cave downstream sump, a feat that was unsuccessful because the underwater passage was blocked by tree trunks (G. Rajka, *pers. comm*.). Later on, the cave was reported closed at ~300 m from the entrance by a dam of tree trunks. A 10-15 m sump formed on the passage upstream and several Montana Caving Club trip reports mention only visits of the Entrance Passage. After the intense summer drought of 2000, a team from Montana Caving Club re-opened the Entrance Passage of the Iza Cave and reached the larger spaces downstream. A thorough re-survey which included longitudinal sections, profiles and geological mapping, was started in 2001 (Tămaş et al., 2009). 4.4 km have been mapped and almost 2 km of new passages have been explored in the Iza Cave until now.

The first attempt to pass the sump at Izvorul Albastru al Izei was made in September 1981 by divers who advanced 7 m until an underwater boulder choke, 4 m below the surface (Nicoară, 1982; Halasi, 1984). In 1984, the sump (30 m long, -5 m deep) was passed and a ca. 500 m long aired active passage was discovered and explored, but not mapped (Sârbu, 1985). The last dive attempt we are aware of was in 1996, when I. Rist (Montana Baia Mare) mapped ca. 10 m down to -6 m. As the water flowing through this passage was heard from a small cave upstream of the Iza spring, there were hopes that it could also be reached by digging. Some mentions of digging in the cave are noted in club reports (Patalita, 1984), but apparently these attempts were unsuccessful. The access to the passage beyond the sump at Izvorul Albastru al Izei was gained in 2004, through a 30 m crawl, of which 9 m were dug in sediments. The cave was then surveyed over 450 m to an upstream sump (now, sump 3). After several dives in 2004 and 2009, the active passage was explored and mapped for some 250 m, until sump 5. At the same time, mineralogical and sedimentological studies on the secondary deposits from the cave (Elekes, 2009) provided new directions for future exploration. Two new digs opened the way to the Fossil Passage and at present, Izvorul Izei Cave is ca. 900 m long (Tămaş, 2011).

GEOLOGY OF THE IZVORUL IZEI KARST AREA

In one of the first informations on the age of the limestones from the Izvorul Izei area published by Kräutner in 1930, all the nummulitic limestones from the Transcarpathian Flysch were considered Lower Eocene (Lutetian) in age. Later on, the limestones were assigned an Upper Eocene age (Priabonian), based on micropalaeontological data and their stratigraphic position (Patrulius et al., 1955, Dicea et al., 1980). The nummulitic limestones have been studied in the Teilor Valley quarry from Săcel by Sylvester (1995), who considered their depositional context, and by Vlad (2003), who was concerned with their economic valorification (as construction materials). The study of Sahy et al. (2008) focused on two complete composite sections of the Upper Eocene limestones (Fig. 1): one in the Iza Valley, just south of Preluca Izei, and the second at the Iza Cave entrance, describing their typical facies and depositional environments.

In the Izvorul Izei area the metamorphic basement of the Rodnei Mountains is overlain by Eocene and Oligocene marine sediments. Endo- and exokarst landforms are hosted by a ~ 40 m thick Upper Eocene limestone succession which is under- and overlain by impermeable crystalline and respectively Oligocene sedimentary rocks. The stratigraphic relationship between individual rock units and their relative distribution on the surface is somewhat difficult to trace due to the relative scarcity of surface outcrops. A combination of outcrop scale observations, regional distribution patterns of certain karst landforms such as dolines and ponors, and extensive geological mapping conducted in the caves from the area was used here to paint a more accurate picture of the local geology.

RESULTS AND DISCUSSIONS

Crystalline rocks

The crystalline rocks from the Izvorul Izei karst area belong to the Rebra series which along with the Bretila series constitutes the metamorphic basement of the Rodnei Mountains (Kräutner et al., 1982). On a larger scale, these units are part of the Central - East Carpathian nappe system (Mutihac, 1990) and are composed of Precambrian rocks metamorphosed to the amphibolite facies (Balintoni, 1997). According to Kräutner et al. (1982), metamorphic rocks cropping out in the north-eastern corner of the Iza area (Fig. 1, 2) belong to the Ineu Formation of the Rebra series, which is dominated by garnet micaschists with subordinate intercalations of crystalline limestone and dolomite, quartzite and amphibolites (Balintoni, 1997). Our observations of the metamorphic rocks come from surface outcrops and the Iza cave.

i) *At the surface*, the contact with the Upper Eocene sedimentary rocks is uncovered in the upper part of Uliţa de Piatră Valley, where micaschists occur in the valley bottom (Fig. 1, 2). The contact with the Priabonian limestones can be followed almost in straight line to Preluca Măgurii and then south to the left side of Sterpu Valley (Fig. 2). The metamorphic rocks (micaschists with quartz bands) also outcrop in the Sterpu Valley bottom, in a small gorge sector 150 m downstream from the Iza Cave entrances, and their contact with the Eocene rocks can be followed to the SE upstream a right hand tributary of Sterpu Valley (Fig. 1, 2). In the northwestern part of the area, metamorphic rocks outcrop in the Iza Valley bottom and then downstream (north) on both sides of the valley. Three dolines identified in an otherwise metamorphic area of the Preluca Măgurii glade may indicate the presence of crystalline limestones, but this could not be verified in surface outcrops.

ii) *Underground*, the passages of the Iza Cave expose micaschists with garnets, quartzites, crystalline limestones and dolomites, and associated mineralization, the latter usually as lenses. Crystalline limestones and dolomites are situated on top of micaschists (Fig. 3, 4). They are either white, forming decimetric "banks" separated by milimetric black stripes, probably graphitic, or consist of alternative centimetric white and gray stripes (Fig. 4). Mineralizations are usually connected with the crystalline carbonate rocks, but were also observed along faults and fractures in the micaschists. They contain pyrite as the main mineral and are probably of Blazna - Guşet type, described by Udubaşa (1981) and Udubaşa et al. (1983) from the southern Rodnei Mountains.

Sedimentary rocks

In the Izvorul Izei karst area, the sedimentary rocks are mostly Upper Eocene (Lutetian conglomerates, Priabonian limestones) and Oligocene (black shales, sandstones) in age. Quaternary deposits occur on small areas at the surface, in the northern part (Fig. 1), and in caves (Elekes, 2009; Tămaş et al., 2011). On the left side of the Iza Valley and to the south, toward the main ridge of the Rodnei Mountains, the Eocene rocks are covered by the Lower Oligocene bituminous shales of the *Valea Carelor* formation. The *Birţu* sandstones are the last unit of the Paleogene sedimentary succession to occur in the area and they outcrop on the Bătrâna summit and at Preluca sub Măguri (Patrulius et al., 1955, Dicea et al., 1980).

Conglomerates

The Lutetian conglomerates form a discontinuous layer up to 1 m thick, separating the metamorphic basement from the overlying carbonate rocks. In surface outcrops they consist mainly of rounded quartz pebbles and subordinately micaschist lithoclasts bound by carbonate cement (Sahy et al., 2008). They occur in two small patches, the first situated north from Preluca sub Măguri, and the second in the southeastern part of the area (Figs. 1 and 2).

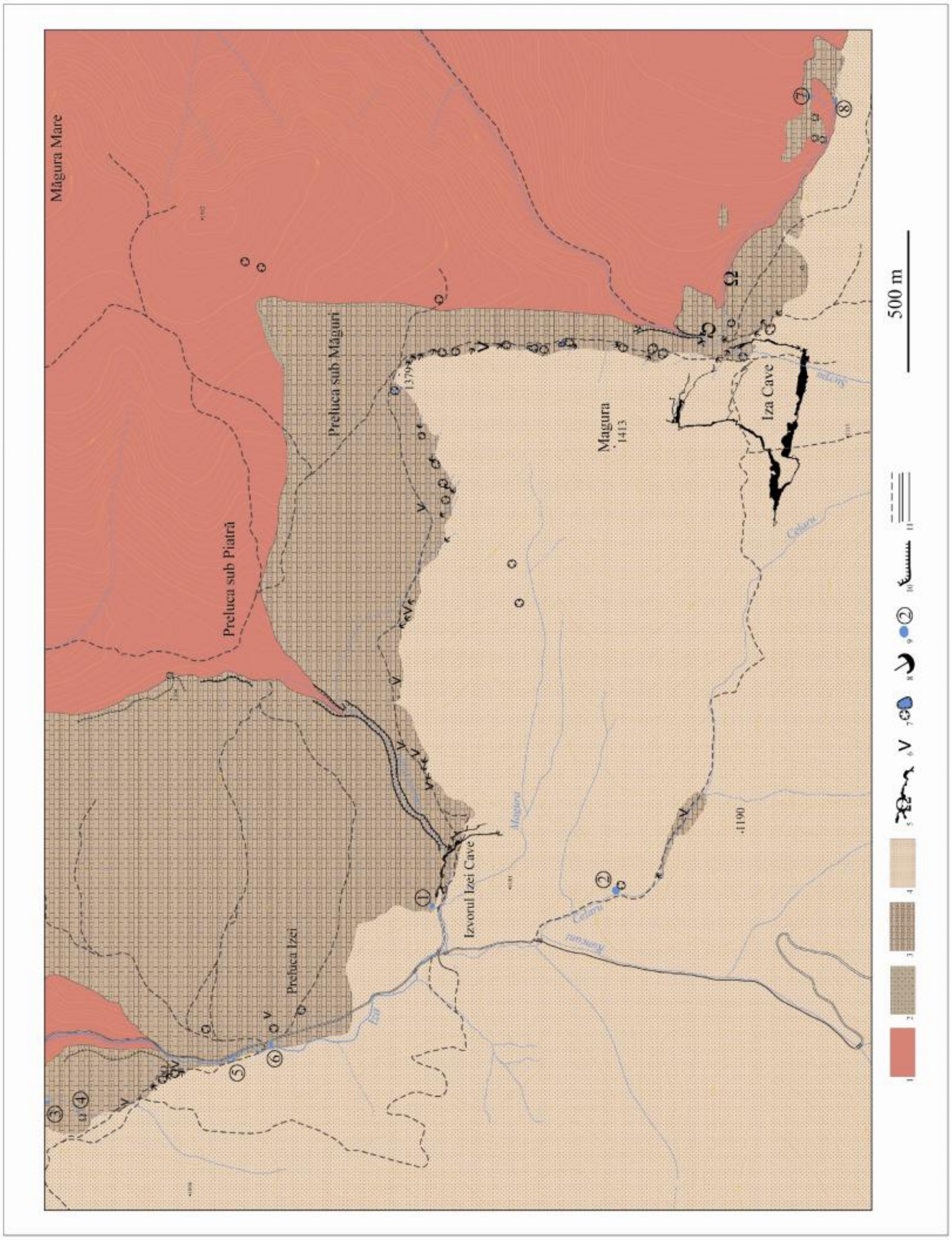

Figure 2: Karst and geologic map of the Izvorul Izei area: 1. crystalline rocks, 2. Lutetian conglomerates, 3. Priabonian limestones, 4. Oligocene rocks, 5. caves, 6. pits, 7. dolines, 8. ponors, 9. springs (1-Izvorul Albastru al Izei, 2-Izvorul Puturos, 3,4-springs in the NW corner, 5,6-springs in Preluca Izei, 7,8-springs on the affluent of the Sterpu Valley), 10. cliffs, gorges, 11. roads.

Figure 3: Contact micaschists - crystalline limestones on the Advancement Passage, Iza Cave.

Figure 4: Mineralized crystalline limestone breccia on the Advancement Passage, Iza Cave.

In the Iza Cave, the contacts between metamorphic rocks, conglomerates and/or limestones can be followed along the walls of the passages for more than 2.5 km. The conglomerates contain varied lithoclasts, sometimes over 30 cm in diameter, consisting of micaschists, quartzites, crystalline limestones, dolomites and oxidized mineralization (Fig. 5). The degree of rounding also varies. It is possible that these conglomerates do not coincide with the base of profile 1 from Sahy et al. (2008), in which the quartz is found in rounded cobbles up to 20 cm in diameter, similar with the ones described by Kräutner (1930), but to represent a lower separate level. When conglomerates are missing from the succession opened by the cave passages, they are replaced by a 0.5 - 1 m level of subangular - subrounded blocks of varying size (up to 1 m long) (Fig. 6) or subrounded or platy decimetric pebbles bound by carbonate cement.

Figure 5: Conglomerate with decimetric micaschist clasts (Iza Cave).

Figure 6: Contact micaschists - Priabonian limestones on the Afluent Passage, Iza Cave; above the contact there is a 0.5 m level of subangular blocks of metamorphic rocks.

Limestones

The Upper Eocene (Priabonian) rocks are nummullitic stratified limestones and massive coral-algal limestones forming a stripe 10 km long and up to 3 km large (Fig. 1). The limestones cover the conglomerates or sometimes directly the crystalline rocks and form a faulted monocline dipping 10-20°W (Kräutner et al, 1982). South from Preluca sub Măguri, the limestones form a band ~150 m large, covered to the west and south by Oligocene formations. From the Iza cave entrance, this band expands towards SE along the right tributary of Sterpu Valley (Fig. 2, 7). On the left slope of the tributary, the limestones are covered by Oligocene formations, while on the right slope two isolated limestone “islands” appear. Another isolated limestone patch occurs in the downstream part of Celaru Valley, uncovered by the erosion of the cover of Oligocene rocks (Fig. 2). The microfacies of these limestones have been studied in detail by Sahy et al. (2008), in two profiles (Fig. 1). Analyzes of these profiles revealed great differences between the southern and the northern area of the ramp where the carbonate rocks had been deposited. The limestones range from open-shelf wackestones and packstones with coral-algal crusts at the cave entrance, to nummulitic sandstones near Izvorul Izei spring (Sahy et al., 2008).

Figure 7: Limestone outcrops in the Izvorul Izei area: a. Cliff in Preluca sub Piatră; b. Isolated limestone tower above the Iza Cave entrance

Oligocene rocks

The Priabonian carbonate deposits are covered by the Valea Carelor Formation (lower Oligocene), consisting of black shales and sandstone intercalations. These rocks occur on the western side of Iza Valley and mostly in the whole northern part of the area (Fig. 1, 2). In the Iza Cave, the black shales have been identified in some lateral passages from the upper part of the Affluent Series (Tămaş et al., 2009, 2011). These rocks consist of a series of thin levels dominated by clay material separated by sequences with a slightly higher amount of quartz grains. The fauna from the black shales is scarce, represented by isolated specimens of planktonic foraminifera whose poor preservation did not allow clear identification (Sahy et al., 2008). The sandstones, last in the succession, forms patches on the topographic heights of Bătrâna peak, Preluca sub Măguri and Muncelul Râios (Fig. 1). These sandstones contain well sorted quartz pebbles with subangular to rounded shapes and mica fragments, as well as feldspars and even carbonates.

KARST

Exokarst

Karren

The most common karren in the Izvorul Izei area are *linear karren* (fracture-controlled) and *rundkarren* (Fig. 8). Other types are *solution pans* (*kamenitze*) and *rinnenkarren* (Fig. 9). Their occurrences are by no means spectacular compared to other karst areas and they are restricted to very few places. All types identified, but especially the former two, are more frequent in the forest road beds and in places where the soil cover was removed by forestry works or torrents (Mureşan, 2010).

Figure 8: Linear karren, initially buried.

Figure 9: a. Kamenitza; b. Rinnenkarren

Dolines and ponors

Surface surveys in the area showed 43 ponors and 42 dolines, of which 90% are less than 15 m from the limit between the Priabonian limestones and non-carbonate rocks. Their survey gives a very good approximation of the lithologic contact, especially in the areas with no obvious outcrops. The ponors (Fig. 10a) and the dissolution dolines (Fig. 10b) are the most representative exokarstic forms from the area. They form two main alignments along the limestones - Oligocene rocks contact, one N-S, parallel with the Sterpu Valley downstream the Iza Cave entrance, and the second W-E, between Preluca de sub Măguri and Uliţa de Piatră

Valley (Fig. 2). In addition to these 2 alignments, a few ponors were mapped on the left side of the Iza Valley, downstream Preluca Izei and in the SE corner of the karst area, on the right-hand side of the Sterpu Valley (Fig. 2). Ponors drain small streams usually less than 100 m long, sourcing from the Oligocene rocks. Dolines are up to 15 m in diameter and generally 5-6 m deep. Most of them are on the Priabonian limestones; three dolines situated NE from Preluca sub Măguri, on crystalline rocks, may mark the presence of metamorphic limestone stripes, whereas two more are developed on Oligocene rocks, probably in an area where these form a thin cover above the Upper Eocene limestones (Mureşan, 2010). Two **collapse dolines** occur at the entrances of the Iza Cave, one being the large entrance normally used by cavers. A third one gives access to a 10 m deep pit, located on the W-E alignment of ponors, parallel to the Uliţa de Piatră Valley (Fig. 2).

Figure 10: a. Ponor on the contact with non-karst rocks at the end of a short blind valley in Preluca sub Măguri; b. Dissolution doline in Preluca sub Măguri.

Tunnels and natural bridges

Four karst tunnels have been identified in the Izvorul Izei area, all of them small parts of old cave sectors, eroded and suspended after the deepening of local base level (Bleahu, 1982). The most impressive are the ones from the right side tributary of Sterpu Valley (Fig. 2, 11). Two other smaller tunnels are located on the left side of Iza, downstream from Preluca Izei, in the NW corner of the area.

Gorges

The only important gorge in the Izvorul Izei area is the so-called "Uliţa de Piatră" (*Stone Alley*) formed along a small stream sourcing from Preluca sub Piatră (Fig. 2, 12). At the downstream end of the gorge, this stream is partly drained underground through diffuse losses in the streambed and reaches the active passage of Izvorul Izei Cave. The gorge sector is ca. 1 km long and ends 100 m upstream from Izvorul Izei spring. It is 15-35 m wide, with walls 5-15 m high and up to 5-6 m of breakdown on the sides due to accentuated limestone fragmentation (Fig. 12). The gorge is generally developed NE – SW. In their uppermost part the metamorphic rocks outcrop in the valley bed and gradually on the slopes. Morphologically, the gorge sector of Uliţa de Piatră continues the limestone cliffs from the eastern side of Preluca sub Piatră (Fig. 2).

Figure 11: Karst tunnel on the affluent of Sterpu Valley, in the SE corner of the karst area.

Figure 12: Uliţa de Piatră Gorge.

Karst springs

Eight karst springs, seven permanent and one temporary, have been identified in the Izvorul Izei area. Izvorul Albastru al Izei is the most important, both in terms of drainage length and flowrate. Their locations are shown in Fig. 2.

Izvorul Albastru al Izei (Fig. 13) has a normal flowrate of probably 30 - 40 l/s (Iurkiewicz, 2010), but can exceed 1m^3/s during floods and snowmelt. The spring is separated from Izvorul izei Cave by a sump (see Previous Work). The main collector is the Iza Cave, capturing underground the Sterpu Valley and partially its right side affluent, with a total flowrate of 10-15 l/s (Iurkiewicz, 2010) through its entrances and several other diffuse losses, to which are added the two main ponor alignments described previously.

Izbucul Puturos *(Smelly Spring)* is located on the right side of Celaru Valley (Fig. 2), at the contact between limestones and black shales and represents the exit point of water drained through diffuse losses in the valley ca. 200 m upstream of the spring (visual observation in May 2006). Its name comes from the characteristic sulphur odor, probably due to the oxidation of sulphides from the Oligocene black shales. It has a flowrate of about 1 l/s and was the entrance to a small cave, now blocked by breakdown.

In the NW part of the area, two small karst springs are the exit points for water from the nearby ponors (Fig. 2). On the opposite side of the valley, a third, temporary one, located under the forest road, drains the limestone band of Preluca Izei. South-east from the Iza Cave entrance, an isolated limestone block hosts two small karst springs, both located at the limestones/micaschists contact. The first is fed by a stream flowing on metamorphic rocks and conglomerates and sinking underground at the contact with the limestones, with an underground drainage ca. 50 m long. The second, at 3 l/s, is fed by water flowing on black shales and sinking at their contact with the limestones. Its underground drainage is 150 m long.

Figure 13: The stream flowing from Izvorul Albastru al Izei during a flood.

Endokarst

The 33 caves and potholes discovered and explored so far in the Izvorul Izei area are presented in Tab. 1 (C.S. Montana, 2011). Due to particular hydrological and lithological factors, the Iza - Izvorul Izei karst system is the only long underground drainage in the area and roughly 50% of the smaller caves discovered, and probably more than 80% of the ponors from the area are hydrologically connected to it. The two longest caves in the Izvorul Izei area belong to this underground drainage: Iza Cave (4410 m), and Izvorul Izei Cave (900 m). The total length of the two caves at the ends of the system now exceeds 5300 m. The straight line distance between the Iza Cave entrances and the spring is of about 2.2 km for a dislevelment of 225 m, whereas the distance left between the respective terminal sumps of the two caves is 1.2 km, for only 60 m of vertical elevation. The other caves usually do not pass 100 m in length or 25 m in depth and rarely consist of more than a single shaft or subhorizontal passage.

Table 1. The caves explored and mapped in the Izvorul Izei area (C.S. Montana, 2011)

Code	Name	Length (m)	Depth (m)	Iza karst drainage*	Year of exploration
1029/1	Iza Cave (Peştera Iza)	4410	-181	yes	1976 - present
1029/2	Peştera din Tabără	12	-3	probably	1977
1029/3	Peştera cu Lapte	49	3	no	1977
1029/4	Peştera nr. 2 de la Ponorul Măgurii	45	-15	yes	1977, 2007
1029/5	Peştera nr. 3 de la Ponorul Măgurii	11	2	probably	1977
1029/6	Peştera Izvorul Izei /Peştera de la Izbuc	900	25 (-7;+18)	yes	1984; 2004 - present
1029/7	Avenul din Preluca de sub Bătrâna	11	-11	yes	1977
1029/8	Peştera cu apă din Ponoare	64	-12	no	1977,1996
1029/9	Avenul cu apă din Ponoare	10	-7	no	1977
1029/10	Avenul de sub stâna de la Ponorul Izei	106	-25	probably	1977
1029/22	Avenul cu Fereastră	no data		no	‘80s
1029/23	Peştera cu Săliţă	no data		no	‘80s
1029/24	Peştera Scurtă	no data		no	‘80s
1029/26	Avenul Scoica	57	-15	no	‘80s
1029/27	Peştera de deasupra Avenului Scoica	9	-1	no	‘80s
1029/28	Ponorul Ungurilor	29	-12	no	‘80s
1029/29	Peştera Izvorul Puturos	27	-2	no	‘80s
1029/30	Peştera Roşie	22	-3	probably	‘80s
1029/31	Ponorul din pădure	45	-12	probably	‘80s
1029/37	Peştera Izbucul Izei	10	-6	yes	1984; 1996
1029/38	Peştera Tunel din Ponoare	15	-1	no	1996
1029/39	Peştera Ascunsă din Ponoare	14	1	no	1996
1029/40	Avenul cu Scară	117	-25	yes	1996-1997
1029/41	Peştera Mică din Ponoare	10	-3	no	1996
1029/42	Peştera Diaclazei din Peretele Izei	12	0	no	1996
1029/43	Peştera Cetatea Izei	26	+19	no	1996
1029/44	Avenul Mare de sub Preluca Măgurii	13	-12	probably	2003
1029/45	Avenul cu apa de sub Prelucă	11	-8	probably	2003
1029/49	Avenul cu Ecou	8	-8	probably	2006
1029/50	Ponorul cu Zmeură	18	-11	probably	2008
1029/51	Peştera din Peretele Mare	10	-2	no	2008
1029/52	Avenul fără Ecou	13	-8	probably	2008
1029/53	Avenul de sub Copac	11	-5	probably	2006

*The former or present hydrological connection between the caves and the Iza - Izvorul Izei karst system is assumed based on their location and on surface and underground observations. To our knowledge, no water tracing studies have been done so far (see also Iurkiewicz, 2010).

Iza Cave

The entrances to the Iza Cave are situated in the Sterpu Valley, at the place also known as “Ponorul Bătrânei”, at around 1250 m a.s.l. Descriptions of the cave have been published by Viehmann et al. (1979), Tămaş (2009) and Tămaş et al (2009). All 3 entrances are in the Eocene limestones. The main river passage (Entrance Passage - Advancement Passage), about 1.2 km long, crosses the contacts between Priabonian limestones, Lutetian conglomerates, and metamorphic rocks at 50 m from Entrance 2, then deepening into the metamorphic rocks until the Confluence Room (Fig. 14). Shortly after the contact, two waterfalls on micaschists and then a 6 m-high fissure-directed passage lead down to a narrow sector carved between two conglomerate beds, the site of a former sump caused by accumulated tree trunks. After a 90° turn along intersected fissures, the Entrance Passage connects to the Advancement Passage by a 15 m drop where the cave stream falls over an overhanging conglomerate ledge.

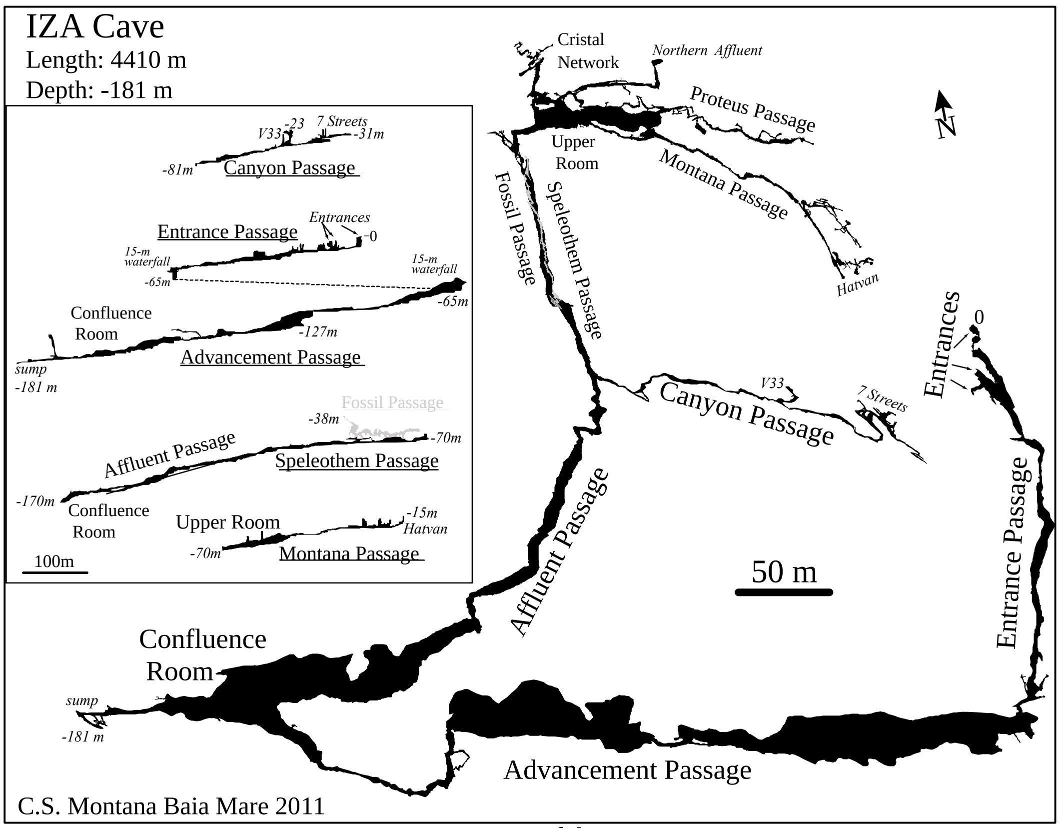

Figure 14: Map of the Iza Cave.

The Advancement Passage (~ 700 m long), has an E-W general direction and three large sectors (up to 15 m high and 50 m width) connected by smaller passages; the floor descends steeply from right to left, following the micaschist dipping. Shifts in the ceiling height along these sectors are caused by SE-NW parallel faults. The first large sector, with the ceiling on conglomerates, ends at -92 m in a narrow hole where the passage crosses the main fault and enters the limestones in its lower left block. After a short canyon carved in limestones, the main fault is reached again. Another large sector on the main fault follows for 120 m, down to -130 m. This ends in a wall of marble breccia and the passage turns S, crossing another fault, and then NE, parallel to the main fault, down to - 160 m, connecting to the Confluence Room, another very large passage along the main fault, with cross sections similar to the previous two; this shape also extends to the first part of the Affluent Passage. Thick clay deposits cover the passage bottom and a large lake forms here during floods. 50 m downstream the confluence, the final, much smaller Sump Passage is developed in limestones once again (possibly after crossing a transversal fault), and after a further 50 m, the final sump is reached at - 181 m.

The Affluent section accounts for three quarters of the cave length so far (Fig. 14). Its first part, oriented E-W, is developed almost entirely in marble and has similar shapes and sizes with the large parts of the Advancement Passage. The passage gets smaller as it turns NE and enters micaschists again, with the Priabonian limestones occurring only in the ceiling and with no conglomerates in-between. This section, about 300 m long, where the affluent forms several waterfalls, ends in a fracture line parallel to the main fault opened by the Advancement Passage. The Affluent makes two turns at right angles, first W then N. Upstream, the passage gets smaller and is oriented N-S again until the Upper Room, developed W-E (Fig. 14).

The Canyon Passage (~400 m long), a narrow canyon parallel to the faults in the Advancement Passage, has formed in limestones, exposing the contact with the micaschists at its bottom. Most of the water from the Affluent section comes from this passage, which ends very close to the cave entrance, under the Sterpu Valley, being probably fed by diffuse losses upstream from the actual entrance (Figs. 2 and 14).

The Speleothem Passage is almost rectilinear, directed N-S, and is nicely decorated, with the limestone - micaschist contact occurring in the lower part of the walls. At its upper end, a short climb up along a canyon leads to the Fossil Level (~300 m), formed by a complex of narrow canyons and pits and some lateral passages. Several restrictions at the upper end of the Speleothem Passage and a 90^o turn E lead to the Upper Room, which, together with the side passages surveyed so far, accounts for 1.5 km (Fig. 14). The lower part of the chamber is rectangular and relatively flat-topped (ceiling on limestone bedding plane), while the upper part forms along a great E-W fissure and ends upstream in a large breakdown covered by sediments and several generations of calcite speleothems. Seven side-passages, some of them interconnected, have already been discovered from the Upper Room (Fig. 14). The longest is the Montana Passage, which accounts for ca. 750 m. Three small streams join the affluent in the Upper Room: the Northern Affluent, a second one along the Montana Passage, and the third from the Proteus Passage. The latest discovery in the Iza Cave is the Cristal Network (150 m mapped so far), a maze of small fossil phreatic passages, at the level of the Upper Room ceiling. The Cristal Network contains the first palaeontological discoveries in the Iza Cave: bear remains and clawmarks, which are now being investigated.

The Iza Cave interior deposits are mostly clastic sediments of various sizes. Clay and silt deposits occur only in the Confluence Room, which during floods was may be filled with water. As a peculiar feature, the cave has very few collapse deposits, in contrast with what one would expect to see in a cave where non-karst rocks account for more than half of the passages. Breakdown consisting of micaschists and a few limestone blocks occur in the largest parts of the Advancement Passage and the Affluent Passage. Classic speleothems, such as stalactites, stalagmites and flowstones are quite rare. Most of them are concentrated along the main fault on the Advancement Passage, in the Speleothem Passage and the Upper Room. Extensive weathering deposits formed on the metamorphic rocks, described by Viehmann et al (1979, 1981), have been reinvestigated by Tămaş et al. (2011). They consist of gypsum, secondary iron minerals (goethite, jarosite, hematite), illite, and kaolinite.

The morphology of the cave is mainly influenced by the lithology and fractures. Passages generally following the limestone/micaschist contact descend with the same dipping (9-10°). Most passages are guided by fractures, the Advancement Passage being developed along parallel faults. Passages in limestones are labyrinthic, with smaller cross sections, while larger passages in areas with micaschists and marble are usually rectilinear. Iza Cave genesis is probably largely due to vadose inflow at the contact zone with the overlying Oligocene deposits. Floodwater dams up behind constrictions and follows diverted routes or creates mazes, and flows torrentially in larger sectors ("floodwater cave" - Palmer, 1972).

Izvorul Izei Cave

The first survey of the Izvorul Izei Cave has been done in september 2004 and the first description has been published by Tămaş and Perşoiu, in 2005. All the passages in this cave were discovered through either digging or diving. The entrance is a small pit, less than 2 m deep, at ca. 1030 a.s.l, opened on the right side of Uliţa de Piatră Valley, 30 m upstream from Izvorul Albastru al Izei. The entrance pit is followed by a 30 m horizontal crawl (of which 9 m were dug in sediments), 4-5 m large and 0.4 m high, developed on bedding planes (Fig. 14). Tunnel 1 connects to a fossil sector parallel to the active passage which reaches very close to the surface. From here on, the passage reaches reasonable size (2x3 m) and is connected to the cave river (Old Passage, ~200m long) by a 3 m drop.

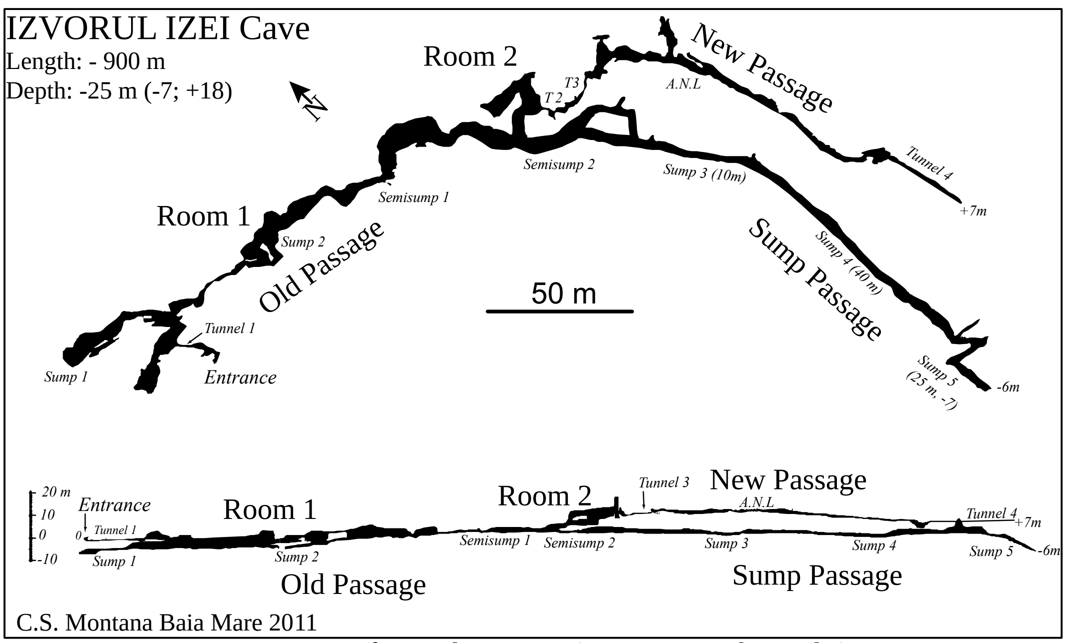

Figure 15. Map of Izvorul Izei Cave (T2, T3 – tunnels 2 and 3)

The active passage has a shape of a flat-topped canyon, between sump 1 and semisump 1 (Fig. 15). The downstream sump (Sump 1), connecting with Izvorul Albastru al Izei, is reached after 40 m. The Old Passage gets larger upstream towards Room 1 (5-6 m x 2 m) and keeps the flat-topped canyon shape until Semisump 1 (Fig. 15). From Semisump 1 to Room 2, the passage is nearly horizontal and the cross-sections are circular to elliptic. Semisump 2 leads upstream to the Sump Passage (~300 m long), explored through several dives between 2004 and 2009 and ending at -6 m in an underwater sediment fill (sump 5).

Goethite nodules found at several levels inside a 3.5 m high sediment filling from Room 2 were thought to originate from the passages of Iza Cave, which hosts pyrite mineralization as well as large amounts of goethite speleothems. After digging Tunnels 2 (6 m) and 3 (8 m) at the top of the sediments, the fossil level (New Passage, ca. 200 m long), was discovered. The New Passage, parallel to the Sump Passage below, is very similar in shape and size: a succession of fossil sumps, ending with a very long one (from A.N.L. to Tunnel 4, over 70 m, see Fig. 15). Originally 4-5 m high and up to 3 m large, it is now almost completely filled with detrital sediments.

CONCLUSIONS

The lithologic succession in the Izvorul Izei area, studied both in surface outcrops and underground, in the Iza Cave, comprises Upper Precambrian crystalline rocks, Eocene conglomerates and limestones, and Oligocene black shales and sandstones. The crystalline rocks belong to the Ineu Formation of the Rebra series and consist of garnet micaschists with subordinate intercalations of crystalline limestone and dolomite, quartzite, and amphibolites, as well as associated mineralization. The Lutetian conglomerates form a discontinuous layer between the metamorphic basement and the Priabonian carbonate rocks. They contain varied lithoclasts, consisting of micaschists, quartzites, crystalline limestones, dolomites and oxidized mineralization. The limestones range from open-shelf wackestones and packstones with coral-algal crusts at the cave entrance, to nummulitic sandstones near Izvorul Izei spring. They form a faulted monocline dipping 10-20°W and are covered by the Lower Oligocene non-karst rocks.

The contacts between these various rocks play an important role in karst landscape development in the area. Oligocene non-karst rocks are the main source of allogenic water for the ponors formed on the Upper Eocene limestones close to the contact. This allogenic water is more agressive, compared with water resulted from precipitations and recharged through dolines, and has a highly variable discharge (Palmer, 2001).

The development of exokarst in the area is influenced by the lithologic contacts between karst and non-karst rocks, by structural and tectonic factors, and by water availability. Ponors and cave entrances follow precisely the map of the contact between limestones and Oligocene rocks. This geometry may be explained by the difference in aggressivity between the allogenic and autogenic water. The lack of karst depressions away from the contacts may also be due to the monoclinal structure, favouring rapid runoff, and to the fragmentation of the limestones. Water from precipitations flows along the dip of the limestone monocline, infiltrating through small cracks and then along bedding planes, producing very little enlargement through corrosion. On the limestone surface, linear karren, rundkarren, solution pans and rinnenkarren are formed, more commonly under the soil cover. The reasons for the reduced presence of karren may also be the thin bedding and fragmentation of the limestones.

The endokarst in the Izvorul Izei area is represented by a major underground drainage, the Iza - Izvorul Izei karst system. The Iza Cave, at present 4410 m long, collects allogenic water from the Sterpu Valley and one of its affluents, as well as most of the surface streams. Once the water reaches underground, another contact, the one between the Upper Eocene limestones and the underlying crystalline rocks plays a major role in the cave development. The main cave river can transport huge loads of trees and debris, and may possibly swell up to several cubic meters per second. The high volume of water entering the cave during floods flows torrentially, eroding the non-karst bedrock and transporting large amounts of sediments, and is dammed behind restrictions, where diversion routes or small phreatic mazes may develop in the limestones. The hydrological regime is therefore very contrasting between low flow and high flow and points to cave enlargement only during major floods. The allogenic inflow and the fracture-guided character make us think that the Iza - Izvorul Izei karst system genesis is largely due to vadose inflow at the contact zone with the overlying Oligocene deposits, and to epiphreatic outflow at the lowermost possible point. Izvorul Izei Cave, at the downstream end of the system, has a morphology showing a combination of epiphreatic and water-table features. This genetic model greatly contributes to the understanding of the typical contact karst from the area.

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