The Palaeontology of the cave bear bone assemblage from Urşilor Cave of Chişcău – Osteometry, Palaeoichnology, Taphonomy, and Stable Isotopes

Ph.D. thesis

MARIUS ROBU

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PREFACE

The book you're holding represents the published version of the Ph.D. thesis of Dr. Marius Robu, appointed researcher at the Department of Karst and Cave Protection, in the "Emil Racoviță" Institute of Speleology of the Romanian Academy of Sciences. He has defended his thesis – entitled "*The Palaeontology of the MIS 3 cave bear bone assemblage from the Urşilor Cave of Chişcău – Osteometry, Palaeoichnology, Taphonomy, and Stable Isotopes*" in April 2015, and I was honoured by the invite to be member in his Examination Committee. This event represented an unexpected chance to meet again my younger colleague, and to learn about his accomplishments as a researcher, long after I first met him – and I would like to recall before anything else that encounter since, I feel, it is highly relevant when it comes to truly comprehend the nature of his achievements synthesized in this book.

A little more than 10 years ago, Marius was a student at the Faculty of Geography of the University of Bucharest, and as such, he followed a short introductory course on Geology. It was then – in 2004 – that he applied to be considered as participant to our yearly summer fieldwork in the Hațeg Basin, where we were looking for and excavating something rather 'exotic' – dinosaur and other vertebrate fossils from the end of the Mesozoic Era. This was indeed a rather unexpected application, as we were usually forming our team out of Geology undergraduates, but Marius was included into the team regardless and he helped us that summer to search for dinosaur remains. Our next encounter was even more surprising and unanticipated: after finishing his undergraduate studies in 2007 and being freshly employed at the "Emil Racoviță" Institute of Speleology, he walked into my office and asked me for assistance in the form of basic information and useful references about '*taphonomy'* – a term and a field of scientific enquiry even most Geology undergrads are not usually accustomed with. We discussed shortly, and I lent him some references, then we parted, leaving me with only a vague impression that, maybe, something important was developing there. Nevertheless, it is now clear for me, after reading through, and seeing the defence of, his Ph.D. thesis, that the path of Marius as a successful researcher was already laid down at that point, and his book now stands evidence in this respect.

As starting-carrier researcher, Marius took up the idea of studying the life and death of the well-known cave bear – *Ursus spelaeus* -, the iconic large predator of the late Ice Ages whose remains are now found scattered throughout the caves of Romania. As main focus of his studies, he choose the notorious '*Peştera Urşilor*' ('*Bears Cave*'), an important cave system of the Apuseni Mountains in western Romania that contains an impressive number of well-preserved cave bear remains. The novelty of his line of attack was that he approached his research topic in an innovative, multidisciplinary way, employing and synthesizing data derived from paleontology, morphometry, taphonomy, paleoichnology and stable isotopes, combined with sedimentology and radiometric dating, in order to address questions concerning the mode of life of *Ursus spelaeus*, its conditions of death, and conditions of accumulation of its fossilized remains in the spelaean sediments of the Urşilor Cave.

The story this book tells, stemming from Marius's research, is an intriguing detective story aimed to understand how and when these prehistoric creatures lived, how they interacted with their environment and with each other, and, finally, how the circumstances of their demise can be gleaned from the way their fossils are preserved in the cave sediments. It is a sound, logical and coherent *science detective story*, the only way scientists (first of all, geologists) can understand the past, can decipher the otherwise inscrutable ebbs and flows of Life and Earth through the ages.

And to conclude, maybe it is also significant that this story is told, with a mix of elegancy and rigorous scientific consistency, by a Geography bachelor who wrote a Geology-themed thesis to receive a Ph.D. degree in Biology. This is a clear testimony that delving into the Deep Past of the Earth and understanding it had truly become possible only through interdisciplinary approaches. It is also a testimony that Marius has succeeded in his self-appointed quest to conduct such an interdisciplinary research; hence, the birth of this book, and of the plethora of scientific papers that will surely succeed it. Enjoy reading it!

december 2015

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The present study represents the collaborative effort of an entire team from the "Emil Racoviță" Institute of Speleology (ERIS) over the last seven years. I feel indebted to several colleagues and I wish to express my gratitude to them for helping me throughout my work on this thesis.

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I would like to thank as well the volunteers from the Faculty of Geography of Bucharest University, for helping me with the conservation, labeling, and measuring of the bones from the palaeontological excavation: **Roxana Constantin**, **Alina Diaconu**, **Beatrice Barbu**, **Irina Năstase**, **Alexandra Hristea**, **Cristian Țepurică** şi **Teodora Badea**.

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ABBREVIATIONS

- „0”-datum = the reference point for the palaeontological excavation
- ^{14}C AMS = Radiocarbon Accelerator Mass Spectrometry
- ASR = Adult Sex Ratio
- C = Clasticiy Index
- C_{inf} = lower canine
- C_{sup} = upper canine
- DAP prox = proximal height
- DT prox = proximal breadth
- ESV = Estimated Settling Velocity
- Hp = the depth of the main paw pad
- HSPF-PP = the depth between the main paw pad and the fingers.
- I_1 = lower first incisor
- I^1 = upper first incisor
- Ip = Index of Plumpness
- ISD = Index of Skeletal Disjunction
- ka = kiloannum
- L = length
- L1 = Level 1 from the palaeontological excavation
- Lf = the length between the fingers (1→5)
- LGM = Late Glacial Maximum
- lp = the breadth of the main paw pad
- Lp = the length of the main paw pad
- LS = Living Structure
- Lt = the total length; it refers to the length of the footprint (when slid down)
- LTL = CEDAD laboratory
- ltp = the total breadth of the main paw pad (when slid down)
- Ltp = the total length of the main paw pad (when slid down)
- M_1 = lower first molar
- M^1 = upper first molar
- MAU = Minimum Number of Animal Units
- Md = grain size median
- MDi = Minimum Distance between each anatomically refit pair (i)
- MIS 3 = Marine Isotope Stage 3

- MNI = Minimum Number of Individuals
- Mo1 = diameter
- Mz_i = mean
- NISP = Number of Identified Specimens
- NNVA = Normal Non-Violent Attritional Assemblage
- ORAU = Oxford Radiocarbon Accelerator Unit
- OSL = Optically Stimulated Luminescence
- P_4 = lower fourth premolar
- P^4 = upper fourth premolar
- POZ = Poznan laboratory
- PU1 = code for the alluvial sections
- PU10-2 = code for sampled speleothems
- SD = Standard Deviation
- Sk_i = Skewness
- TSR = Total Sex Ratio
- U/Th = Uranium/Thorium
- Urşilor = Urşilor Cave
- U-Series = Uranium Series
- VERA = Vienna Environmental Research Accelerator
- VPDB = Vienna Pee Dee Belemnite
- σ_i = sediment sorting

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INTRODUCTION

In recent decades, many palaeoenvironmental and paleoclimatic studies have been based on cave deposits (Ford and Williams, 2007; White, 2007). Currently, speleothems are considered one of the most reliable sources of data for paleoclimate reconstruction from caves (Fairchild and Baker, 2012), whereas the fluviatile (or lacustrine) sediments from caves represent other useful tools for recording paleohydraulic regimes and climate (Sasowsky and Mylroie, 2004).

With regards to the associations of fossil remains, the micromammals have long been considered as a useful a paleoclimate proxy (Belmaker and Hovers, 2011) and, recently, even the invertebrate fossil associations from karst settings have been used as palaeoenvironmental proxies (Moldovan et al., 2012).

The use of the direct and indirect dating methodologies (e.g. Grün, 2006; Couchoud, 2006; Berger et al., 2008) allowed for a better interpretation of both the timing and the palaeoenvironmental significance of large fossil accumulations and/or archaeological sites. However, especially in deep-cave settings, the correct understanding of the evolution of the given cave system is a key requirement for understanding the taphonomy of paleontological deposits. Moreover, the understanding of a cave system's evolution is possible only when a wide range of cave archives are studied from an interdisciplinary point of view (Constantin et al., 2014).

Excepting some studies (*e.g.* Constantin, 2003; Petculescu and Murariu, 2009; Haüselmann et al., 2010), the majority of papers on the evolution of karst systems from the Romanian Carpathians are based only on stratigraphic and geomorphological records. Although Urşilor Cave (= Urşilor) is no exception, there were earlier attempts to reconstruct the evolution of the cave and the depositional mechanisms and chronology of it (Hadnagy, 1977; Terzea, 1978; 1989; Vălenaş, 1979; Jurcsák et al., 1981), relying mostly on the analysis of the mineralogy of sediments, on cave morphology, and on palaeontological records – taphonomy, ichnology, and osteometry.

Our study integrates the relevant cave deposits (clastic sediments, speleothems, and fossil bones) which were directly or indirectly dated by means of optically stimulated luminescence (OSL), U-series, and radiocarbon dating. It also integrates new, detailed, geomorphological and topographical surveys of the cave that are relevant for improving the speleogenetic scenario. The aim of the study was to provide a solid chronological, hydrogeological, and palaeoevolutionary basis for both the taphonomic interpretation of the massive fossil accumulation from the Scientific Reserve and to establish a chronological and evolutionary framework for Urşilor in the last ~300,000 years.

Osteometry

The measurements performed on the cave bear bones from the palaeontological excavation within the Scientific Reserve have been compared with those obtained from Oase Cave (= Oase), in which a cave bear population lived between >46,000 and 38,450 yrs cal BP (Higham and Wild, 2013). As the cave bear population from Oase has been attributed to the east-European branch of the *Ursus ingressus* Rabeder et al., 2004 (Stiller and Hofreiter, 2013), we do not exclude a similar possibility for Urşilor, since the thanatocoenosis from the Scientific Reserve has a similar age (47 – 40 ka cal BP) and, therefore, they may have been contemporaneous. Moreover, two other *U. ingressus* cave sites, Gammsulzen and Potočka Zijalka, have been added to this osteometric comparison.

Taphonomy

According to Efremov (1940) taphonomy is the science of the laws of embedding or burial. More completely, it is the study of the transition, in all details, of the organics from the biosphere into the lithosphere or geological records.

Caves are among the best terrestrial archives which can provide valuable information regarding the chronology and the palaeoecology of Quaternary fossil and extant populations (Constantin et al., 2014). As such, the study of the fossil vertebrate remains found in caves is crucial in order to reconstruct changing environments and climates, to study the anatomy of extinct animals, to infer their ethology, and to assess the composition and the size variability of fossil vertebrate communities. Therefore, the context in which bones occur is important for assessing the significance of finds. Strictly speaking, the analysis of the context in which a thanatocoenosis „forms and evolves”, is the main goal of *cave taphonomy*.

As caves are very complex depositional settings, vertebrate bones are found in many different contexts - generally, they can be split into two large categories: surface occurrences (bones found unburied on the cave floor, in cave streams or on ledges) and occurences within sediments (fossil remains buried by sediment).

Vertebrate remains occurring in caves on various surfaces can be of palaeontological relevance, but very often their importance is hardly assessed since the surface material might not be of the same age throughout a cave. On the other hand, bones occur within cave sediments in a great range of possible settings. Toomey (1994) has summarized the most common occurrence types: within talus cones or talus piles associated with entrances, cave fluvial deposits or guano, buried by colluvial material washed into the cave, and encased in speleothems. As caves are often very complex depositional settings, more than one type of context can occur within a single deposit and therefore it is frequently difficult to point out how and when the sedimentary units formed. Even so, the presence of bones embedded within sediments is more palaeontologically relevant than the surface occurences, since the bones covered by sediments are easier to set apart by age, at least in broad terms. This is of great interest when the bones are used for studying palaeoecological changes in fossil species and environmental fluctuations over the time.

For this reason, a comprehensive tapho-demographic approach was used, in order to detect the palaeobiological characteristics of *Ursus spelaeus'* (Rosenmüller and Heinroth, 1794) thanatocoenosis from the palaeontological excavation within Urşilor and to compare the results with the data gathered from other European cave bear sites.

Palaeoichnology

Palaeoichnology studies the biogenic structures generated by the fossil species (also called *"life traces", bioglyphs* or *palaeoichnofabrics*). For a long time, the study of the bioglyphs has been focused on Mesozoic megafauna. The „life traces" of the fossil vertebrates reflect the local sedimentary conditions from the time when they were made, but, on the other hand, they can provide valuable information about the behaviour of animals and their way of locomoting.

The close link between the sedimentary features and the footprint morphology has recently become a topic for debate, as more and more palaeoichnological evidence have been investigated (Allen, 1997; Gatesy et al., 1999; Nadon, 2001; Fornos et al., 2002; Mazin et al., 2003; Milan and Bromely, 2006).

Over the last five decades, the progress of the cave explorations has led to the discovery of many *U. spelaeus* sites, although only a small percentage of caves contain bioglyphs. The palaeoichnology of *U. spelaeus* includes quantitative and qualitative analyses of the cave deposits, marked by bioglyphs generated *by locomotion* – autopod imprints (anterior or posterior limbs), fur impressions, scratch marks (claws marks made on walls, cave floors and terrace slopes) and *by habitation* (hibernation or gestation nests, nest scratch marks).

The palaeoichnofabrics generated by the cave bears have been found only in subterranean environments, their preservation being a time constant consequence of the microclimatic parameters (air temperature and humidity, the lack of ventilation) and of reduced microbiological activity. As bioglyphs have generally been formed on fine, very moist sediments, they can be preserved in exceptional environmental conditions. The disturbance of a single parameter may lead to the irremediable degradation of these features.

The quantitative and qualitative study of cave bear "life traces" may provide important information regarding the paleobiology of this extinct species at the end of the MIS 3, and may fill in the palaeoclimate picture of a time when a major part of the Upper Pleistocene megafauna vanished.

Although vertebrate palaeoichnofabrics have been identified in caves for a long time (Breuil, 1908), only a few studies have been performed on this kind of palaeobiological archive. Most of these investigations have followed a general approach, touching on the subject of the wall scratch marks, in order to document the presence of the cave bears (Lemozi, 1929; Koby, 1953) or to morphologically compare the human and Ursidae-related bioglyphs (Bednarik, 1994).

The scientific literature rarely mentions paleoichnological studies dealing with Quaternary mammal "life traces", despite the fact that the first descriptions of these forms date back to the beginning of 20th century in Abel (1931). Although it has a long history, cave bear bioglyph studies have not been thoroughly undertaken, either due to their rare occurrence within the *U. spelaeus* sites across Europe or because their study has been considered devoid of the possibility of interconnection with other disciplines of palaeontology.

Nonetheless, over the last five decades, there has been some progress in the study of the cave bear biogenic structures identified within European sites (Viehmann et al., 1968; Viehmann, 1973, 1987; Jurcsák et al., 1981; Bednarick, 1994; Garcia, 2005; Fosse et al., 2006; Rosendahl and Döppes, 2006), although the majority of studies have been focused on two main mountain ranges - the Carpathians and the Pyrenees.

The reconstruction of cave bear palaeobiology requires the study of the bone material and of the biogenic structures discovered within the hibernation sites. Footprints, nests, access pathways on paleosurfaces (areas periodically crossed by cave bears), alongside wall scratch marks, have been identified in several caves, but still they have not been studied enough. These bioglyphs are well represented in the Carpathians and the Pyrenees, as a result of both the geographic location of the sites containing tracks of the cave bears activities (at low or medium altitude, between 500-1000 m a.s.l.) and of the fact that the Upper Pleistocene and the Holocene climate changes seem to have affected the „life traces" from these caves less than in alpine areas (Fosse et al., 2004).

Bioglyph types:

Cave bear fossil remains largely occur within Romania, while its „life traces" are sporadic. The following cave bear bioglyphs have been found in caves: (1) polished rocks („*Bärenschliffe*"), (2) hibernation (or/and gestation) nests, (3) scratch marks, (4) footprints, and (5) fur impressions.

(1) *Polished surfaces* (= *Bärenschliffe*) represent smooth and sometimes even bright rock surfaces, formed as a result of the bears' movement, by the rubbing of their fur along the walls. These surfaces can be found not only in the narrow passageways, where bears would have inevitably touched the walls, but also in corners and on big blocks in chambers or large passages. The first reference of a polished rock surface has been ascribed to the Austrian explorer Erzherzog Rainer, who described these features in 1806 from Mixnitz Cave (Abel, 1931). The *Bärenschliffe* term was coined in 1826 by the geologist Johann Jacob Nöggerath (Nöggerath, 1826), after the observations he made in Alte-Höhle Cave from Northrhine-Westfalia, Germany.

(2) *Hibernation or gestation nests* are negative, elliptical features, with a diameter between 50 cm and 3 m, and depths of' a certain number of cm. These are interpreted as bioglyphs made by *U. spelaeus* (rarely also by *U. arctos* Linnaeus, 1758) for hibernation (in the case of adult or juvenile males) or gestation (in the case of females).

(3) *Scratch marks* (groups of 3, 4, or 5 individual scratches) - show the bears' habit of sharpening their claws by rubbing them on either rough (Rosendhal and Döeppes, 2006) or soft surfaces (limestone walls or clay surfaces); typical for carnivores with claws, this cave bear habit remains a debated issue. The analysis of the scratch marks is one of the most important sources of information for cave bear ethology, due to both their morphological complexity and diversity, and their location within a cave.

(4) *Footprints* are generated by the transit of cave bears on sediment surfaces that allow their imprint and conservation. This results in autopod footprints of anterior or posterior limbs.

(5) *Fur impressions* have recently been brought to the attention of reseachers as a result of the study performed in Urşilor; they are a result of cave bear transit through narrow, clay coated passageways. These are, probably, the most ephemeral cave bear bioglyphs, due to their very small size, and they may be easily destroyed.

For the Romanian karst, there are only a few cave sites that have been studied paleoichnologically: Urşilor - with an inventory and measurements of the cave bear nests (Jurcsák et al., 1981), Şălitrari Cave (Lascu, 2000; Lascu and Puşcaş, 2002) - with a description of wall scratch marks and hibernation nests with an emphasis on *U. spelaeus* ethology; Peştera cu Oase (Quilès et al., 2006) - with a documentation of the cave bear bioglyphs and measurements on the nests; Ciur-Izbuc Cave (Webb et al., 2014) – with concise morphological descriptions and measurements of the footprints left by *Homo sapiens* and *U. spelaeus*.

Although there is a classification of the cave bear bioglyphs found within the Romanian karst (Viehmann, 1973, 1987), it is rather inconsistent, since it has been built using multiple criteria (*e.g.* ichnology, taphonomy, osteo-morphology). Therefore, a re-assessment of the palaeoichnology of cave bears is needed strictly based on palaeoichnological principles and on knowledge of the ecology of similar extant species (*e.g. Ursus arctos*, *Ursus americanus,* Pallas, 1780).

Urşilor hosts one of the most complete ranges of cave bear bioglyphs among the European cave sites - scratch marks, hibernation nests, footprints, fur imprints, etc. Although new caves bearing cave bear "life traces" are discovered every year, there are few sites systematically analyzed from an ichnological point of view in Romania and abroad. Moreover, in the light of new technnological possibilities and an understanding of the implications of such rare features (in order to comprehend the ethology of this fossil species), an assessment of cave bear ichnofabrics found within this site was needed.

Stable isotopes analysis

The diet of cave bears was first assessed by Kurtén (1976), based on the dental morphology, mandibular ecomorphology and dental wear gradients analysis, and he concluded that they had a primarily vegetarian diet. This has raised the issue as to how a large ursid could live in a cold temperate to subarctic enviromnent without a minimal amount of animal protein, fat, and other nutrients. Therefore, alternative methods like stable isotopes, quantitative ecomorphology and dental microwear analysis have been used, in order to assess the cave bear diet.

Stable isotope ($\delta^{13}C$ and $\delta^{15}N$) analysis performed on bone collagen was recognized as the most reliable tool in determining the trophic level of the animals, and was applied to research on the Upper Pleistocene palaeofauna, including cave bears (*e.g.*, Bocherens et al. 1994, 1997, 2006, 2011a; Nelson et al. 1998; Vila-Taboada et al. 1999).

$\delta^{13}C$ variation recorded in the bone collagen of palaeofauna from the Late Pleistocene of Europe reflects paleoecological differences (Hedges et al. 2004) and variable access to marine resources (Pettitt et al. 2003; Mowat and Heard 2006). Collagen carbon isotope composition indicates a wide range of trophic enrichment with increasing trophic levels (1‰–7‰) (Bocherens and Drucker, 2003; Froehle et al., 2010).

The $\delta^{15}N$ of the bone collagen (and most other tissues) is ^{15}N enriched by ~3‰ to ~5‰ relative to the dietary protein (Minagawa and Wada, 1984; Schoeninger and DeNiro, 1984; Schwarcz and Schoeninger, 1991; Jenkins et al., 2001; Bocherens and Drucker, 2003; Robbins et al. 2005; Hedges and Reynard, 2007; Florin et al., 2011) and reflects the mean trophic level of the mammal's protein sources.

Together with the assessment of the dietary range of the extinct Late Pleistocene cave bear, the implications of the extinction of these mammals prior to the last glacial maximum (Pacher and Stuart, 2009) was also investigated. The results of the stable isotope analyses of the MIS 3 cave bear bone collagen from European cave sites has split the scientific community into two groups: those that argue for a vegetarian diet (Bocherens et al. 1994, 1997, 2006, 2011a, 2011b; Nelson et al. 1998; Vila-Taboada et al. 1999; Fernandez-Mosquera et al. 2001; Munzel et al. 2011) and those that contend cave bears had a more flexible (omnivorous) diet (Hilderbrand et al., 1996; Richards et al. 2008a; Trinkaus and Richards, 2013).

The diet of the MIS 3 cave bears from the Romanian Carpathians has been assessed (Richards et al., 2008; Doboş et al., 2010; Trinkaus and Richards, 2013) based on an analysis of cave bear collagen samples from Oase, Cioclovina and Muierilor caves. The $\delta^{13}C$ and $\delta^{15}N$ isotopic profiles indicate a more flexible palaeodiet for the MIS 3 cave bears than previously assumed for cave bears from central and western European sites.

This study presents the results of the stable isotope ($\delta^{13}C$ and $\delta^{15}N$) analyses obtained from cave bear bone collagen from Urşilor, representing the diet of its *U. spelaeus* population. Previously, based on the analysis of cave bear dental features, Jurcsák et al. (1981) concluded they had a vegetarian diet.