UNIVERSITATEA
BABEȘ-BOLYAI

Faculty of Biology and Geology
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Late Quaternary environmental changes as revealed by the sedimentary archives from Muierilor Cave, Romania

Doctoral Thesis

Extended Summary

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Keywords: Late Pleistocene, MIS 3-2 fauna, *Ursus spelaeus,* cave sediments, LGM, deglaciation, palaeofloods, reversed chronology, geochronology, South Carpathians.

Chapter 1. Introduction

Studies investigating cave deposits are increasingly becoming more relevant resulting from the value of the palaeoenvironmental archives they hold (Sasowsky and Mylorie, 2007; Ford and Williams, 2007; Bradley, 2015). These archives can be investigated through the use of more proxies and dating techniques that reveal stages of cave evolution connected to regional or global events. The proxies used in this research refer to palaeoclimate proxies that can be related to chemical and biological materials preserved within the geological record. These proxies can help us to analyze and corelate past climate and environmental parameters with the present ones (Bird et al., 2007; Parkinson et al., 2014; Moldovan et al., 2016; Winkler et al., 2016; Lyman, 2017; Hatvani et al., 2018). The stable microclimate conditions in caves allow the possibility of having information about clastic sediments deposition, faunal association and climate conditions at a certain time from various proxies (sediments, fossils and speleothems) in the same cave (Sasowsky and Mylroie, 2007; Bradley, 2015; Álvarez-Lao et al., 2015; Constantin et al., 2014; Fairchild and Baker, 2012). Moreover, large mammal assemblages and micromammals are some of the oldest palaeontological records (Lyman, 1994; Parmalee, 2005) to indirectly determine the ages of sediments and general climatic conditions for a particular region. Speleothems are the most used climatic archives in caves due to the accurate reconstruction of palaeoclimate at a regional scale and they can be accurately dated by using the U/Th method (McDermott, 2004; Fairchild et al., 2006; Obreht et al., 2017; Hatvani et al., 2018; Rossi et al., 2018; Isola et al., 2019). Clastic sediments found also in caves are an important feature as they can reveal a large amount of information about complex palaeohydrological features (Sun et al., 2017; Arriolabengoa et al., 2018). However, these deposits can be affected by post-depositional alteration (Sasowsky and Mylorie, 2007), one of the most important process in reworking sediments being extreme events like palaeofloods. Most of the floods can be linked with extreme precipitation, snow and ice melting (White, 2007), the latter being related with the deglaciation pulses. In the South Carpathians there are several studies undertaken regarding deglaciation and the magnitude of the related processes (Urdea, 2004; Reuther et al., 2007; Urdea and Reuther, 2009; Urdea et al., 2011; Kuhlemann et al., 2013; Gheorghiu et al., 2015; Mîndrescu, 2016). In this context, interdisciplinary studies of cave deposits have been carried out in Romanian Carpathians in some of the most important karstic systems to establish a palaeoenvironmental and palaeoclimate general framework (Onac et al., 2002; Constantin, 2003; Tãmaş et al., 2005; Petrea et al., 2006; Constantin et al., 2007, 2014; Drăguşin et al., 2014; Robu, 2015; Moldovan et al., 2016, Tîrlă et al., 2020). This type of studies can reveal information regarding the evolution of a region and represent a key-requirement in the interpretation of the evolution of a cave system (Constantin et al., 2014). Most of the cave deposits from the studied sites were affected by post - depositional processes showing a complex depositional context as Cioclovina Cave (Soficaru et al., 2007), Oase Cave (Constantin et al., 2013) and Urșilor Cave (Robu et al., 2011; Constantin et al., 2014; Robu, 2015). In the South Carpathians there are several sites in which cave deposits are extensive and are of particular importance both as climatic archives and for the migratory routes of anatomically modern people (AMH) along the Danube corridor (Riel-Salvatore et a., 2008; Doboș et al., 2010, Fu et al., 2016). One of these sites is Muierilor Cave, a show cave located in the Parâng Mountains, which holds impressive Marine Isotope Stage 3 (MIS 3) fossil assemblages (Doboș et al., 2010). Moreover, the sedimentological, mineralogical and fossil remains content represent elements of interest in the evolution of the cave within a regional context (Diaconu et al., 2008).

1.1. A brief history of research conducted at Muierilor Cave

The scientific importance of this cave was recognized in early 1870, when several researchers visited this site and remarked the fossil bone accumulation, the abundance of speleothems and the comprehensive clastic sediments. After those observations new perspectives have emerged and new data, regarding the palaeontological and evolutive context of the cave, were made based on excavation pits and detailed studies. Although the fossil bone accumulation was identified in the 1870s, the first systematic excavations in Muierilor Cave (= Peștera Muierilor; Cave of the Women) started in 1929 (Nicolăescu-Plopșor, 1935-36) and continued during the 1950s (Nicolăescu-Plopșor et al., 1957). Apart from human remains, there were also found fossils of an MIS 3 fauna consisting mainly of *Ursus spelaeus* (hereafter - *sensu lato*)*, Panthera spelaea* and *Crocuta crocuta spelaea.* The excavations extended from the Southern Entrance towards the Mousterian side - passage. At that time, only a small part of the cave's lower level (Level 1) was known and the researchers assumed that the actual entrance had been used as a shelter and entryway by both humans and large mammals. A Holocene human skeleton was found in the entrance area, while the Upper Paleolithic human remains were found much deeper in the cave, in the Mousterian Passage (Păunescu et al., 1982, Păunescu, 2001; Doboș et al., 2010). Fossil remains found in Level 2 (Turistică Passage) during the 1951-1955 campaigns (Bombiță, 1954) comprise both carnivores (*Ursus, Panthera, Hyaena, Canis, Vulpes, etc.*) and herbivores such as *Megaloceros, Cervus, Capra, Saiga, Bos, Equus* (Bombiță, 1954). The detailed macromammal association from this cave was first determined by Bombiță (1954) and comprises *U. spelaeus, P. spelaea, Panthera pardus, Lynx lynx, Felis silvestris, Canis lupus, C. c. spelaea, Vulpes vulpes, Gulo*

gulo, Lutra lutra, Martes martes, Saiga tatarica, Capra ibex, Rupicapra rupicapra, Cervus elaphus, Megaloceros giganteus, Bison priscus, Bos primigenius, Alces alces, Equus caballus, Coelodonta antiquitatis (=Rhinoceros trichorhinus) and *Mammutuhus primigenius.* However, one of the most important discoveries in Muierilor Cave are the remains of one of the earliest anatomically modern humans (*AMH*) in Europe, directly dated to ca. 35 ka cal BP (Soficaru et al., 2006b) and a more recent date indicating an age ca. 33 cal ka BP (Fu et al., 2016a). Moreover, these human fossil remains were found in the Musteriană Passage (= The Mousterian Passage) among the MIS 3 fauna, near the entrance towards the Urșilor Passage (= The Bears Passage) and comprise a cranium (neurocranial vault, a zygomatic bone, the maxillae, a partial mandible, and ten teeth), a temporal bone, a scapula and a fibula fragment (Doboș et al., 2010). These findings are placing Muierilor Cave among the most important palaeoanthropological sites from southeastern Europe. The more so, as the cave is located close to other sites with modern human remains (Cioclovina Cave and Oase Cave). Cioclovina Cave being located only at ca. 70 km north - west from Muierilor Cave and from this site was obtained a date of ca. 32 cal ka BP (Cioclovina1 - cranium) and Oase Cave located ca. 150 km west from Muierilor with a date of ca. 39 cal ka BP (Oase1 - mandible). This "triangle" of modern human remains (AMH) discoveries is strengthening the hypothesis that southwestern Romania has functioned as a transit route for early modern humans (Riel-Salvatore et al., 2008b). Humans who entered towards Central Europe from the south, were using the Danube corridor and its major tributaries, during the climatic optimum that characterized MIS 3 (Doboș et al., 2010; Fu et al., 2016b; Riel-Salvatore et al., 2008b). The fact that these findings are related to caves highlights once again the exceptional importance of the cave deposits, giving us confidence that Muierilor Cave represents an extraordinary site where interdisciplinary studies are required more than ever before. Also, other comprehensive studies at Muierilor cave have been carried out since the late 1950s on geomorphology (Bleahu, 1956; Ilie and Lupu, 1962; Lupu and Ilie, 1962), palaeontology (Bombiță, 1954), bat fauna (Dumitrescu et al., 1962), general geology and mineralogy (Bleahu, 1956; Diaconu et al., 1975; Diaconu et al., 2008, Trifulescu, 2008), and palaeoanthropology by Doboș, Soficaru and Trinkaus (2010).

Chapter 2. Geological setting

The studied area is located in the southeastern area of Parâng Mountains (South Carpathians). The geological features of this part of the Parâng Mountains result from the overthrust of the Getic Nappe over the Danubian Autochtonous (Danubian units, in Săndulescu, 1984). This area consists mostly of metamorphic rocks from the pre - Alpine orogenic events, belonging both to marginal

Dacides (Danubian Units) and the Getic Nappe (the main rock types being quarzitic gneisses and micaceous schist) as well as magmatic intrusions (the granitic bodies) (Iancu and Seghedi, 2017; Fig. 1). The magmatic rocks outcrop at high altitudes while the metamorphic and sedimentary rocks are distributed in marginal areas. The sedimentary cover in the region is cropping out in small patches and is largely represented by Upper Paleozoic and Mesozoic limestones, conglomerates and Cenozoic rocks (gravels, sands and clays) as well. The area of Polovragi – Cernădia is made of carbonate rocks of late Jurassic-Aptian age known as *The Oslea - Polovragi Limestone Formation* (Bandrabur and Bandrabur, 2010). The formation consists of white – grey or white limestones of which surface karst landforms are poorly developed; the main landforms being represented by the Galbenul Gorges. Limestones indicate a NV - SE orientation and a thickness between 150 - 250 m (especially in the Galbenul Valley), gradually decreasing to the northeast. The width of the limestone bar varies between 2 and 0.8 kilometers (Lupu and Ilie, 1962). The thrusting of the Getic Nappe over the Danubian Units represents the most important feature from the tectonic point of view. The striking thrust plane has a NE - SW orientation (Bandrabur and Bandrabur, 2010), while the joint and fractures are oriented in two main directions N - S and NW - SE (Ponta et al., 2019). The Jurassic is well represented in the southern part, consisting of white - grey or white limestone, occurring as a compact mass forming an almost continuous limestone bar, which has favored the development of large karstic systems (like Muierilor and Polovragi caves) but at the same time numerous smaller cavities (more than 26 caves, only in the Galbenul Valley; Goran, 1982). The extensive development of the gorges and the caves as well is closely related to the tectonic process, where the extensive underground systems were conditioned by the main fracture lines (Lupu and Ilie, 1962).

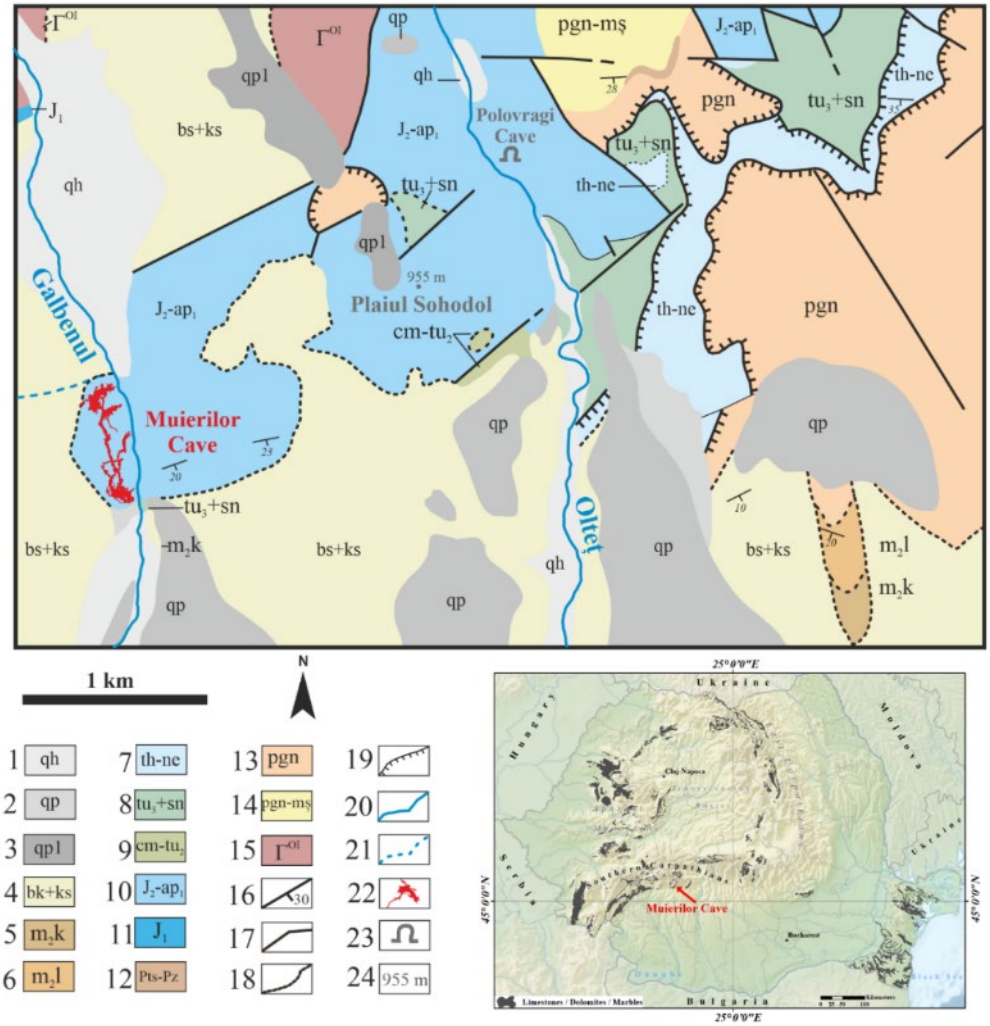

Figure 1. Geologic map of Muierilor Cave area (after Hann H. et al., 1986). 1.Holocene alluvial deposits; 2. Pleistocene terrace deposits; 3. Pleistocene fluvial gravels; 4. Bessarabian – Kersonian sands and gravels; 5. Miocene clays, shales; 6. Miocene-Badenian marly clays and tuffs with orbulines; 7. Tithonian-Neocomian calcareous sandstones, calcareous marls, limestones; 8. Upper Turonian- Upper Cretaceous ("Senonian") silty-clays; 9. Cenomanian- Turonian calcareous marls; 10. Middle Jurassic-Lower Aptian micritic limestones; 11. Lower Jurassic arkoses; 12. Upper Proterozoic–Paleozoic amphibolites; 13. Upper Proterozoic paragneisses; 14. Upper Proterozoic paragneisses and micaschists; 15. Paleozoic granitoids; 16. Strike and dip of bedding; 17. Fault; 18. Transgressive base formation; 19. Overthrust; 20. River; 21. Intermittent stream; 22. Cave passages; 23. Cave entrance; 24. Altitude. The map of Romania was modified from (Onac and Goran, 2019).

Chapter 3. The site

The Polovragi - Cernădia karstic area is characterized by a fragmented limestone ridge, incised by two major streams (Galbenul and Olteț rivers) from North to South, having the watershed in the high part of Parâng and Căpățânii mountains (Ion and Lupu, 1962; Lupu and Ilie, 1962) (Fig. 2). Both of these rivers cut deep gorges in the limestone ridge forming underground meanders of the valley and evolving in multilevel cave systems over time (Mirea, 2018). The Galbenul Valley in the gorge area is relatively wide when compared with Olteț Gorge, delimited by limestone walls and edged with scree deposits (Constantin et al., 2002) (Fig. 2). The Galbenul Gorges have 800 m in length and 60 to 120 m width. The surface features in this area are represented only by deep gorges and underground drainages. Muierilor Cave (Fig. 3) is an extensive cave system and one of the most known show caves in Romania. Located in the Polovragi – Cernădia area (Baia de Fier, Gorj County), the cave is accessed through two entrances (Northern and Southern, respectively), likewise including a third entrance which is currently closed, the geographic coordinates of the cave are 45°11'31.78"N and 23°45'14.07"E. Moreover, Muierilor Cave is a tiered karst system carved in the Upper Jurassic - Lower Cretaceous limestone, on the right side of the Galbenul Gorge, at 650 m a.s.l. (Level 2). The cave network broadly trends NNW - SSE, matching the main local fracture lines (Lupu and Ilie, 1962). It has been created by dissolution along local fracture systems, simultaneously with the incision of Galbenul (Diaconu and Medeșan, 1975). The cave has functioned as a succession of underground meanders of the Galbenul River, the passages presumably evolved in parallel with the gorge incision that was completed by the main stream (Ion and Lupu, 1962).

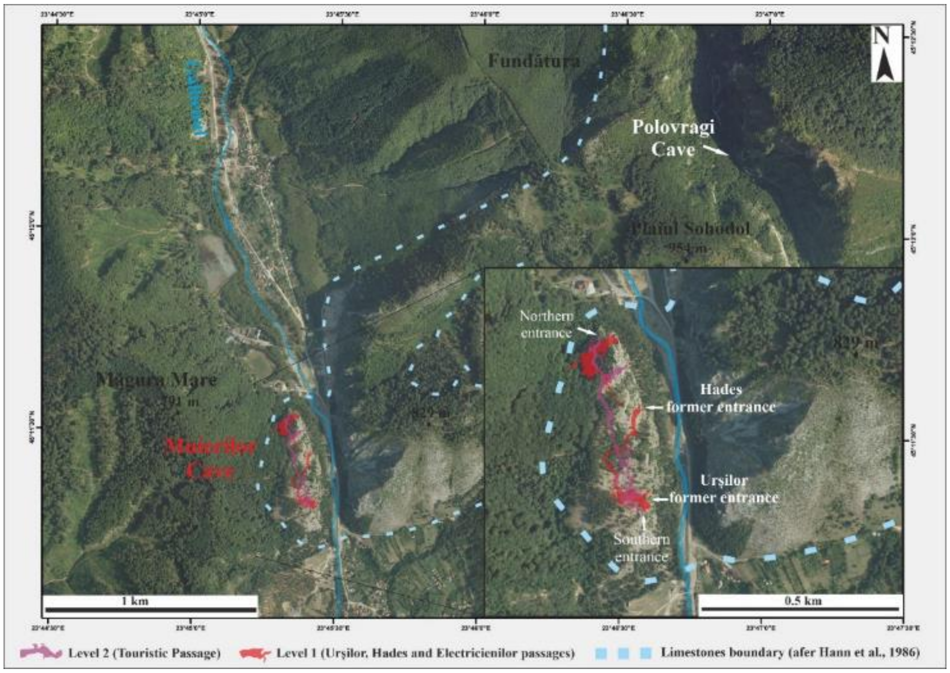

Figure 2. The orthophoto of the Polovragi - Cernădia area with the Muierilor Cave map.

The underground system has a total length of more than 8000 m and disposed over at least five levels (with a vertical development on 80 m, the uppermost being Level 4 and the lower one Level 0) (Fig. 3 and 4). Two of them are distinct (Level 2 and Level 1) due to the findings made there, and as a result of the way they developed over time. The formation and subsequent abandonment of the horizontal passages on levels 2 and 1 is closely related both to the periods of stability and to the acceleration stages of the river incision. The incision pulses are represented by many pits that connect the cave levels, these being the response of the Galbenul River to the periodic adaptation to the local base level. Therefore, the pits that are linking the levels of the caves are relevant owing to their status in revealing the changes in the gradient of the Galbenul River profile and to advance the fossil remains and sediments transportation.

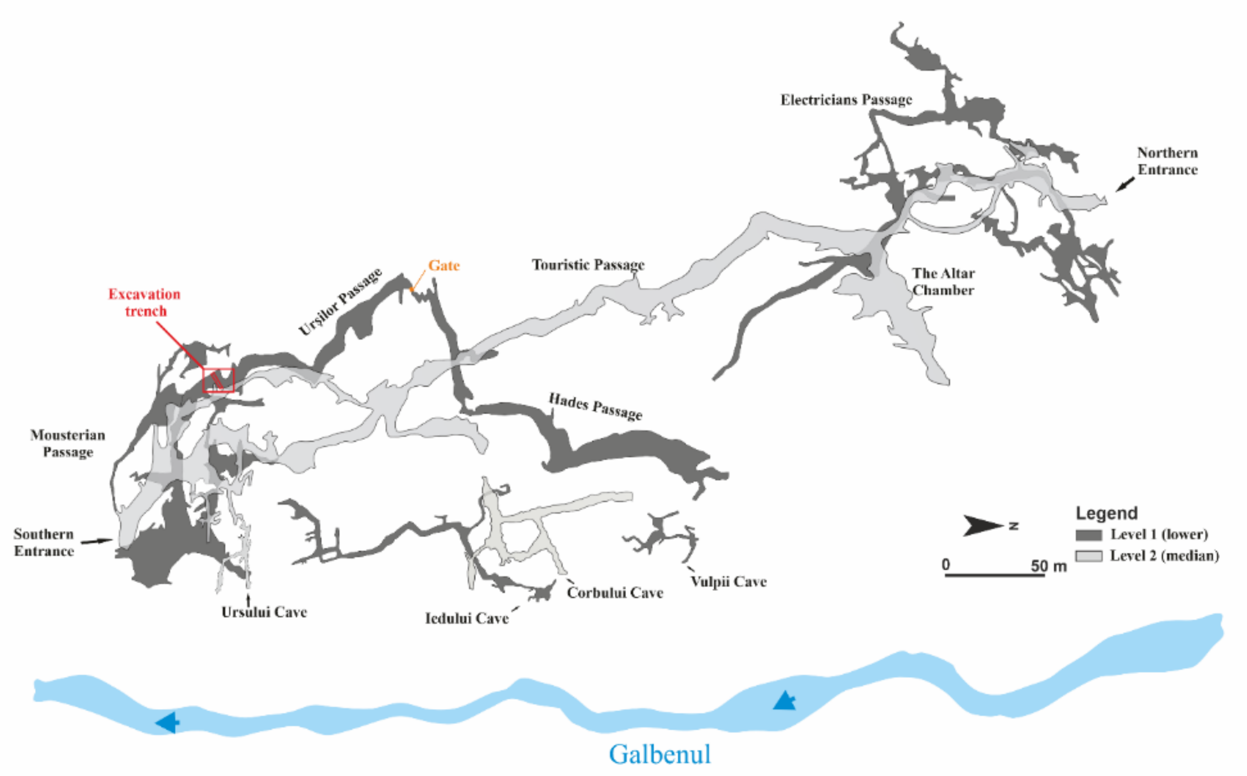

Figure 3. Simplified map of Muierilor Cave (surveyed by the "Hades" Caving Club and "Emil Racoviță" Institute of Speleology; courtesy of Grigore Stelian).

The main passages are composed by the Touristic (Level 2) and the scientific reserve (Level 1), these two levels are crossing through the limestone band with a nearly N - S orientation and with a length over 5600 m, they are separated by a series of pits with depths between ten and fifteen meters. The other levels have been linked over time through some pits and several other small cavities (Fig. 4). Most of them were already connected, but as a following of repeated flooding events they were infilled (Grigore Stelian, pers. comm., 2014). The Turistică Passage (= The Touristic Passage; Level 2) has developed parallel to the gorges segment at 50 m relative elevation with different developed secondary passages on both sides expanding on more than 2150 m in length (Fig. 4) The lower passage (Level 1 or the Scientific Reserve – comprising Urșilor, Hades and Electricienilor passages) includes a horizontal passage with several large chambers and side - passages with a main orientation of NNW - SSE and a secondary orientation on WNW - SSE – ESE (Constantin et al. 2002), being formed of three individual passages with a total length over 3500 m (Fig. 4). The Urșilor Passage (= Bears' Passage, ca. 800 m in length; Level 1) is relatively horizontal, with narrow segments that link several large chambers. The passage is linked with Level 2 through a series of pits. It is representative mostly for the abundance of fossil remains that it hosts. More than 35 cave bear skulls were found since the early exploration of this passage on a surface of only 50 m^2 with many other bone remains. Furthermore, this passage has a complex development as within we can find a great abundance of fossil remains, extensive deposits of clastic sediments, speleothems and a large diversity of carbonate minerals. The newly discovered Hades Passage (ca. 900 m; Level 1) is located in the central part of the Scientific Reserve (Fig. 4), representing the most pristine section of the cave, hosting exceptional layered clastic sediments, speleothems, articulated skeletons, coprolites and ichnofabrics. The Electricienilor Passage (= The Electricians' Passage; ca. 800 m; Level 1) is the upstream segment of this level, the access being made on a single narrow passage for a few meters and then climbing down a 12 meters pit from Level 2. Also, in this level extensive sediment deposit can be found, in some places deep pits have developed in the clastic sediments (15 to 20 m deep, Grigore Stelian, pers. comm., 2014).

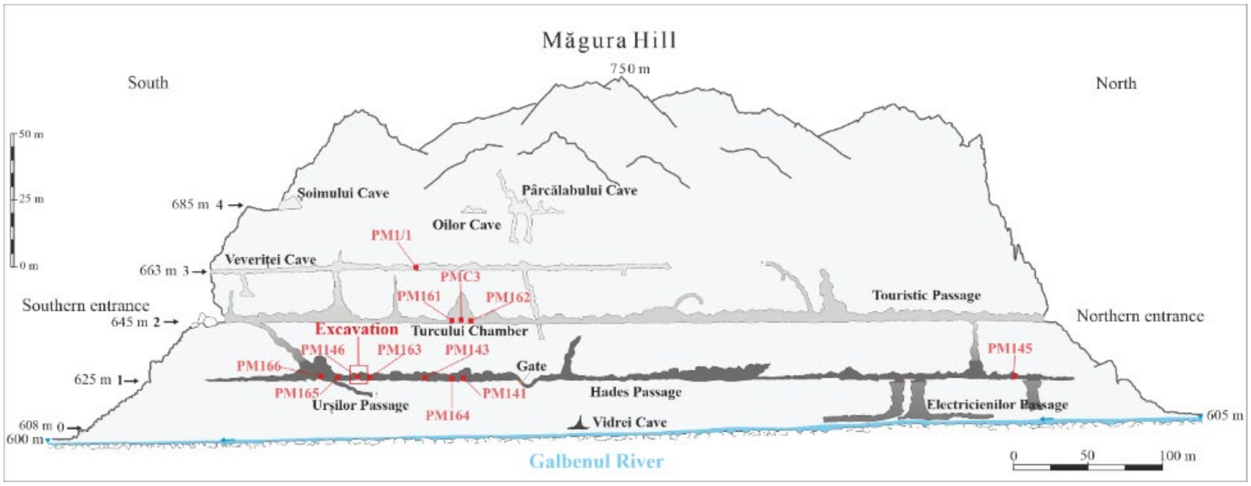

Figure 4. Simplified profile of Muierilor Cave (modified from Grigore Stelian)

3.1. Clastic sediments

For Muierilor Cave, clastic sediments along with the fossil remains may give important knowledge about the infilling episodes. These clastic sediments can be found through the entire cave system having considerable thickness in some passages (e.g. Electricienilor Passage, ca. 15 m). The infiling events are complicated and hard to trace down as the reworking processes are frequent in caves. In some cases we can find even reverse chronology in the sedimentological profile, making it difficult or impossible to constrain certain regional or local events. In this research a reverse chronology refers to the fact that the ^{14}C ages on fossil remains young ages were found in the lower part of the trench and the older ones closer to the surface. Along the main passages of the Muierilor Cave, the former stream and the episodic flood events deposited a large amount of clastic sediments. As the cave functioned as an underground meander, the main infill is associated to the Galbenul River inputs (Ion and Lupu, 1962). The main source area of these sediments is probably in the upper drainage basin reaching the maximum altitude in the alpine zone of the Parâng Mountains (about 2500 m a.s.l.). We do not exclude the possibility to have complementary processes and factors that brought clastic sediments into the cave system, to some extent the run-offs during heavy rainfall can be very effective at transporting sediments and some small intermittent rivers at the extremities of the limestone ridge can have the same effect. Nevertheless, the major input of clastic sediments in the Muierilor Cave is related to river Galbenul.

3.2. Speleothem deposits

Carbonate speleothems in this cave are represented by stalactites, stalagmites, columns, flowstones, pools and helictites. They are present in all the cave`s passages, the most abundant can be found within the Turistică, Urșilor, Hades and Electricienilor passages. The stalagmites and flowstones are well developed, in most of the passages overlying the clastic sediments, and in some cases capping even the bones (Ion and Lupu, 1962). Moreover, the bones accumulated in some parts of the cave are incorporated into flowstone. From the mineralogical point of view, besides the common carbonate species (calcite, aragonite) have been found phosphate minerals such as hydroxylapatite [$Ca_5 (PO_4)_3(OH)$] and brushite [$CaH (PO_4)$] $2H_2O$ (Diaconu, Dumitraș, and Marincea, 2008) in the lower level of the cave.

3.3. Fossil remains

Muierilor Cave revealed many fossil remains mostly belonging to cave bears, cave lions and fewer remains of cave hyenas and wolves (Bombiță, 1954; Doboș et al., 2010). This view emphasizes that omnivores and carnivores are well represented within the preliminary fossil accumulation assessment in the cave passages as the earlier studies showed (Bombiță 1954; Doboș et al. 2009; Doboș et al., 2010). In addition, few fossil remains of herbivores and micromammals contemporaneous with carnivore fossil remains were found in the same excavations (most of them in the Turistică Passage, Musteriană Passage and Urșilor Passage). The archeological excavations extended in Level 2 and reached towards the Mousteriană Passage from 1929 to 1955 (Nicolăescu-Plopșor et al., 1957; Doboș et al., 2010), discovering not only many archaeological artefacts but also a diversified faunal association. In the early 1930s, only a small part of the cave was known, mostly the Turistică Passage, and the researchers assumed that the actual entrance had been used as a shelter and entryway for both humans and large mammals, this level being considered to be the main passage with fossil remains. In 1952, fossil human bones have been discovered in two areas of the cave. Holocene human remains were found in the entrance area, while the Upper Palaeolithic human remains were found much deeper in the cave, in the Musteriană Passage (Nicolăescu-Plopşor, 1935-36; Nicolăescu-Plopşor et al., 1957; Păunescu et al., 1982).

Chapter 4. Materials and methods

4.1. Sediment analysis

Grain - size measurements and anisotropy of magnetic susceptibility were performed for two on-site logs located on the lower level of the cave (Level 1). Grain size measurements were performed on bulk samples of sediments. The first profile is represented by the palaeontological excavation (PMP1; Fig.6) located in the Urșilor Passage, and the second one (PMP2, Fig. 5) located at the end point of the Urșilor Passage, near the entrance to the Hades Passage. The grain size analyses have been performed on 31 samples of sediments for PMP2, where complex structures with well-defined sand silt and clay levels could be identified. Bulk samples were taken at 15 centimetres along the length of the profile. The samples were analyzed on a Horiba Partica LA - 950V2 Laser Scattering Particle Size Distribution Analyzer, in aqueous solution, after treatment with a dispersing agent, 2% extra-pure sodium polyphosphate [Na(PO3)n, n ≈ 25 - Graham's salt] (Merck Millipore). The statistical processing of the results has been carried out with a Microsoft Excel application - GRADISTAT, version 8 (Blott and Pye, 2001). The grain size statistical parameters have been obtained by the graphic, logarithmic method (Folk and Ward, 1957). The particles settling velocity has been assessed with another Microsoft Excel application – FallVel (Parker, 2004), based on Dietrich (1982). Measurements of the anisotropy of the magnetic susceptibility (MF in this study) were performed throughout the profiles as a complementary technique to grain-size analyses. MF provides information about the magnetic fabric and can unravel the hydrodinamics of sediment transport. The MF interpretation is based on the statistical orientation of the paramagnetic or ferromagnetic crystals in sediment that have positive magnetic susceptibility. MF was measured on 41 samples (480 cm profile) from PMP2 and only 3 samples from PMP1 (from 220 to 240 cm depth). For PMP1 we performed fewer measurements of magnetic susceptibility as the profile is made of coarse sediments, boulders and bones possibly affected by reworking processes which can lead to a misinterpretation. Samples were collected in plastic cylinders (11cm^3) specially designed to avoid rotation during the measurement, the cylinders were pressed into the clean part of the profiles, at sampling intervals of about 10 cm. In the laboratory the samples were kept in cold conditions to preserve the original humidity. The measurements were made using a MFK1A Kappabridge (Agico) and a 3D Rotator at a heating-cooling cycle from room temperature up to 700 °C. The MF data were analysed using Anisoft 5.1.01 (AGICO). Both grain-size and AMS measurements were done in the laboratories of the University of Bucharest.

4.2. Luminescence dating investigations on samples extracted from PMP1 and PMP2

Sediment samples for Optically Stimulated Luminescence dating (OSL hereafter) were collected by hammering plastic tubes (20 cm – long, opaque) into the sediment sections under no light conditions, both in the excavation trench (PMP1) and in the test pit (PMP2) near the Hades Passage (Fig. 7). For these measurements, we collected nine samples in total, four from PMP1, from top to 240 cm depth and five from PMP2, from top to 460 cm depth. From the total of nine samples only seven gave reliable data. Luminescence measurements were performed using an automated Risø TL/OSL-DA-20 reader equipped with blue and infrared light diodes emitting at 470 ± 30 nm and 875 ± 80 nm, respectively. The OSL dating was done at the Environmental Radioactivity and Nuclear Dating Centre (Babeș-Bolyai University) following the same protocol as in Constantin et al. (2014). Since the sediment-water content has strong effects on resulting age estimates (e.g. Zander and Hilgers, 2013), we computed the age using both the "as found" water contents and assuming a 30% water content. The later value is probably a better approximation of the moisture conditions in the cave sediments during the period of burial being close to the maximum values measured in our samples. All the errors represent 1σ. Since the sediment-water content has strong effects on resulting age estimates (e.g. Zander and Hilgers, 2013), we computed the age using both the "as found" water contents and assuming a 30% water content. The later value is probably a better approximation of the moisture conditions in the cave sediments during the period of burial being close to the maximum values measured in our samples.

4.3. Uranium-Thorium method

Calcite subsamples were used to establish absolute geochronometry of several speleothems within the levels of the cave. The speleothem samples have been collected from Muierilor Cave including the upper passage, Turistică Passage, Urșilor Passage, Hades Passage and Electricienilor Passage from stratigraphically relevant locations (Fig. 4). A total of 15 speleothems were dated (50 hand drilled subsamples), including 13 stalagmites (top and base) and 2 stalagmite base cores. For this study, we used relevant data only from 11 speleothems and 1 flowstone core. For one sample (PM1) we used U-series alpha-spectrometry (1σ error) at the U - series Geochronology Laboratory, Bergen University (reported in Constantin, 2003). The analytical procedures for alpha-dating are described also in Constantin et al., (2007) and the spectra were processed using an in-house software. The other samples were processed and measured at the Miami University (Miami, USA) using a Thermo Fisher –Neptune Plus MC-ICP-MS. Approximately 0.20 g of subsamples was collected from the growth axis by hand-drilling, for all the stalagmites were sampled at least top and base, but additional samples were dated for further studies. The subsamples were dissolved in 6 mol/l nitric acid, spiked with IRMM - 3636a and processed though extraction chromatography for the separation of U and Th. Uncertainties for the ages is reported at 95% confidence interval (CI) based on Monte Carlo simulations. The detailed U/Th geochronometry and the propagation of random and systematic uncertainness are described in Pourmand et al. (2014).

4.4. AMS ^{14}C dating

The bone samples were collected from the Urșilor Passage (surface and excavation) and Hades Passage (surface and two from a test pit). The AMS ^{14}C dating was performed at the Poznan Radiocarbon Laboratory (Poland). The collagen extraction procedure is described in Longin (1971) with further modifications (e.g. Piotrowska and Goslar, 2002). The degree of collagen degradation is checked using the analyser Flash EA 112, the samples are suitable if the nitrogen content in bone is not lower than 0.6%, and ratio C/N is not higher than 5. The bone treatment followed the method described by Brock et al.(2010), including the collagen extraction and then purified on Elkay 8 µm filters, and ultrafiltered on Vivaspin 15 MWCO 30 kd filters. The CO_2 was produced by combusting the sample, the collagen was combusted in a closed quartz tube, together with CuO and Ag wool, at 900 °C over 10 h. The obtained gas was reduced, using Fe powder as a catalyst (Czernik and Goslar, 2001), and the $^{14}C/^{12}C$ ratio in the C-Fe mixture was measured using the AMS spectrometer as described by Goslar et al. (2004).The calibration of ^{14}C ages was performed using the program OxCal ver. 4.2 (Ramsey and Lee, 2013), against the INTCAL13 radiocarbon calibration curve (Reimer et al., 2013).

4.5. Pollen analyses

Four hyena coprolites (between 95 and 16 g) from Hades Passage were analyzed in order to have an overview of the structure of vegetation around the Muierilor cave. The samples were analyzed at Maison méditerranéenne des sciences de l'homme (LAMPEA – UNR 7269 laboratory). The sample preparation was done through the precise cleaning of the surface, by intensive brushing under a jet of water; in order to remove potentially polluted material and to ensure that only the content of the coprolites was treated. The content of the coprolite was then prepared by concentration in a dense liquid by decarbonatation with hydrochloric acid, desilicification with hydrofluoric acid (concentration 40%, cold test). Removing the organic matter was done by heating in potassium hydroxide solution for 10 minutes and the concentrated in a dense solution (Tholuet solution, potassium iodomercurate d = 2). The next step was to mount in glycerin. The samples were washed out with distilled water after each operation. The detailed procedures are described in Argant and Philippe, (2011) and Argant (2018).

4.6. The palaeontological excavation

As Urșilor Passage holds the largest amount of fossil remains, we established the new palaeontological excavation in this passage. The excavation is located in southern part of the passage, close to the southern entrance of the Muierilor Cave, and is compounded from nine squares, 1m^2 each that are transposed transversally on the Urșilor Passage. The trench was designed to intercept the entire width of the Urșilor Passage on the excavation site in order to reveal the palaeohydrological conditions and the deposition of the fossil remains accumulation. The excavation technique used are a development in microstratigraphy technique (1 - 5 cm/layer) working with fine tools, surveying, *in-situ* photography and measuring (3D) with a Leica Total Station, labelling, and sampling the fossil remains. Large bones were cleaned and prepared for the laboratory stage. The removed sediment was labelled, transported out of the cave, sieved and sorted for small mammals' content, and other elements of interests. Most of the findings were identified (ca. 70%), determining species/subspecies and measurements will be taken for qualitative and quantitative analysis, aiming to identify the faunal assemblage features. Samples were taken from the main points, according to a particular methodology for radiocarbon dating, U/Th dating, OSL dating as well as for the stable isotope. To set up the infrastructure for the excavation was a real challenge, considering the tight passages and the amount of fossil remains on the floor, this forcing us to improve the excavation techniques continually. In the following campaigns, we uncovered a significant part of the digging trench regarding the thickness of the bone bed and we reached extensive limestone boulders, mostly collapsed from the ceiling, so far, we reached a depth of 260 cm from the datum point. Until now, the excavation from Muierilor Cave revealed a significant number of fossil remains predominantly belonging to cave bears, cave lions, cave hyenas and grey wolfs, which emphasize that carnivores are well represented. Moreover, few fossil remains of herbivores and small mammals contemporaneous with fossil carnivore remains were found in the excavation trench. Outstanding amounts of fossil remains were found in the first six levels (up to 60 cm thick) of the excavation trench and fewer elements in the remaining levels (up to 20 levels). We approximate over ca.10.000 fossil fragments were extracted during the excavation campaigns in the last years.

4.7. The spatial analyses of long bones

Spatial orientation and density estimation was performed on the long bones, extracted from the digging trench representing the three levels of the excavations (ca. 30 cm below "0" datum). The analyzed faunal samples belonging to *Ursus spelaeus* were recorded, photographed and surveyed on the excavation grid and on a 10 × 10 cm sub-grid for each quadrant. The kernel density analysis was employed for 291 (N = 291) bones and bone fragments, while for the spatial orientation we measured 105 (n= 105) long bones (humeri, ulnae, tibiae, femora) with a good rate of preservation. The kernel density analyses was evaluated within the palaeontological excavation trench using a 50 cm radius between points (individual bones).The orientation was calculated only for long bones with a good rate of preservation represented by humeri (n=34), ulnae (n = 20), tibiae (n = 20) and femora (n = 31). The bone surveying was performed using high-resolution pictures and measuring the azimuth with a compass (ST=5º), results being plotted as rose diagrams with bi-directional data distribution. For the kernel analysis we classified the specimens from the excavation in 3 categories of degradation, mainly based on the weathering degree. The first type includes long bones with epiphyses and diaphysis (represented by long bones with visible degradation), the second one represents bones without epiphyses (with a medium degree of weathering along the diaphysis), and the third one consist of only scarce fragments (determinable) of epiphyses or diaphysis with significant degradation (Kos, 2003; Mirea et al., 2017).

4.8. The osteometry analysis, carnivore impact, stable isotopes and mtDNA

To have a complete picture of the fossil assemblage at Muierilor Cave we applied several methods and procedures. From the ostemetric analysis of the cave bears from the excavation trench, were investigated the most relevant elements of dentition (lower canines, upper canines, upper and lower molars and upper and lower premolars). For the osteometric comparison we used data from Gammsulzen caves (Pacher, 2004a, b; Withlam, 2004). For carnivore impact we identified and analyzed more then 100 bite marks. The investigation was assesed by counting the remains with traces of carnivore impact and were classified acording to the type of the bite mark. The dietary profile for the cave bears at Muierilor Cave was asssed by using the two stable isotope, carbon and nitrogen and identified th major source of proteins of the analyzed collagen using the equation δ = [(Rsample/Rstandard)-1] (1); where Rsample = is the $^{13}C/^{12}C$ and $^{15}N/^{14}N$ of the analyzed sample (Coplen, 2011). As for the DNA analysis we used the cervical root of cave bears adult canines, by revealing the pulp chamber. For some steps in our analysis we followed the procedures from Hofreiter et al., (2002). The bone powder was hydrated with 100µl RNALater. DNA extraction was performed using QL Aampcador Pathogen Mini Kit an then the quuantification of aDNA was performed using QbitdsDNA HS Assay kit. The detailed procedures are described in Hofreiter et al., (2002). DNA extraction and amplification was performed at the Animal Infectious Diseases - Research and Training Laboratory from the University of Agronomic Sciences and Veterinary Medicine of Bucharest. Here we will summarize the results of the stratigraphy of the excavation, the geochronological data from speleothems, clastic sediments and bones, the orientation of the long bones in the first 30 cm (top to bottom) and typical osteometric measurementson cave bear bones as well the evolution of the cave system reveled by the cave sediments in the last 120 ka BP.

Chapter 5. Results and discussion

5.1. Sedimentological analysis

In the palaeontological excavation (PMP1) we have found 10 sedimentary layers (Fig. 5). The maximum depth resulting from our excavation reaches 260 cm in the central area of the palaeontological excavation (T6 square). The first 30 cm (L1, L2 and L3) are very rich in fossil remains, sediments being poorly sorted. The abundance of the fossil remains is found in the median area of the palaeontological excavation (T6 and S6 squares). Along with the depth, the concentration in fossil material decreases. L1 and L2 are the richest bone layers excavated, including almost only bones fragments. In L3, L4 and L5, the fossil remains are poorly evidenced and mainly made of small bones mixed up with boulders. Layer L6 corresponds to a sedimentation stage with a thickness of 40 cm, characterized by fluctuations in transport agent dynamics generating successive channel traces represented by L3, L4 and L5 layers. In L7, L8, L9 and L10 levels, the density of the palaeontological material decreases and un-weathered roof-fall blocks can be distinguished, occupying important areas from the squares.

The roundness of allogeneic clasts and their size suggests short - distance transport and the abundance of large fossil remains as well as high energy transport. The magnetic susceptibility (MF) was performed on only 3 samples from the lower part of the profile (between 220 - 240 cm), as the rest of the profile being affected by reworking processes and susceptible for misinterpretation. The most likely interpretation is that sedimentation took place in a high energy stream and the particles were mainly transported by rolling. The PMP2 profile (located in the final part of Urșilor Passage, near the Hades Passage entrance) was the main point of study for sedimentological analysis. Unlike the first excavation, sediments in this section have complex structures with levels of sands, silts and clays well evidenced. As can be seen from Figure 6, sedimentation on the first three meters is dominated by an alternation of sand and silt. This indicates a succession of floods. Larger percentages of clay appear only in the final part, which, together with the colour change of the sediment indicates a change in the source area that allows the transport of finer sediment. Clay alternates with more sand, indicating the persistence of high energy streams at the end of the profile. The magnetic susceptibility (MF) was performed on 41 samples and from bottom to top the profile (Fig. 6, C), starts with 100 cm (stage IV), where sedimentation is produced in a stagnant water regime (this distribution show that sedimentation is produced in quiet water), most likely due to a small lateral lake located on the main flow. The minimum susceptibility axes are thus grouped to the centre of the diagram and the other two axes are relatively uniformly distributed in the plane of sedimentation. The next 240 cm are characterized (bottom to top; stage III), by a fast current that has produced particle rolling. This type of sedimentation produces a group of maximum susceptibility axes perpendicular to the direction of current and an elongated distribution of the minimum susceptibility axes in the direction of current. This type of distribution allows determining the direction, but not the sense of the current. In the studied section the direction of current obtained from MF is oriented parallel to the axis of the passage. The next 50 cm (stage II), are again characterized by sedimentation in a stagnant stationary water regime. The final part of the profile (stage I), is characterized by a fast-current regime in a direction similar to the one previously identified. We therefore assume that the flow direction was NE - SW with possible “apparent reversals”, such as those due to vortex-type flows generated by cave walls topography.

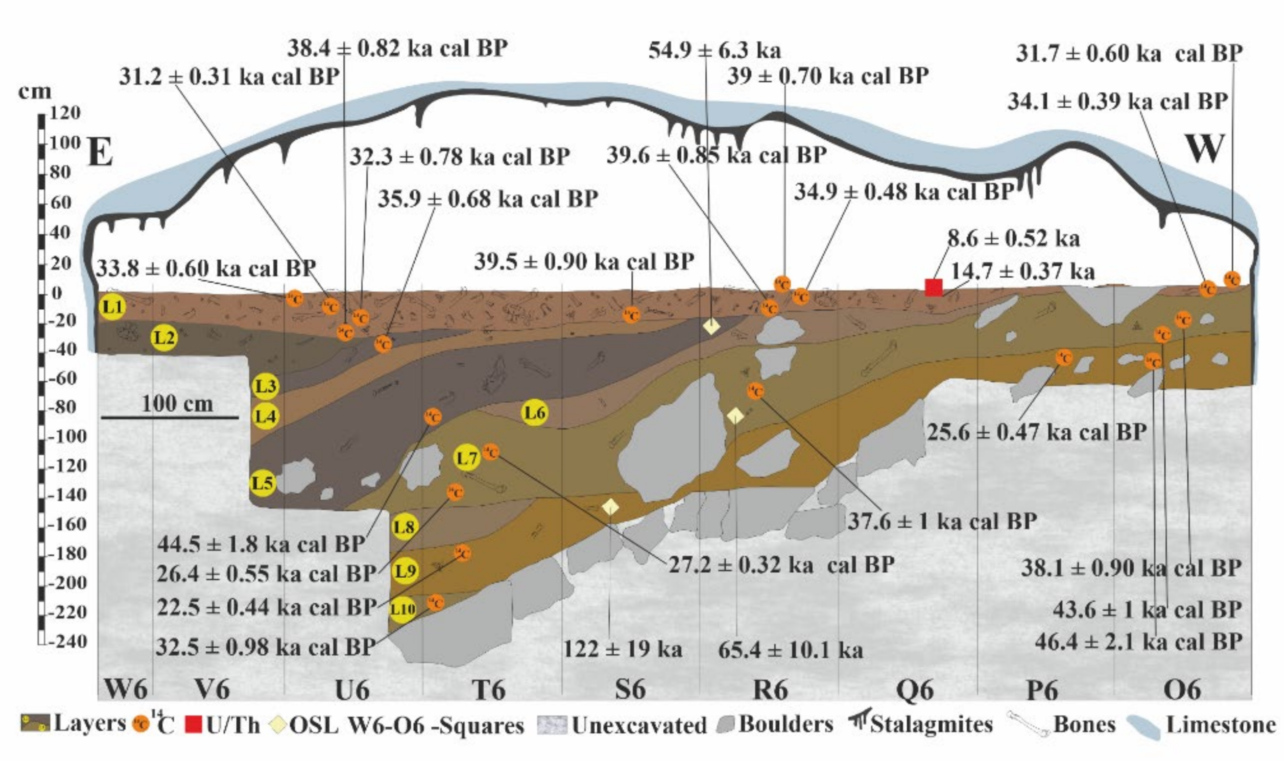

Figure 5. Stratigraphic section of the excavation trench of Urșilor Passage

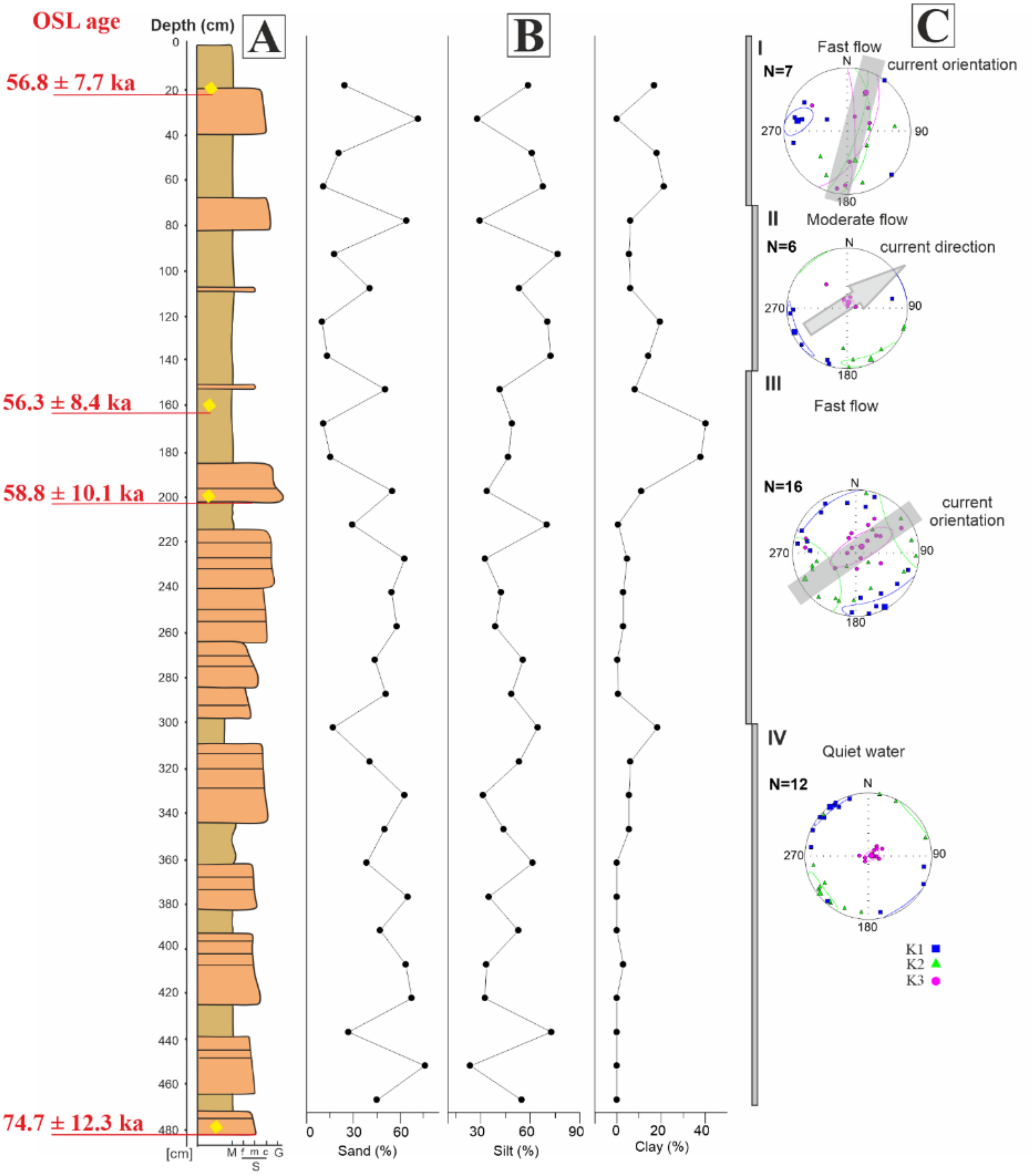

Figure 6. PMP2 section (Urșilor Passage): **A**. The lithological profile; **B**. Grain size measurements; C. Anisotropic direction

5.2. OSL ages

The values for radionuclide concentrations, the total dose rates, the average De values and OSL ages are shown, Figure 7 (yellow diamonds). From nine samples (from OSL1 to OSL9), seven were suitable for dating (OSL4 and OSL8 gave no signal). The obtained result of the two profiles ranges between 122 ± 19 ka to 54.9 ± 6.3 ka. Most of the samples are clustered around 58 - 54 ka, with only one sample higher than this range, OSL3 from the lower part of the paleontological excavation with a date of 122 ± 19 ka. All the samples show typical uncertainties of >10% (1σ). For the PMP1 profile, from four dated samples, three of them were dated, and are in stratigraphic order. The first sediment layer from PMP1 has an age of 54.9 ± 6.3 ka at 20 cm depth, indicating a reworking of the sediments as they hold bones with a much younger age (between 46 – 22 cal ka BP, with the regard that some ^{14}C ages can be questionable). The same for the OSL2 sample dated to 65.4 ± 10.1 ka. For the OSL3 sample, we obtained a date of 122 ± 19 ka, suggesting a reworking of older sediment from the passages of the cave, as this sediment contains much younger bones. We consider that the deposits within this profile indicate a reworking of older sediments from the upper levels of the cave and a multiple inflow at different time intervals. The contradiction between the OSL ages of sediments and the radiocarbon ages of the bones within the sediments may be due to a reworking of older sediments from remote parts of the passages from the upper levels of the caves that as well can indicate a reverse chronology. From PMP2 test pit, we obtained four OSL ages from five samples. From top to base (480 cm depth) the OSL ages are in the same range for all the samples, taking into consideration the systematic errors, between 74 to 56 ka. From PMP2 we do not have radiocarbon ages from bones. Furthermore, the OSL ages indicates an age range similar from top to base (only the bottom sample shows a rather older age) suggesting that the sediments deposited here have the same source, but, as the sedimentological analyses indicate, the deposition of the same sediment took place in separate episodes of inflow, most of the sediments being removed from Hades Passage. Overall, the OSL ages provides information regarding repeated episodes of inflows but these ages did not provide a precise chronology of the sediment profiles (PMP1 and PMP2), only constraining the input stages of the sediments in the cave system.

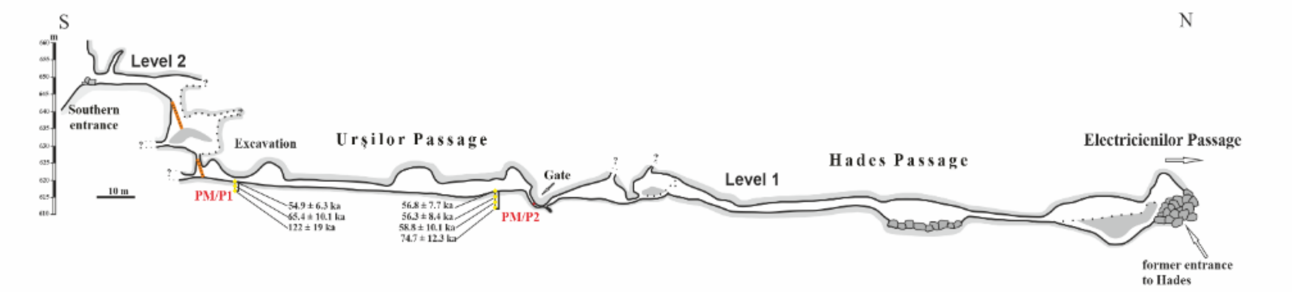

Figure 7. General profile of Urșilor and Hades passages.

5.3. Uranium / Thorium - series dating results

The results of the speleothem samples dated from the Muierilor Cave system, including five passages, from 11 stalagmites and 1 core. Speleothem samples from the levels of the cave have been dated using the U/Th method and yielded ages between 119 ± 5 ka to 6.5 ± 0.09 ka (Fig. 4, - red squares). The samples have a relatively good U - content, ranging between 0.2 to 0.9 ppm. Most of the samples show low ^{230}Th/^{232}Th ratios that can suggest a certain detrital contamination. The errors associated with the alpha date were relatively low, owing to the high U - content (0.3 -0.5 ppm, Tab. S4) and low Th contamination (Constantin, 2003). From all samples, most of them show young ages between 19 ka to 6 ka (MIS 2) and few are older spanning the radiocarbon ages (MIS 3) and just two samples have an older range between 119 ± 5 ka to 82 ± 5 ka (MIS 5). Stalagmite **PM1/1** (ca. 65 cm, 0.3-0.6 ppm) grew over sediments in the superior level of Muierilor Cave (Veverița Cave - Melcilor Passage, Level 3) being a classical candlestick stalagmite having a relatively good U-content between 0.3 and 0.6 ppm, yielding a reliable age of ca. 119 ± 5 ka, which indicates that the sediments from this superior level of the cave can be older than this age surprising the end of the MIS 5e. The **PM161** (ca. 20 cm, 0.3 ppm) and **PM162** (ca. 30 cm, 0.3 ppm) samples were small stalagmites from the median level of the cave (Turisitică Passage or Level 2) from the Minunilor Chamber, both growing on top of the flowstone deposit, both having ca. 0.3 ppm U and yielding base ages around 28 ±0.2 ka and 19 ± 0.2 ka. The third sample (**PMC3**) from Level 2 is a core (ca. 30 cm, 0.25) from a stalagmite base (the stalagmite was broken) that was incrusted in flowstone, the base of the core yielded a date of ca. 10.3 ± 0.74 ka. This sample is located on the main passage of Level 2. The passages belonging to Level 1 are separated as they evolved different over time. Even if the passages were formed at the same time, functioning as a lower level of the Muierilor Cave, they were separated by major collapses and later by a sediment plug as a result of major hydrological events. Furthermore, for the Level 1 (the Urșilor Passage) we sampled 7 stalagmites and for 6 of them we dated only the bases. **PM141** (ca. 21 cm; 11.7 ±1 ka) has a U-content of 0.25 ppm with a relatively small ^{230}Th/^{232} Th (ca. 3) and was engulfed in the topmost clay layer and can provide important information about the last flooding event that occurred after ca. 15 ka. **PM143** (ca. 120 cm, 0.37 ppm) is the oldest record (ca. 82.1 ± 5.7 ka) that we dated from this passage, this stalagmite was found broken and lying on top of the sediment. It is possible that this stalagmite may have grown on this limestone terrace and not on the sediments. This is a rather dirty sample as the ^{230}Th/^{232}Th activity ratio is ca. 2.7 and the U-content is ca. 0.37 ppm, this suggesting some hydrological activity during their growth. For **PM146 (**ca. 5 cm, 0.5 ppm**)** we obtained dates for both base (14.7 ± 1 ka) and top (8.6 ± 0.52 ka) as this small stalagmite (ca.6 cm) grew over Layer 1 (L1) from the paleontological excavation. The U-content for this sample is 0.5 ppm an ^{230}Th/^{232}Th activity ratio is ca. 3. PM146 was engulfed in the first layer of the paleontological excavation suggesting that this clay layer (L1) has been deposited before 14.7 ± 0.37 ka. This stalagmite was engulfed in the sediments and the top was incrusted in the flowstone that covered a part of the paleosurface around the paleontological excavation. The other samples were located near the paleontological excavation. **PM163** (ca. 60 cm, 0.6 ppm) being located at few meters from the excavation, the base of the sample was incrusted in the flowstone (ca. 15 cm), yielded a date of ca. 31.2 ± 0.19 ka, this is the oldest ages for a sample that grew on top of the sediments from this passage. **PM164** (ca. 35 cm, 0.4 ppm) was located few hundred meters from the excavation and grew on a limestone terrace yielding an age of 6.5 ± 0.08 ka, being the youngest base age from all base samples. **PM165** (ca. 65 cm, 1.0 ppm) is one of the clean samples, having a U-content ca. 1.0 ppm and a ^{230}Th/^{232}Th activity ratio about 12, yielding a date of 10.2 ± 0.19 ka. This stalagmite was located in proximity of the excavation towards the southern entrance of the cave but in a small chamber where a shaft (ca. 10 m) connects with Level 2. The **PM166** (ca. 25 cm, 0.85 ppm) has a U-content ca. 0.85 ppm and an ^{230}Th/^{232}Th activity ratio about 15, yielding a base date of 8.1 ± 0.11. This sample was located on top of the sediment on the main Urșilor Passage near the small chamber where PM165 was found. From Electricienilor Passage we obtained a base age for **PM145** (ca. 25 cm, 0.20 ppm) of 12.1 ± 0.10 ka, this being the only sample from this passage it is hard to constrain any related events with the floods, but we know that this is a minimum age when this part of Electricienilor Passage became a dry passage.

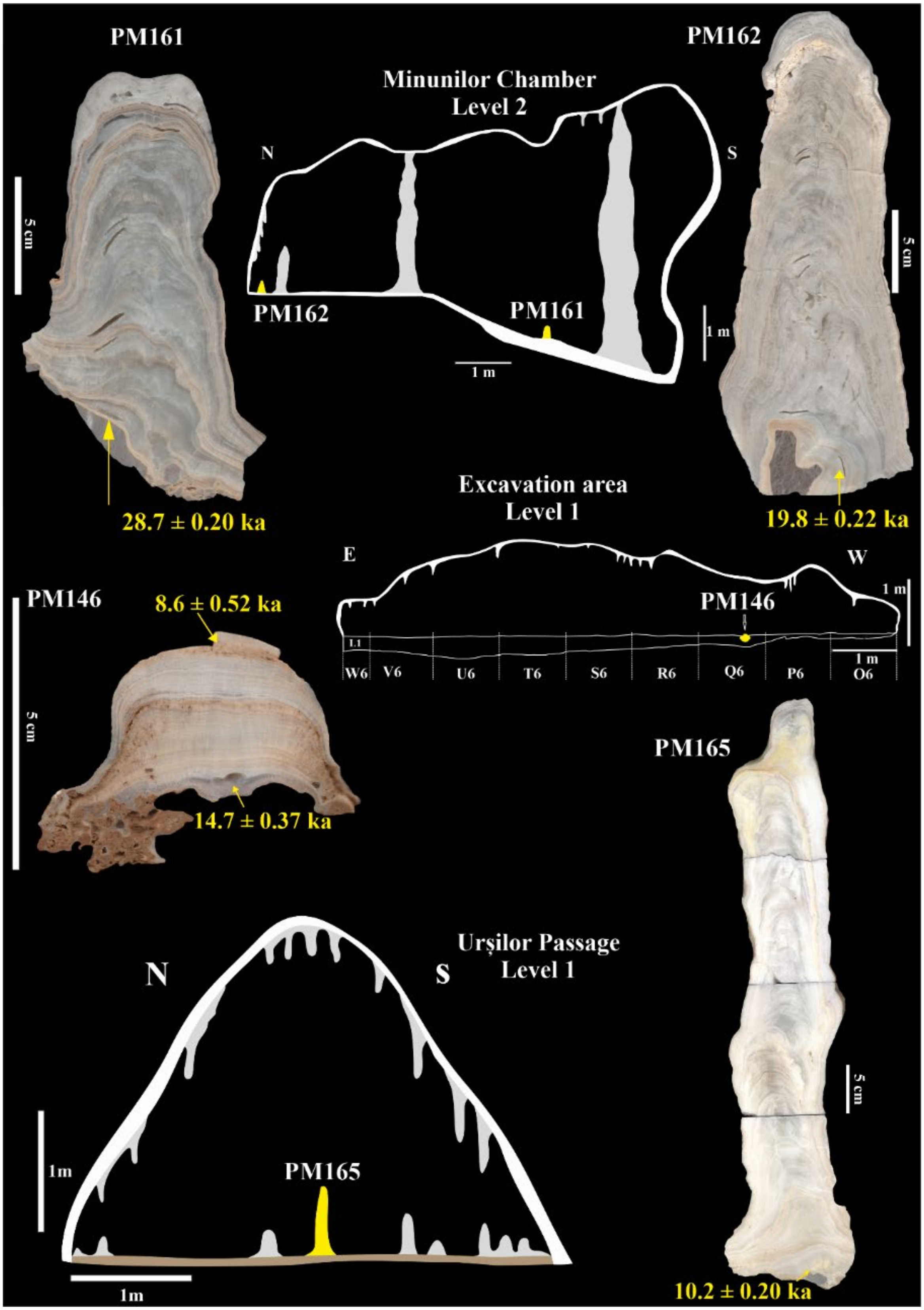

Figure 8. The cross - sections of the stalagmites (PM146, PM161, PM162 and PM165).

5.4. Radiocarbon dating results

Radiocarbon dating results are summarized in Figure 9, all samples investigated are falling within MIS 3 interval. The total number of samples analysed were 31, but we discarded the results that either show abnormally low %N (<0.5%) or collagen yields lower than 0.6 % (N = 13). All ages were calibrated using the OxCal 4.3 program (Ramsey and Lee, 2013) and the IntCal13 calibration curve (Reimer et al., 2013). The samples dated provided a range in extractable collagen yields from 0.1 to 3.5. Radiocarbon ages from the Urșilor Passage (26 bone samples) collected both from surface and from the palaeontological excavation are between ca. 46 cal ka BP to 22 cal ka BP (median values). We have discarded 11 samples from surface and from excavation as they show abnormally low collagen yield and relatively high analytical uncertainties. For most of the samples discarded, especially for the samples that were sampled from the lower part of the excavation showed abnormally young ages (-115 to -200 cm below datum). As well, samples from the rest of the profile and also from surface have the same issues as they were reworked within the sediments suggesting that we rather have a revers chronology due to inflow episodes triggered by snow or/and ice melting in the high mountains near Polovragi - Cernădia area. As the most of the samples were reworked from the superior passages of the cave and other cavities that were connected at that time and/or by some small intermittent streams tributaries to Galbenul River, we assume that those samples have been exposed a long time on the surface before being flooded and deposited along the Urșilor Passage. Radiocarbon ages from the Hades Passage (N = 5) showed a time span between ca. 48 cal ka BP to 33 cal ka BP (median). The ages from this newly discovered passage showed rather older ages than the Urșilor Passage. However, all the dated samples from this passage show a negative %Cncoll ranging between -0.64 to -0.04, this depletion in non-collagen can be associated with a major loss of collagen as the most of the sample were sampled from the sediment surface. Only one of the samples (PM/GN-0-006, sampled from a test pit ca. -30 cm) showed a higher %Cncoll as this sample was located in sediment and all the rest being on the surface of the sediment. Some cave bear samples with questionable ages, like Poz-87737 (18640 ± 180 years BP) have the computed C/N ratio (3.2) within the accepted range (2.9 – 3.6) allowing them to be taken into consideration (with precaution). Nonetheless, the age of these samples is in agreement with the reliable radiocarbon and OSL results, indicating as well as reversed chronology.

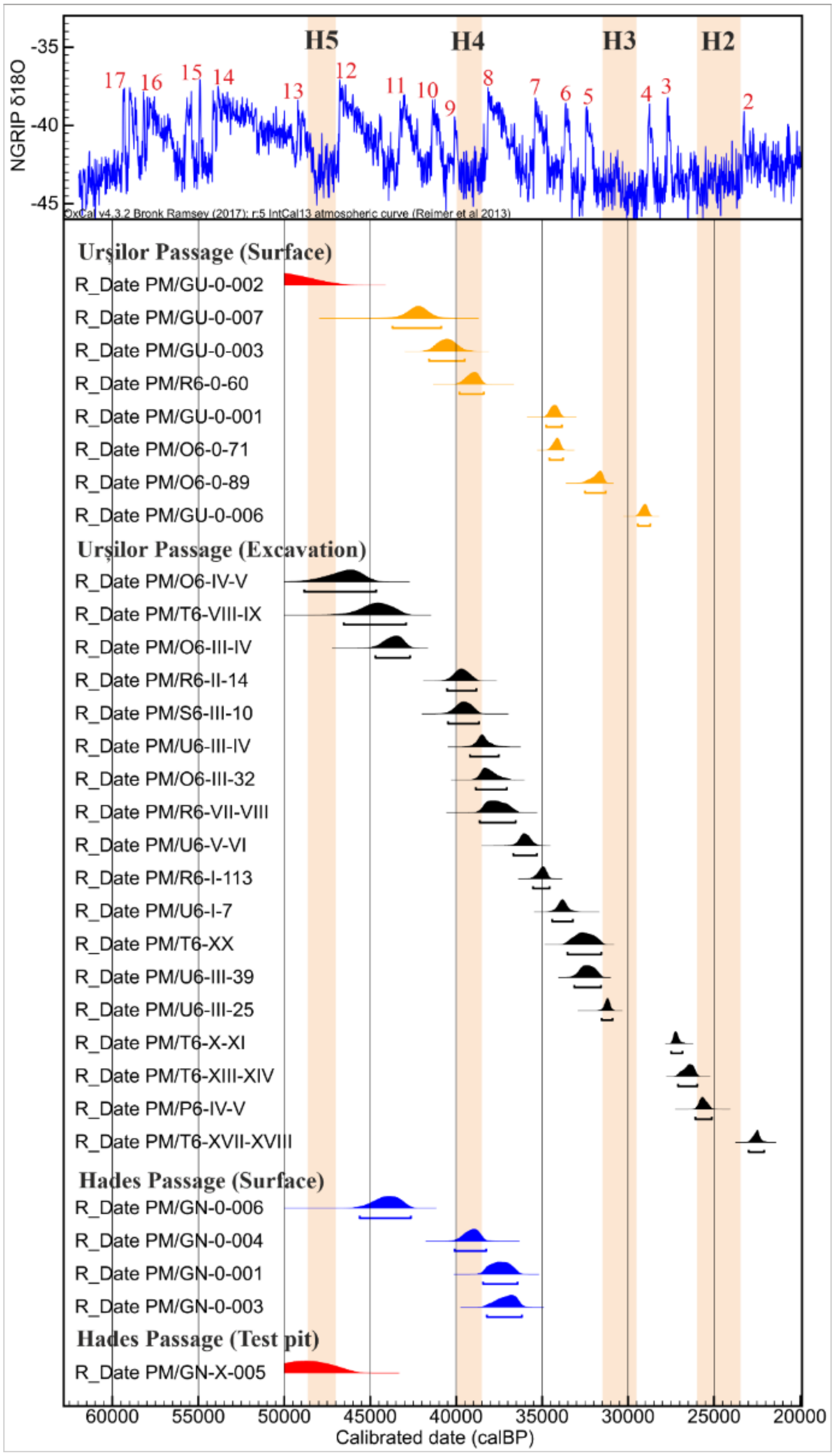

Figure 9. Radiocarbon ages of the fossil remains from Muierilor Cave (correlated with NGRIP data). PM/GN-Cop4 was not plotted with ^{14}C bone samples.

5.5. Pollen results

The coprolite samples from Hades Passage contained pollen grains in small quantities and most of the samples were damaged as they were found on the cave floor, where the presence of a small pool can be observed. As a result, the coprolites were calcified, but in the same time, some of the pollen grain were damaged. These coprolites were found near the skeleton of the articulated *U. spelaeus* which holds an age of ca. 33 cal ka BP, while the ^{14}C dated coprolite is ca. 18 cal ka BP, and also, close to those some hyena bones fragments were found. The fact that this coprolite is the youngest age from Hades Passage, determined us to think that this sample was contaminated with younger carbon, due the presence of water in that area. The reliable samples for the pollen analyses were Cop2 and Cop4. The number of taxa is variable (10 in Cop3 and 22 and Cop4), the maximum being 34. The four coprolites samples yielded 162 pollen identified grains and spores, this allowed us to calculate the percentages. The pollen analyses of these four coprolites suggest that herb largely dominates (83.95%), they being represented by grass especially Poaceae (14.81%) and Asteraceae (*Cichorioidae, Carduaceae, Artmisia* and *Centaurea*, summing more than 47.5%). In this preliminary analysis, no typically hygrophilous or aquatic plants occur. From trees (ca. 11.73%) the most abundant is *Pinus* (7.4%), being the only present in these samples. The other taxa are mesophilus broadleved trees: *Corylus* and *Tilia* occur in three samples, *Alnus, Betula, Carpinus* and *Quercus* in two samples and *Fraxinus, Buxus* and *Platanus* in one sample. As the Poaceae and Compositae represent a strong presence in the samples and fewer arboreal pollen, the general landscape can be represented by an open vegetation, mainly with herbs, with scattered trees mostly growing in valleys. As those are the preliminary results, we need more analyses to conclude and new ^{14}C ages on the coprolites are needed.

5.6. Fossil accumulation

Within the cave levels of the Muierilor cave system we can find fossil remains from a few scattered remains to hundred fragments and even articulated skeletons suggesting primary and secondary thanatocoenosis, as the fossils accumulation determining factors were multiple from hibernation and carnivore den to fluvial transport and floods. One significant fact is that the numbers of articulated skeletons or parts of skeletons are not present in Urșilor Passage surface (where the central area with fossil remains from this cave is), but in Hades Passage we found at least three articulated skeletons (a bear, a wolf and a fox on the cave floor) but fewer scattered fossil remains. In the upper cave levels (Level 3) we can find a few scattered fossil remains and ichnofabrics within the passages on the palaeosurface, mostly weathered and poorly preserved. In the median level (Level 2) of the cave fossil remains can be found mostly in secondary chambers and passages, as on the main touristic route the changes that occurred during the early infrastructure fitting and the constant touristic flow removed or degraded most of the findings. But, the early archeological investigation by Nicolăescu-Plopșor et al. (1957) provided valuable information regarding the fossil remains found in those excavations and showed that in this level there are a great amount of fossils, as most of them are found within the sediments, or/and in secondary passages or chambers (Bombiță, 1954; Soficaru, Dobos, and Trinkaus, 2006; Ştiucă, Popescu, and Petculescu, 2007; Doboș, Soficaru, and Trinkaus, 2010). None of these findings reported articulated skeletons in this cave level. Furthermore, the greatest abundance of fossil remains is found in Level 1 (Urșilor Passage) since the upper levels and other cavities connected (e.g. Perlelor Chamber) with this passage were washed-up during episodic flood events. The new palaeontological excavation (Fig. 6), until now yielded numerous fragmented and broken fossil remains (ca. 10000 bones and bone fragments) due to the reworking processes. The largest bone accumulation in the studied karst system is undoubtedly the one located within Urșilor Passage, where an extremely high density of fossil remains (sometimes up to 200 bones/m^2) was documented in the PMP1 excavation (within the first 60 cm of sediment from surface). Based on the spatial assessment of the long bones located within the first levels of the paleontological excavation a main orientation was determined. The orientation is in accordance with the general inferred flow direction. The spatial distribution analysis indicates that fossil remains from the southern part of the Urșilor Passage were transported under a turbulent hydrodynamic regime.

5.7. The spatial orientation of the long bones result

From the spatial orientation of the long bones and the kernel density assessment, we can extract some important elements in the processes that constrain the fossil accumulation. From the orientation assessment, we can delineate a main orientation NNW - SSE of the long bones that is in accord with the general flow direction derived from the MF analyses, at least for the first levels of the paleontological excavation (Fig. 10 and 11). The examined femora (n= 31) show a primary orientation NNW-SSE (320 - 140º N). The surveyed humeri (n= 34) from the digging trench show a random pattern of orientation, the mean vector of the humeri is NNE –SSW (33 - 213ºN). The analysed tibiae (n= 20) have a main pattern of polarity and a mean vector of E - W (90 - 270ºN). Like humeri, the ulnae (n= 20) have a random pattern of orientation with the average vector as NNE-SSW (54 - 234º N). The spatial distribution analysis carried out show that the fossil remains from the southern part of the Urșilor Passage were deposited from different sources. There are many scenarios regarding the input of sediments and bones, but certain this fossil accumulation is related with the pulses of deglaciation. The kernel density tool was used to identify where clusters of damaged bones where most concentrated in the palaeontological excavations. Therefore, the kernel density result for Muierilor shows high concentrations of degraded bones in the median area of the Urșilor Passage. The result of the kernel density analysis suggests a fluvial transportation in the central part of the palaeontological excavation, most likely in the T6 and S6 squares. The concentration of degraded remains correlated with the number of faunal remains converged in T6, S6 and R6 squares (40.3% of the total samples analysed) can delineate a former stream bed. To a better understanding of our data and the processes involved in fossil remains accumulation, we compared our data with the available data from Urșilor Cave (Western Carpathians, Romania) published by Robu, (2015). The Urșilor Cave fossil accumulation and the processes that gathered the bones in the Excavation Chamber, at a first review, look distinct from the Muierilor bone accumulation. In this regard, the long bones horizontal distribution from Urșilor Cave reveals a random distribution with multiple groups of bone orientations (Robu, 2015). The humeri (n= 136) show a random orientation with a general direction of NW-SE (344-164º N). The main orientation of ulnae (n=71) is NW - SE (302 - 122º N). The surveyed femora (n= 92) have a random direction, but the general direction is WNW - ESE (296 - 116º N). The general direction for tibiae (n= 94) is WNW - ESE (315 - 135º N). Unlike Muierilor, Urșilor kernel density analysis shows a low frequency of degraded remains (in the third category of the damaged bones at Urșilor we have only 25% of degraded remains in contrast with the high percentage of 40% at Muierilor). A significant concentration of degraded remains can be located D1 - E2 squares, and coincide with the limit of the Shaft (20 m height), may suggest that a pitfall entrapment can be one of the main causes for the bone accumulation. Furthermore, the low percentage of degraded remains correlated with the result of bone orientation indicates that we cannot consider the fluvial transport as the leading component for Urșilor Cave. The results of the spatial analyses indicate a main polarity for the analysed bones, suggesting transportation for Muierilor bone deposit and a random pattern with multiple orientations for Urșilor excavation. This preliminary research suggests reworking processes for the fossil bones from Muierilor excavation related to flooding events and an in-situ accumulation for Urșilor bone deposit as a result of pitfall entrapment.

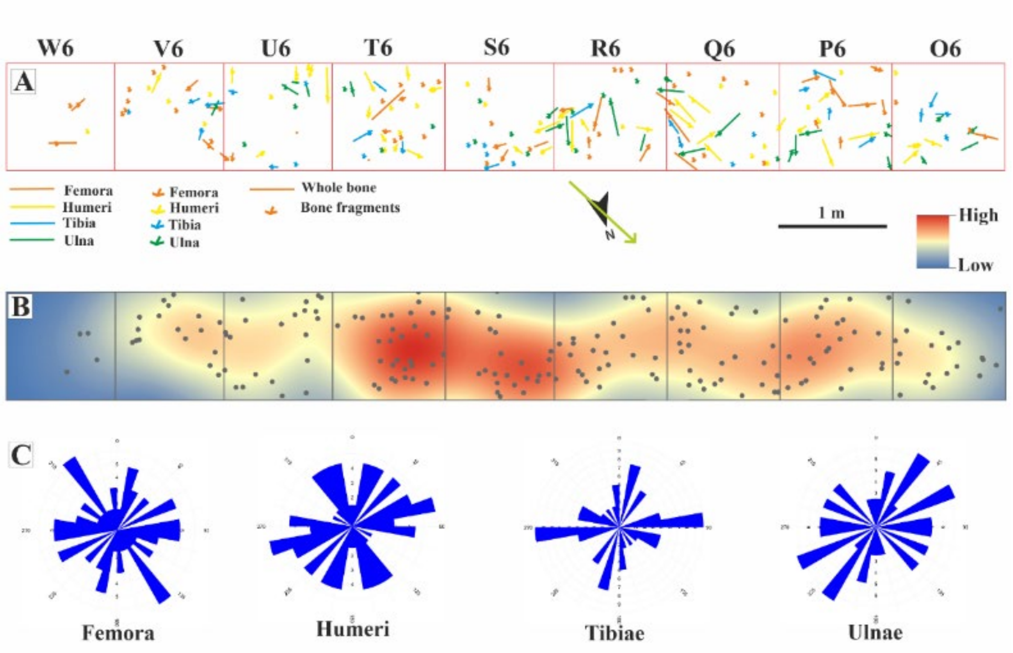

Figure 10. **A**. The excavation trench and the bones that were used for the geostatistical analysis; **B**. Kernel density map of the degraded bone from the excavation trench; **C**. Long bones orientation from the first levels of the palaeontological excavation.

At this point, the Urșilor Passage deposit appears to comprise a secondary thanatocoenosis affected by several reworking episodes. On palaeosurface were not found any articulated skeletons and in the excavation trench only few articulated elements were observed, hard to be linked with former palaeosurfaces. From our observations most of the fossil remains that are on surface are accumulated in the southern part of the cave system, as the main water input was from Galbenul River (north to south drainage) and some small tributaries, through different entrances and passages. Another significant factor is that the northern entrance of the cave was opened by anthropic intervention in the late 1950, only the entrance near the Altar Chamber being accessible at that time. The most abundance of fossil remains is in Urșilor Passage as this lower level was connected with the upper level through several pits and belonging to the southern part of the lower level. The different context in Hades Passage makes us to consider it the pristine area of the entire cave. This passage shows a primary thanatocoenosis with articulated skeletons, gestation nests, scratch marks and other types of ichnofabrics. This was possible as this passage was closed in the northern part (near the Electricienilor Passage) by a collapse of the former entrance while in the southern part of the passage was sealed by a sediment plug making possible the preservation of this traces.

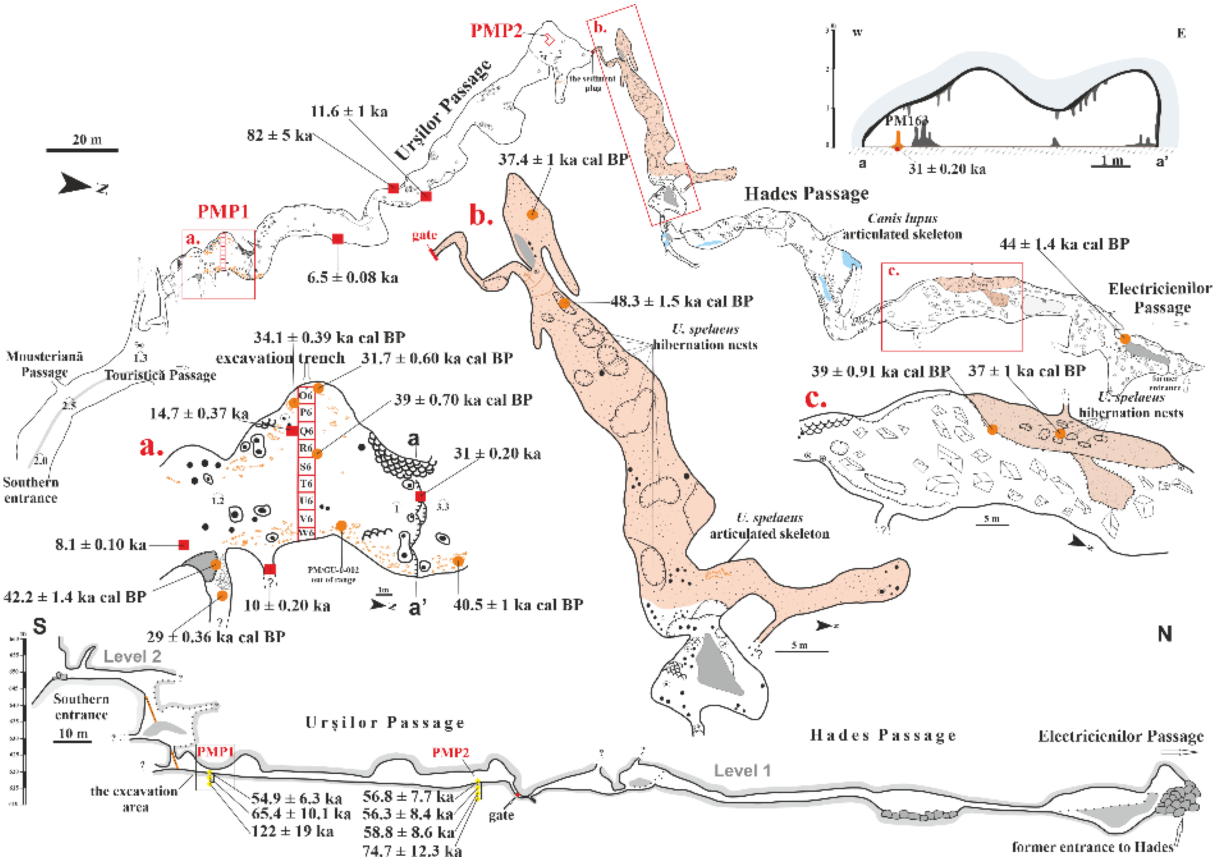

Figure 11. The location of the sedimentological sections and sampling points from Urșilor (a) and Hades passages (b, c). Legend: red squares = U-Th data; yellow diamonds = OSL data; orange circles = calibrated ^{14}C data.

5.8. Small mammals

The small mammals (rodents) are known to be more sensitive to changes in their environment and for this reason they are a significant ecological indicator (Petculescu, 2013). In this regard, we sieved ca. 12 m^3. This stage of the excavation was one of the most difficult as we had to get out of the cave the sediments and transport them and to sieve them in the nearby river (Galbenul River). From the total of the sediments, we managed to pull out only 60%, and to sieve only 50%. This work is still in progress as it is very difficult, involving extensive logistic and many people. Until now from the excavation we found nine species of small mammals (MNI = 62, using M1 sin). From this first data, we consider that the small mammals can be assigned to MIS 3 being represented mostly by *Microtus arvalis - Microtus agrestris* (ca. 40%), this group being assigned usually with a warmer and humid period. The presence of this group within MIS 3 was mentioned by Petculescu (2013) for Central Dobrogea.Therefore, we found others species (in smaller percentages) as *Clethriomomys glareolus, Sorex araneus, Arvicola terrestris* that suggest also a warm and humid period with some forest vegetation. Our investigation on small mammals from the excavation trench is in progress as the sieving process is still ongoing.

5.9. Fossil population structure, mortality analysis, biochronology, carnivore impact and stable isotopes on cave bears from Muierilor Cave.

To have a clearer picture of the cave bears population in this region in MIS 3 we carried out a series of analyses on the cave bear bones from the palaeontological excavation. The analytic work supposed: osteometric measurements of the bones, identification of the bite marks types and the dietary profile from stable isotope ($\delta^{13}C$ and $\delta^{15}N$). From a taphonomic point of view, until now, our data suggest a high diversity of MIS 3 -2 species in Urșilor and Hades passages, distinguishing two type of thanatocoenoses. In Urșilor Passage the information unearthed until now, indicates a secondary thanatocoenosis denoting a reworked primary thanatocoenosis from Level 1 (Perlelor Chamber) and Level 2 (Turistică Passage), mobilized firstly by floods and secondly by runoffs and small intermittent streams that occurred above and in the vicinity of the cave (the latter is still on debate). The primary thanatocoenosis (*in situ* deposited bone assemblage) is representative for Hades Passage where we found articulated skeletons and bioglyphs (scratch marks, hibernation or gestation nests). As this passage was discovered only 20 years ago (by Hades) and it is considered to be the pristine passage of the cave, revealing outstanding bioglyphs and fossil remains, it is the main area of the cave where we can study the behavior of cave bears. Comparative, the secondary thanatocoenosis in Urșilor Passage yielded a great number of bones and bone fragments, mostly reworked material from the places mentioned above, where young bone ages (^{14}C dates) was mixed up with older sediments (OSL dates), completing the image of the bone assemblage from this cave. Furthermore, in the excavation trench in the first 60 cm we discovered a bone density of 200 bones and bone fragments / square meter. This is a very high bone density compared with other MIS 3 cave bear site (Urșilor and Oase caves). In this manner, to extract more information about the cave bear population we applied a few classical methods as: Minimum Number of Individuals (MNI), the $P_4/^4$ morphodynamic index, the mortality distribution and the carnivore impact assessment on the cave bear bones, in order to have a preliminary image of the cave bear bones assemblage. This new data from Muierilor Cave can lead us to a better understanding of the faunal association during MIS 3 in South Carpathians and also may shed light on the underlying causes of the extinction of *Ursus spelaeus (sensu lato)*.

5.9.1. Fossil population structure, mortality analysis and sex - ratio

For MNI study we measured the left and right lower canines (C_{inf}), P4 premolar and M^1 superior molar. The result of measurements for $P4^{sup}$ (left and right) helped us to identify 69 individuals, respectively 64, and for $P4_{inf}$ (left and right) have been identified 37 individuals for both sides. A large number of individuals were identified for the lower canines (C_{inf}). For left and right C_{inf} have been distinguished 72 individuals respectively 82. The highest number of individuals were found from the measurements of M^1 (left and right) with 84 individuals respectively 99. The fossil population structure was assessed using measurement of C_{inf} from which it follows that *Ursus spelaeus* (69.5%) is the dominant species followed by *Canis lupus* (19.5%) and *Crocuta crocuta spelaea* (7.6%) and with lower percentages *Vulpes vulpes* (2.5%) *and Panthera spelaea* (0.9%).

The mortality analysis, biochronology and the carnivore impact methods were applied only for cave bears from Urșilor Passage. As it follows, for mortality analysis we analysed lower M_1 (for left side MNI= 45; right side MNI= 67). The left M_1 measurements revealed a high percentage of mortality of juveniles and subadults (66.7%) from the population. The old adults and neonates have the lowest percentages (7%, 2.2% respectively). This data shows a normal mortality profile, „U" –shaped, showing an attritional death pattern, suggesting the existence of a hibernation den where the most susceptible to die while hibernating are juveniles and old/senile individuals. The nests found in Hades Passage (more than 20) support this result through the fact that there were multiple uses of the cave along MIS 3 stage, and there were more spots with hibernation nest around the cave. For right M_1 the measurements show a high percentage of juveniles and subadults (61%) from all measurements (Fig. 12). Adults have a 26.8%, suggesting a relatively high death rate while the neonates and old individuals are under-represented with only 6% for both. This mortality pattern is again a „U"- like shaped profile but with a significant death rate for the adult individuals. The „U"- like shaped profile represent a normal death pattern but with the remark that the high percentages of dead adults can suggest a violent cause of death. These causes can be related to the high presence of the carnivores among the faunal association, and the possibility that some of the cave bear were attacked while they hibernate is to be taken into account.

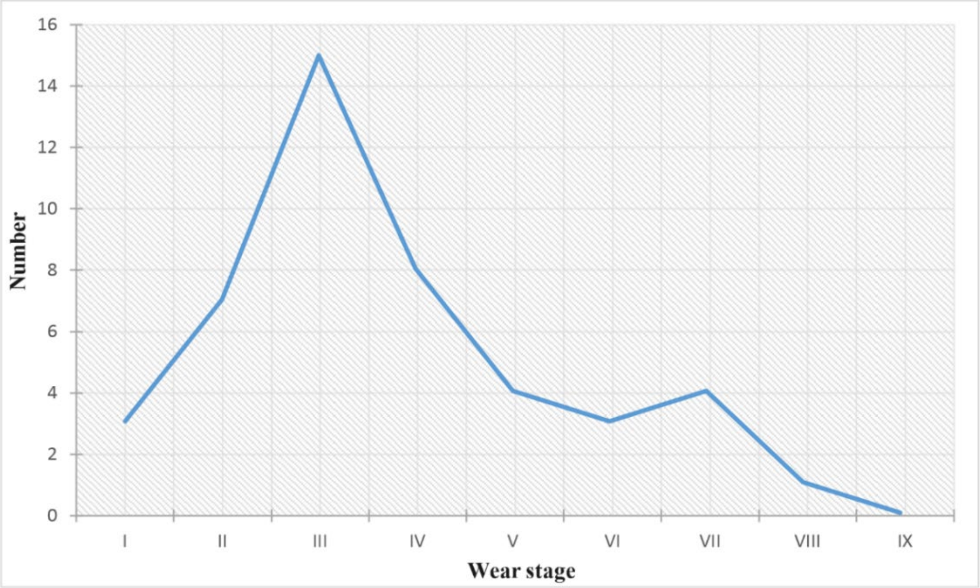

Figure 12. Mortality profile – left M_1.

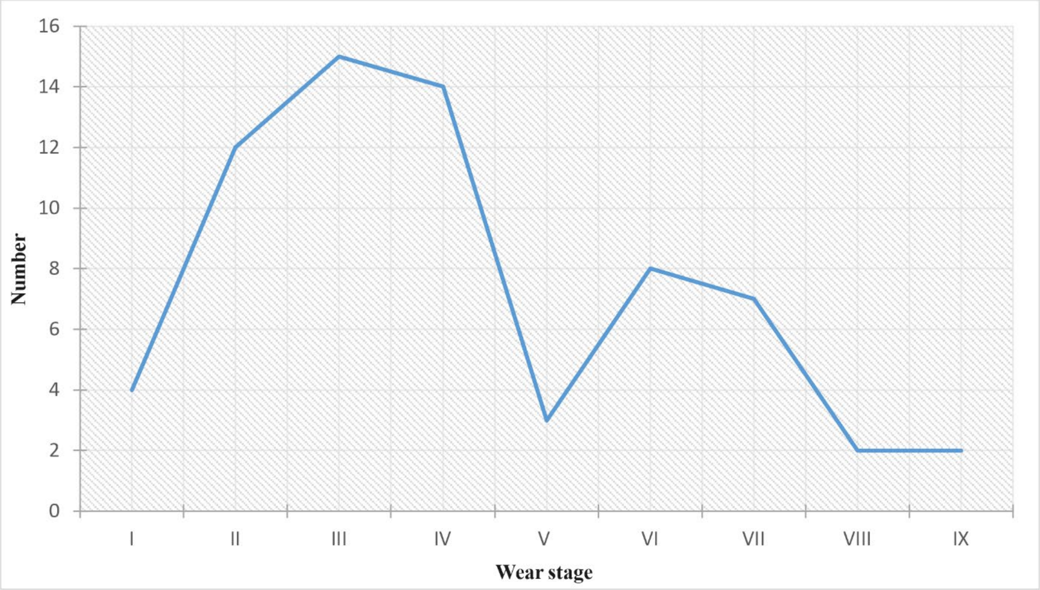

Figure 13. Mortality profile – right M_1.

For the sex ratio analysis of cave bears from Muierilor Cave we measured the lower canines (C_{inf} right). The graphic shows only the Adult Sex Ratio (ASR) as this representation can better highlight dimorphism. Total Sex Ratio (TSR) was analysed, taking into consideration all the ages of the individuals. All the measured canines have been morphologically and independently sexed. The length and width of the cave bear lower canines shows a weak differentiation between sexes. Figure 13 shows that the females significantly outnumber the males (33 females to 9 males; ASR = 3.7.1), this being a common context for most MIS 3 sites with cave bears in Romanian Carpathians (e.g. Urșilor Cave, Oase Cave). Moreover, we plotted the measurements of the length and width of the Cinf (dex) of the cave bears and the carnivorous species (Fig. 14). Pulling together the data from the mortality (M_1) and sex-ratio (M^1) analysis we can conclude that the bone assemblage from Muierilor Cave represent a common situation for MIS 3 cave bear sites from Romanian Carpathians where all the ages are represented, juveniles being the most representative among all and the obtained sex - ratio being normal.

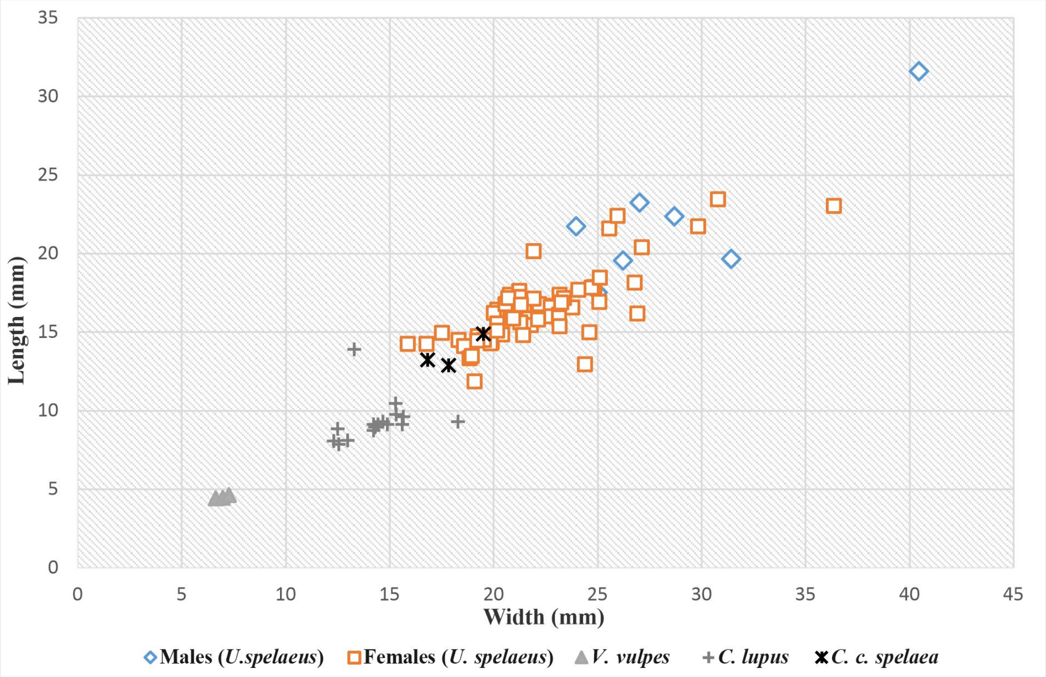

Figure 14. Bivariate plot of the length and width of the C_{inf} (dex) of the cave bears and the carnivorous species.

5.9.2. Biochronology

In order to have a better understanding of the chronology of the bone assemblage at Muierilor Cave, other than de direct dating of the cave bear bones we used the morphodynamical investigation of the lower and upper premolar 4 ($P_4/^4$), using the method developed by Rabeder and Tsoukala (1990). This method assumes the identification of the morphotypes and ordering these morphotypes in accordance with a morphodynamic scheme followed by the statistical analysis. The equation used for determination of the morphodynamic index is:

$$\frac{\textbf{MphtProduct}}{\frac{\textbf{P4}}{\textbf{4amount}}} \textbf{ x 100\%} \qquad [2]$$

Where: **MphtProduct** is the product of all P4/4 morphotypes;

P4/4amount represent the total number of P4 analyzed.

$P_4/^4$ index was standardized by Gamssulzen Cave $P_4/^4$ index, as this index (**$P_4/^4$ Gamssulzen = 225.12**) is the most used and the most representative for the cave bear population (*Ursus ingressus* for Gamssulzen site) from Upper Pleistocene. As it follows, the equation used was:

$$\frac{\textbf{P4index Muierilor}}{\textbf{P4index Gamssulzen}}\ \textbf{x 100\%} \qquad [3]$$

This analysis shows that the main morphotypes for P_4 (lower) are C2 (protoconid, paraconid, metaconid and hypoconid) and C3 (protoconid, paraconid, metaconid, hypoconid, entoconid), both morphotypes summing more than 74%. $P_4/^4$ index at Muierilor revealed a value of 237.87 suggesting a cave bear population relatively evolved with the occlusal surface of lower P_4 quite complex. For upper P^4 the main morphotype is D (protocone, metacone, hypocone, metastyle and small accessory cusps) with 66% from total. The value index is 255.22, having an evolved occlusal surface. Overall the $P_4/^4$ index calculated for the cave bears for this excavation is 245.04 and after the standardization using the date from the Gammssulzen Cave the **$P_4/^4$ value is 108.85** (Fig. 15), this placing the cave bear population from Muierilor Cave together with ^{14}C ages in MIS 3 and also it is worth pointing out that this value is one of the highest $P_4/^4$ index value among the European cave bear sites.

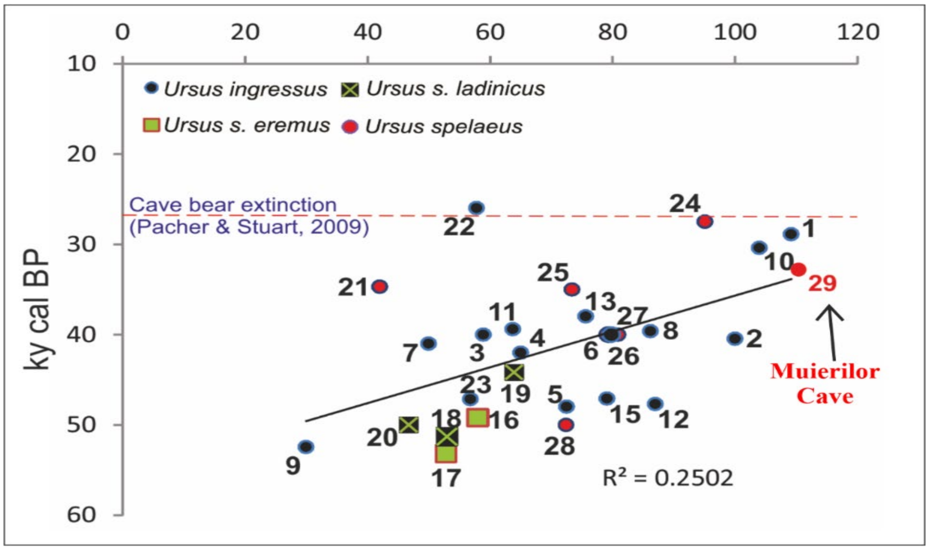

Figure 15. The representation of $P_4/^4$ index value for Muierilor cave.

5.9.3. Carnivore impact on the cave bear bones at Muierilor Cave

The carnivore impact analysis on the bones can contribute to a better knowledge on the faunal association within the fossil remains accumulation. Therefore, the study of carnivore impact on the cave bear bones at Muierilor Cave helped us to understand the dynamics of the carnivore species through the identification of these species, their behaviour and also adding information for the palaeofaunistic reconstruction. The measurements made on the carnivores' impact were conducted in order to determine which taxa are responsible for this impact and to establish the carnivorous behavior.

From this excavation, we found a great number of bones and bone fragments that were affected by carnivores. Most of the impacts were related to puncture marks and less to destruction or gnawing marks. For the study of the carnivore impacts we identified 125 bones and bones fragments belonging to *Ursus spelaeus*, (**NISP**$_{\textbf{left and right =}}$ **125**). We measured the diameter of the impacts on bones and bone fragments, both for adults and juveniles, identifying traces of punctures or perforations on both cancellous and cortical bones. To have a better understanding of this carnivore impact, we compared the measurements with the bite marks values of the modern brown bear (Europa) and hyena (Africa) and also with known values of bite mark of cave hyena. We found 279 punctures and perforations in the cancellous bones (spongy bones) and only 50 in the cortical bones. Most of the bite marks were identified on the long bones (humeri, ulnae, radii and femora) where the highest rate of punctures was found on the epiphyses, followed by vertebrae and pelvis bones.

The measurements made on the cancellous bone show (Fig. 16) that the puncture density is higher in this tissue as the carnivorous species prefer the terminal part of the long bones were the density of the bone is lower. From the morphometric analyses of the bite marks on the bone assemblage from Muierilor Cave one can distinguish that the responsible species are *Canis lupus* and *Crocuta crocuta spelaea,* but we don't exclude the fact that some of the bite mark can be assigned to *Panthera spelaea*.

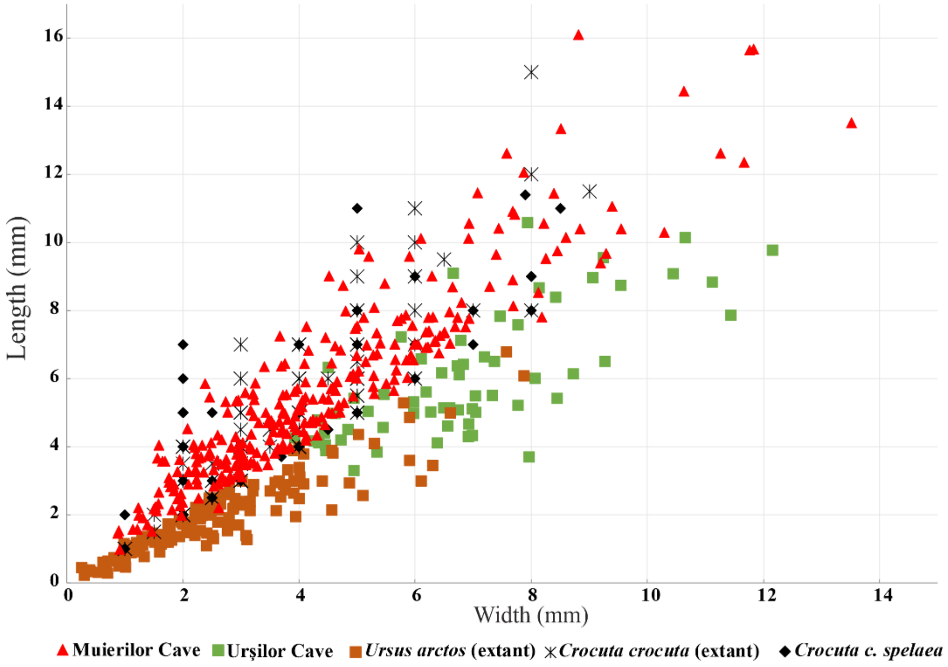

Figure 16. Bivariate plot of the length and width of the bite marks on the cancellous bone.

Regarding the cortical bones (being more dense than cancellous bones), one can determine that the pattern is rather similar with the previous, as the main species responsible for the bite marks are *Crocuta crocuta spelaea*, followed by *Canis lupus* and also, we should take into account that some of the bite marks can be assigned to *Panthera spelaea* (Fig. 17).

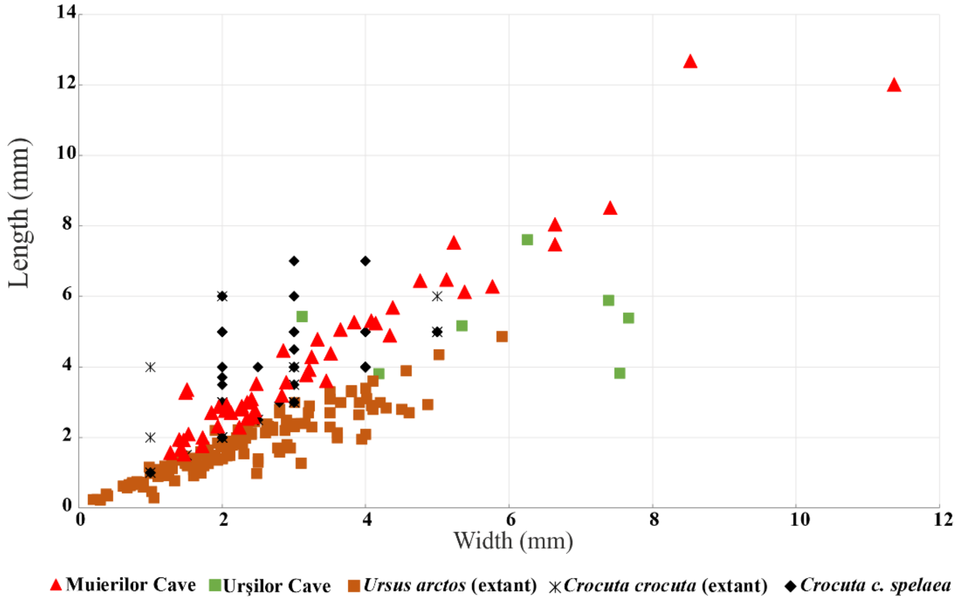

Figure 17. Bivariate plot of the length and width of the bite marks on the cortical bones.

As we analysed the punctures and perforation on the cancellous and cortical bones from the fossil deposit (Muierilor Cave) and inferred those results with the carnivorous species identified at this site, we can state that the carnivore impact was quite high at this site and the main species responsible for this impact can be *Crocuta crocuta spelaea*, *Canis lupus,* and *Panthera spelaea*. Consequently, the high number of carnivore species can show that the faunal association was diversified, highlighting that this variety was not only among carnivores, but also in particular among herbivore and omnivore species. From these data, we can conclude that in MIS 3, around Muierilor Cave we had complex habitats that could sustain a great number of carnivore, herbivore and omnivore species as well as anatomically modern humans who could benefit from these resources and the shelter provided by the cave.

5.9.4. Dietary profile ($\delta^{13}C$ and $\delta^{15}N$) for the cave bears from Muierilor Cave (preliminary results)

The dietary profile of the cave bears from Eurasia it is an extensive discussion and is still in debate. Considering the fact that some cave bear population had a flexible diet and other rather more specific, rise some question about these variations and also if these dietary ranges can be linked with their extinction. To have a correct overview on the cave bear population diet at Muierilor, we also analysed the stable isotope ($\delta^{13}C$ and $\delta^{15}N$) for carnivorous and herbivores species found in the fossil accumulation. From a total of 54 samples submitted for analyses only 44 samples showed reliable result, including 28 samples for cave bears, 15 samples for carnivorous species and 8 for herbivores species. The carnivorous and herbivorous species are clearly differentiated based on the result of $\delta^{13}C$ and $\delta^{15}N$, while the cave bears stand to have low $\delta^{15}N$ values, indicating less meat consumption. So far, we know from our data that the cave bear population at this site could be one of the last cave bear population from Europe (several ^{14}C ages are between 27 and 22.5 cal ka BP; although new dates are required to confirm), and from the fossil record we also know that during MIS 3 in this region of South Carpathian the palaeofauna was diversified (Doboș et al., 2010). These facts can help us to better understand our isotope data since a diverse palaeofauna assume more competition on resources among the species. This data could drive the cave bear population from this region to be specific about their diet. The stable isotope result (N=28) on cave bear population from Muierilor Cave show a more vegetarian diet when compared with other sites from Romania (Oase and Urșilor Cave). To understand the dietary preferences of the cave bear populations across Eurasia has been a very important, challenging and open problem for the last decades.

5.9.5. DNA preliminary results

DNA was successfully amplified from all the samples analysed, by using the following primers: CB 2558 (3R), CB 2620 (3F), CB 2670a (1F), CB 2671d (2R), CB 2718a (2F), CB 2719 (1R) as described by Hofreiter (2002). We were able to reconstruct 285bp of DNA hypervariable region I for all the samples. As this analysis are still in the experimental stage, we hope to have better result in following years that could hint to new clues regarding the genetic history of the cave bear population during MIS 3 in South Carpathians. This research on the cave bear population around the Carpathians could pinpoint to some exceptional findings. Until the discovery of new evidence, controversy rages between researches across Europe regarding the causes of the extinction of the cave bears. We made a first step by starting to look into palaeopathology of the cave bear bone and also to examine some past infectious diseases that could have occurred in cave bear population. With these new and original data, we are confident that the further studies based on our present study will come closer to better understand the life and death of the cave bear across Europe.

Chapter 6. The general evolution of Muierilor Cave system from MIS 5 to Holocene

A preliminary hypothesis of the cave system evolution in the last ca.120 ka can be developed based on the sedimentological research and dating of the various cave deposits in Muierilor Cave system. A broad scenario from the end of MIS 5 to the Holocene emerges (Fig. 18), highlighting some key-phases of cave evolution based on the chronological information obtained so far. We present these phases and associated chronology below:

MIS 5 (ca. 130-80 ka). During MIS 5 the South Carpathians were under a series of important climatic oscillations with both climatic optimum (the warm MIS 5e) with interglacial conditions and more restrictive episodes (colder and drier) with stadial conditions (like MIS 5d) (Rasmussen et al., 2014). At Muierilor Cave at the end of the MIS 5e, stalagmite PM1/1 (119 ± 5 ka) started growing on sediments in the upper level (Level 3, Melcilor Passage), suggesting that prior to this date the upper level sedimentation was over and functioned as dry passages. This stalagmite has a relatively fast-growing episodes (1.2 and 1.4 cm/ka) during this period and slow-growing phase towards the end of MIS 5 (Constantin, 2003). The PM1/1 top has a date around 90 ± 6 ka, the calcite deposition has stopped somewhere between the end of MIS 5c or at the beginning of the MIS 5b. The growing of PM1/1 stalagmite suggests that around this time the upper levels of the cave were represented by dry passages and shows that during MIS 5 the underground river was already flowing at a lower level revealing that the conditions for calcite precipitation were optimal, suggesting a period favourable for soil formation. The OSL ages, more specifically OSL3 sample (122 ± 19 ka) indicate that during the Eemian, the sediment input in the median level (Level 2) was extensive, depositing great amounts of clastic sediments, that were remobilized (between MIS 3 and MIS 2) long after their deposition, along with much younger bones. In the lower level of the cave (Level 1) the PM143 stalagmite, started to grow on top of a rock terrace between the end of MIS 5a and the beginning of MIS 4 (ca. 82 ka) suggesting that prior to this time this level of the cave indicates a modification in the water input as this stalagmite was on top of a rock terrace showing that the flow of the underground river was reduced around that time, allowing the calcite precipitation. Moreover, the underground calcite deposition depicts that at that time above the cave we had a certain vegetation pattern that allowed the soil formation and suggesting that the other impermeable formation above the limestones were long removed. At this time, the processes that depict both accumulation of clastic sediments and the formation of the speleothems indicate that the cave passages were under the influence of climatic pulses of MIS 5 with climatic optimum and more restrictive conditions, but not too restrictive for calcite deposition.

MIS 4 (ca. 80 – 60 ka). This period comprises climatic events from MIS 4 and reflect mostly a cold continental climate with low temperatures and with low evaporation (Woronko et al., 2019). From our OSL data, we know that during this period we had constant sediment input in the lower passages of the cave. At the beginning of this phase the stalagmite PM143 (found on a rock terrace of ca. 60 cm height), started to grow in the lower level of the cave (Level 1) suggesting the possibility to had a free-flowing stream at that time in this level. Moreover, the OSL ages from this level support our scenario as one of the sedimentation stages took place somewhere between ca. 56 to 74 ka, and the emplacement of those sediments it would not happen without being transported by a stream.

MIS 3 (ca. 60 – 27 ka). The MIS 3 climate was defined by abrupt warming of the climate, followed by gradual cooling (many of the major cooling episodes being related to Heinrich events) (Rasmussen et al., 2014, Staubwasser et al., 2018). From the fossil accumulation, we know that MIS 3 was one of the most dynamic periods of the cave evolution as large mammals and the first modern humans used the passages of the cave as a shelter. The data we gathered until now suggest that the water input in Level 1 was bidirectional (N to S in the early stages of passage development before the entrance to Hades collapsed, and S to N later as this passage functioned as a lateral flow for Level 2, possibly from an intermittent stream tributary for Galbenul or /and the input from another cave that could be linked with Urșilor Passage like Iedului Cave or through Perlelor Chamber). For the median level (Level 2) the only information we have on ^{14}C from the old archaeological excavations span from 46 cal ka BP (205 cm depth) to 34 cal ka BP (90 cm depth), which suggest that the sedimentation processes were active at the end of MIS 4 and the beginning of MIS 3. This hypothesis is supported by U-Th dating on our samples that are not older than 34 ka. From the clastic sediments record for this phase, the OSL ages are situated from ca. 65 to 54 ka for the PMP1 profile and from ca. 58 to 56 ka for PMP2 profile. The time span revealed by OSL ages suggest that around ca. 58 or 56 ka the sediment input into the cave system was extensive and distributed through most of the passages. The OSL ages from PMP2 test pit show a time span between 70 and 50 ka (with typical uncertainties of >10%) on a profile almost 5 meters deep, suggesting that the clastic sediments input entered the cave system relatively at the same time and having the same source. The remobilization of those sediments was triggered by multiple high and low flooding events at different time intervals as the anisotropy analyses, ^{14}C dates on bones and U-Th dates on speleothems suggests. This period was one of the most dynamic for South Carpathians and of the cave recent history as the big mammals and the first modern humans used this cave as shelter at this time suggesting a rich and dynamic environment outside the cave. Some of the speleothems from the upper and lower level of the cave are formed in this period, as from 12 speleothems chosen for U - Th dating, 5 stalagmites were dated within this interval. Moreover, most of the ^{14}C dates performed on the fossil remains are reported to belong to this time interval, this suggests that climate oscillations during this time interval were not drastically enough to prevent speleothem formation and represented by a relatively rich environment for large mammals (especially cave bears and large carnivores). The fossil deposit from this period has a great biodiversity which include cave bears, cave hyena, cave lion, wolf and herbivores (red deer, ibex, and bison) being more extensive and diversified than other fossil accumulations from Romanian caves, such as Oase Cave (Quilès et al., 2006) and Urșilor Cave (Robu et al. 2011; Constantin et al. 2014), which include almost exclusively cave bears. The presence of the large mammals in the fossil deposit as well the presence of the speleothems from this time interval suggest that at this time in Muierilor Cave existed dry passages, used by animals for shelter, hibernation and carnivore den and probably humans. Furthermore, speleothems were actively growing during this period of time in both Level 2 and Level 1 indicating that the main water input that remobilized both the clastic sediments and the fossil remains was represented by high energy flooding events.

MIS 2 (ca. 27 -14 ka). Both the LGM and the deglaciation period are comprised in this time span. During this period, we can acknowledge a decrease in mammal palaeopopulation. Also, the speleothem formation diminished during MIS 2 (e.g. Constantin et al., 2007). In this time span the deglaciation pulses were particularly intense highlighting a massive post-LGM remobilization of both sediments and MIS3-2 fossil remains. These events were fast and short events which deposited bones with an age range between 30-40 cal ka BP, suggesting that the upper levels of the cave were hydrological inactive or with a minimum intermittent flow mostly from runoffs under heavy rainfall or the activity of small streams near the cave. The main sediment and bones inputs into the cave system being related to rapid and short floods. Other archives also documented these abrupt climate changes in Europe (eg. Menot et al., 2006; Soulet et al., 2011; Sanchi et al., 2014; Gheorghiu et al., 2015), highlighting major hydro-geomorphological impact for de landscape. Furthermore, the PM146 stalagmite has a base age of 14.7 ± 0.4 ka, the stalagmite was engulfed in the first layer of the excavation (Q6 square), the top of the stalagmite being incrusted in the palaeosurface. Therefore, this stalagmite suggests that between ca. 14.7 – 8 ka, we had the one of the last inflow episodes that could be linked with deglaciation pulses (corresponding roughly to the beginning of Bølling - Allerød warming). After this events the sedimentation processes in the lower levels of the cave is over (ca. 8 ka) as the Galbenul River incised more than 40 meters of limestone from the main entrances of the cave and the major floods on the Galbenul River have not reached the upper and lower cave levels but, the last inflows in the Urșilor Passage could be linked with an intermittent stream tributary to Galbenul or / and the inflow within the Iedului Cave to this passage. This hypothesis is suggested also by the PMC1core from the main touristic passage were the base of the core has a U-Th age of 10 ± 0.2 ka. In a broader scenario, the geomorphological events that remobilized the older sediments towards the Urșilor, Hades and Electricienilor passages can be attributed to Henrich 1 and its sub-phases.

MIS 1 (<14 ka). Despite the harsher and more restrictive climate condition of the later phases of MIS 2, speleothems are more abundant as the Holocene speleothem formation was very fast and extensive, typical of post-LGM period, the same for more caves from Romania (Constantin, 2003; Constantin et al., 2004; Constantin et al., 2007, 2013; Drăguşin et al., 2014). Nine stalagmites from Muierilor Cave have base ages <15 ka, suggesting high calcite deposition and optimal climate conditions, indicating that in this phase significant hydrological events did not occur, being related to the warm and moist Bølling - Allerød interstadial. One of the most important speleothems from Level 1 is PM146 stalagmite with a base age of 14.7 ka growing on the top of the first sediment layer of the excavation in Q6 square. This sample also suggest a calm period without considerable hydrologically episodes.

6.1. The sedimentation context of the cave and taphonomic considerations of the large mammals

The reconstruction of the sedimentological context of the cave and the taphonomy of the fossil deposits led to a better understanding of the cave evolution beginning with the end of MIS 5 to Holocene. The fossil deposits in the upper and lower levels of the cave were associated in most studies with the *Ursus spelaeus* as the dominant species, but the new excavation and the newly discovered Hades Passage indicate a more balanced mix of species (carnivores, omnivores and herbivores). The nature of the fossil accumulation seems to result from both primary thanatocenosis in the Hades Passage, while a secondary thanatocenosis, is distinguishable in the Urșilor Passage as the result of the episodic floods from the upper levels of the cave and from another cave that was connected in the past with this level of the cave (Iedului Cave). The ^{14}C ages on *Ursus spelaeus* fossils depict a period of usage in Muierilor Cave between 46 to 22.5 cal ka BP, suggesting the use of this cave by the cave bears for a much longer period of time than previously thought, indicating the co-usage of the cave's many entrances/passages by large mammals and modern humans (AMH). Moreover, the young cave bear bones ages suggest that the south part of the South Carpathians could have been a place of refuge for the cave bears during MIS 3. The challenges in understanding the clastic sediments deposition from the excavation trench are related to a revers chronology based on ^{14}C ages on fossil remains as the young ages were found in the lower part of the trench and the older ones closer to the surface.

Moreover, the first two layers of the excavation were constrained by U-Th ages that were deposited sometime after 14.7 ka and before 8 ka, the main input being related to the inflows of an intermittent stream that was captured along the touristic passage and /or a possible connection with other cavities from the karst system.

The OSL dating combined with ^{14}C and U-Th dating made possible the rough estimation of the evolution of the cave system allowing us to infer the timing of some of the hydrological events that occurred in the last ca.120 ka. These events highlight both depositional and erosional episodes which hinder the interpretation of the fossil accumulation and deposition episodes of the clastic sediments. Our data suggest that the main events responsible for the accumulation of fossil remains in the lower level of the cave are the episodic floods, mostly the events from MIS 1. The OSL ages constrained the time when the clastic sediment entered the cave system, and long after the deposition in the cave passages was remobilized in multiple phases along with younger fossil remains from the upper levels of the cave. Furthermore, the OSL ages led to a better understanding of the provenance of the clastic sediments suggesting that large amounts of sediments were deposited along the Hades Passage from north to south, blocking the entrance in Hades Passage by a sediment plug and the entrance of Hades Passage collapsing sometime after ca. 35-30 cal ka BP, according to the ^{14}C ages, favoring the sealing of the passage as the pristine part of the cave. The anisotropy of the magnetic susceptibility revealed the presence of deposited sediments both in moderate current and in fast current regime with multiple sources, from the upper levels of the cave and from the former entrances as well to other tributaries streams in the lower level, the extensive clay deposits being triggered by paleofloods at different time intervals, some of them being caused by snow and ice melting during the deglaciation. Our data regarding the constrains of the deglaciation period are in accordance with the latest surface exposure dating in Parâng Mountains as Gheorghiu et al. (2015) describe the Late Glacial events. When comparing our data with other similar cave site from Romania (Urșilor, Oase and Cioclovina caves) we draw a general pattern of the cave evolution and the dynamics of the use of the cave passages at a global scale and a more complex and intriguing evolution at regional scale. Moreover, the reverse chronology of the ^{14}C ages on fossil remains in the excavation trench challenged our understanding of the cave sediment deposition suggesting the relevance of multiple proxies in reveling the palaeohydrological extreme events occurred in caves. Although the real scenario must have been more complex, the phases described here provide a better understanding of the evolution of the cave and completing previous studies, offering new opportunities to a better understanding of the palaeoenvironmental conditions in South Carpathians.

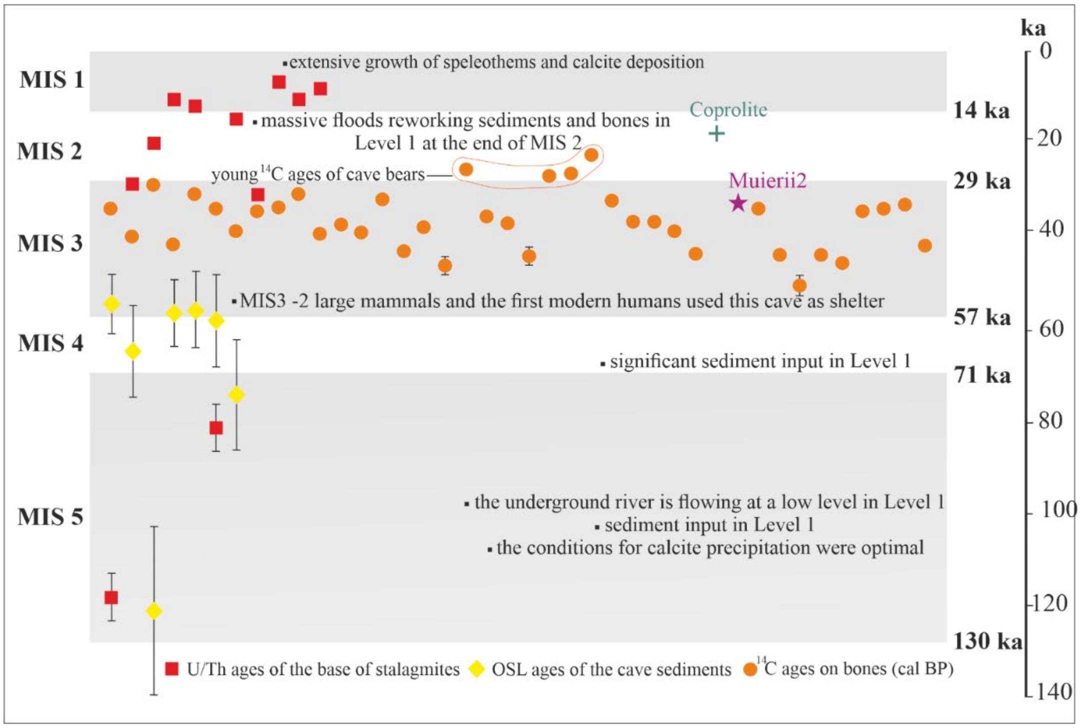

Figure 18. Age model for the radiometric and OSL samples from Muierilor Cave system.

Chapter 7. Conclusions

This research brings to light new and original data regarding the cave bears population, the flood events and the last deglaciation pulses from South Carpathians (Romania). By reconstructing the sedimentary history of Muierilor Cave system using a multidisciplinary approach we managed to put together complex information extracted from the cave deposits, resulting a comprehensive scenario, which opens the possibility for new studies. The sedimentological and geochronological work at Muierilor Cave shows that the evolution of the cave system in the last ca. 120 000 years is closely related to the regional climatic pulses from MIS 5 to Holocene, highlighting the importance of the palaeoflood events in the dynamics of cave deposits triggered by deglaciation. The data presented here, considering the OSL ages, dated speleothems, ^{14}C ages and sediment analysis, suggest that: (**1**) the clastic sediments were reworked multiple times under the influence of post-LGM paleofloods triggered by deglaciation pulses; (**2**) speleothem formation in Muierilor Cave encountered slow rates during Greenland stadials but did not cease during such cold periods; (**3**) the fossil accumulation within the cave passages is represented by a mix of species (carnivores, omnivores and herbivores) suggesting a longer interval of cohabitation and multiple use of the cave (hibernation, carnivore den) overlapping with the human presence in the region; (4) the reverse chronology in the excavation trench revealed a general pattern of cave sediments provenance from multiple sources; (**5**) the young ^{14}C ages on cave bear bones highlights the importance of South Carpathians as a refuge area for the cave bear population from Europe; (**6**) the stable isotope and osteometric analysis shed new light on the cave bear population dietary profile and the dynamics of the population. However, current sedimentological and palaeontological data from Muierilor Cave completes previous research and opens new possibilities to integrate new data into Late Pleistocene studies by a better understanding of the ecological context and inter - faunal relationships. Further analyses on the taphonomic processes and the fossil accumulation, including, osteometric measurements, stable isotopes and detailed DNA analysis together with a more precise geochronology on cave deposits and detailed sedimentological analyses, could provide more information about cave system evolution and the climatic framework of the South Carpathians. The U - dating, OSL ages and ^{14}C ages, proved to be very important for constraining the deposition of the fossil assemblage and the sediment input in Muierilor Cave passages. Therefore, in PMP1 almost at the bottom of the palaeontological excavation a ca. 22.5 cal ka BP age of a cave bear bone was recorded indicating the *terminus post - quem,* while on the top of this stratigraphic section, the stalagmite PM146 started to grow at ca. 14.7 ka, representing the *terminus ante-quem*. Despite the fact that these results help us to better understand the sedimentary history of this passage, it is hard to constrain very precisely the geomorphological events that remobilized the older infilling towards the Urșilor Passage. Nevertheless, this remobilization of the older sediments and bones should be attributed to the Henrich 1 event, with its sub - phases. Corroborating the stable isotopes data from the cave bear bones with the osteometric measurements and the preliminary information on the DNA, we can highlight a dynamic cave bear population in this region between MIS 3 and MIS 2. Moreover, bone collagen isotopic signatures (nonetheless, Muierilor has high δ^{15}N values, compared with Urșilor and Oase sites) of the cave bears from Muierilor Cave have high values that can place them close to a vegetarian diet. The phases described in our study provide a better understanding of the regional context, and complement existing knowledge on the deglaciation events in this part of the Carpathians. We assume the real scenario of the Muierilor karst system evolution must have been more complex than here described. Nonetheless, the phases highlighted here provide a better understanding of the evolution of the cave and complete the previous studies, offering new opportunities to a better understanding of the late Quaternary environmental changes in South Carpathians.

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