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Radiocarbon dating and palaeoproteomic analysis from the archaeological site of Ruzina Pecina, a late Middle to Later Palaeolithic site in Bosnia and Herzegovina

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1.0 Abstract (German)

Die Fundstätte Ruzina Pecina in Bosnien und Herzegowina gehört zum Paläolithikum. Dort konnten wissenschaftlich Moustérien- und Levallois-Technologien sowie ein Aurignacien-Werkzeug-Komplex nachgewiesen werden, die über 50.000 Jahre alt sind. Dies galt über 40 Jahre lang. In den 1990er Jahren war die wissenschaftliche Forschung in Bosnien und Herzegowina noch nicht sehr weit entwickelt, und Wissenschaftler verwendeten veraltete Methoden zur Beschreibung der Funde aus paläolithischen Fundstätten in dieser Balkanregion. Diese Vorgehensweise führte zu vielen ungelösten Fragen und problematischen Situationen ohne klare Antworten und eindeutige Ergebnisse. Die größten Unklarheiten betrafen die Chronologie der ausgegrabenen Schichten. Damals war die Beschreibung des gefundenen paläolithischen Werkzeug-Komplexes die einzige Möglichkeit, die Besiedlung Dauer der Fundstätte zu bestimmen. Leider wurde die Fundstätte Ruzina Pecina fast 40 Jahre lang als deutlich ältere Stätte angesehen, die in die Zeit der Neandertaler datiert wurde. Die Anwesenheit von Neandertalern in einer Region ist von großer Bedeutung, muss aber mit wissenschaftlichen Methoden überprüft werden. Diese Dissertation lieferte die ersten Belege für die Fundstätte mit hilfe moderner Technologien wie der Radiokohlenstoffdatierung, der Zooarchäologie mittels Massenspektrometrie (ZooMS) und der Isotopenanalyse. Durch diese Arbeit konnte ich zeigen, dass Ruzina Pecina deutlich jünger ist als bisher angenommen, eher in die Epigravettien-Phase der europäischen Vorgeschichte fällt und überhaupt keine Neandertaler-Fundstätte ist. Die Ergebnisse deuten stattdessen darauf hin, dass Ruzina Pecina in die späte Gravettien-, frühe Epigravettien- und Spätglazial Maximum-Periode (SMP) fällt und den Zeitraum von 26.900 bis 19.515 cal BP umfasst. Die ZooMS-Methoden zeigten eine starke Präsenz von Rothirschen. Isotopenanalysen deuten darauf hin, dass sich diese Tiere von einer Paleo-Diät ernährten, die auf nährstoffarmen Gehölzen basierte, während offener lebende Arten (wie der Auerochse) an relativ nährstoffreiche Gräser angepasst waren. Ich fand auch Hinweise auf einen Rotfuchs mit einer charakteristischen fleischfressenden Paleo-Diät, die wahrscheinlich Tiere wie Nagetiere und einige größere Säugetiere umfasste. Die Knochen von *Homo sapiens* stammen von Neugeborenen mit erhöhten Stickstoffisotopenwerten, die wahrscheinlich auf das Stillen zurückzuführen sind, aber ebenfalls in die Neuzeit (weniger als 200 Jahre) datiert wurden. Zusammengenommen zeigen diese Ergebnisse, dass die Fundstätte Ruzina Pecina eine der wichtigsten jungpaläolithischen Fundstätten in Bosnien und Herzegowina darstellt und in eine Periode von großer Bedeutung fällt. Sie wirft ein neues Licht darauf, wie sich Gruppen von Menschen vor 26.000 bis 19.000 Jahren an gefährliche Klima- und Umwelteinflüsse angepassten.

2.0 Abstract (English)

The Ruzina Pecina site from Bosnia and Herzegovina belongs to the Paleolithic period where, scientifically we could see presence of the Mousterian and the Levallois technology and presence of the Aurignacian tool complex which are over 50,000 years old and more. That was believed for over 40 years. During the 1990`s scientific research in Bosnia and Herzegovina was not too much developed and scientists were using old fashioned ways to describe the findings from the Paleolithic sites in that region of Balkans.

That way of scientific work brought a lot of unresolved questions and problematic situations without clear answers and without clear results. The most unresolved situations concerned the chronology of the excavated layers, and at the time the description of the Paleolithic tool complex recovered was the only way to estimate the period of occupation at the site. Unfortunately, for almost 40 years the site Ruzina Pecina has been seen as much older site, dating to the time when Neanderthals were present. The presence of Neanderthals in any region is of great importance, but needs to be tested using scientific methods. This dissertation produced the first evidence for the site based around modern technology like radiocarbon dating, Zooarchaeology by Mass Spectrometry (ZooMS) and isotopic analysis. Through this work I managed to show that the Ruzina Pecina dates much more recently than previously suspected, more in the Epigravettian phase of European prehistory, and is not a Neanderthal site at all.The results suggested instead that Ruzina Pecina dates to the Late Gravettian, Early Epigravettian and Late Glacial Maximum (LGM) period covering 26,900 - 19,515 cal BP.

ZooMS methods showed the strong presence of red deer. Isotope evidence suggested that these animals subsisted on a paleodiet based around depleted woody shrubs, whilst more open dwelling species (such as aurochs) were adapted to relatively enriched grasses. I also found evidence for a red fox, with a characteristic carnivorous paleodiet probably including animals such as rodents and some larger mammals. The bones from *Homo sapiens* were neonates with elevated nitrogen isotope levels probably due to breastfeeding, but also dated to the modern period (<200 years). Taken together, these results show that Ruzina Pecina site represents one of the most important later Paleolithic sites in Bosnia and Herzegovina fitting within a period of great importance and shedding new light on the means by which groups of humans adapted to deleterious climate and environmental influences 26,000-19,000 years ago.

Table of Contents

4.0 Introduction

The Balkans are a key region in discussing the movement of humans during phases of prehistory such as the Neolithic or Palaeolithic. The region lies directly in the path by which humans must have traversed from east to west, south to north through Balkan Peninsula. The Balkan Peninsula is bordered by the Alps in the west and the Sava and Danube Rivers in north bordering Central Europe. To the south and the east, the peninsula is bordered by the Aegean Sea, the Sea of Marmara and the Black Sea. The Dardanelles Strait separates Asia and Europe forming a land bridge between two continents at lower sea- levels during the Pleistocene glaciations (Roksandic et al., 2023).

The Balkan Peninsula route represents animal and human migrations from the Levant into Europe during colder phases of the Early Pleistocene, making that region an integral part of the Balkan refugium during Late Glacial Maximum (LGM). The presence of Neanderthals in Croatia and Greece leaves a very important clue for ongoing research of Neanderthal settlements in the Central Balkans, as researched by Roksandic (2016). Sadly, there are few archaeological sites that date to the period of the Middle to Upper Palaeolithic transition; when early Homo sapiens replaced the resident Neanderthals who had occupied Europe and western Eurasia for more than 250,000 years. Recent research suggests that the roots of this dramatic population replacement can be traced far back to events with the appearance of distinctively modern human remains and artefacts who are present from 40,000 years ago

(Mellars, 2004), not only in Asia and Europe, but in the Balkans. The European coast of the Mediterranean route together with North Eastern Italy, Northern Spain and the Balkans are known for Archaic or Protoaurignician industries, as well as the classic Aurignacian followed in term by Gravettian, Epigravettian and Neolithic industries leaving a useful record of the period covering the dispersal of Neanderthals and their replacement with anatomically modern humans (AMH), up to more recent phases of prehistory.

Some researchers suggest that Balkan Neanderthals from Croatia (Vindija Cave) were the youngest of their kind according to radiocarbon dating. However, more recent reliable radiocarbon dating of hydroxyproline, shows that these dates were underestimated and that the real age of these Neanderthals is ~45,000 cal BP (Devièse et al., 2017). Neanderthals in Bulgaria (Bacho Kiro Cave and Temnata) were replaced before 45,820–43,650 cal years ago according to Fewlass et al. (2020), when the earliest AMH appeared.

Sommer et al (2006) have suggested that the best way to reconstruct the glacial refugia of animals and humans is through fossil records and genetic data. Unfortunately, my project is based only on fossil records of mammals and humans and not on genetic data, but this will be discussed later in a project.

Paleodemographic estimations show dispersal of hominins towards the transition from the Middle to Upper Palaeolithic, with population sizes ranging between 25,000-200,000 Neanderthal individuals and 1738-28,359 Homo sapiens individuals in the Aurignacian and later Gravettian (44-25ka) period. Metapopulation size was estimated through the size and number of known archaeological sites and their connection with paleoclimatic records and evidence for pollen and vegetation changes. This shows a relative population size in Europe of 0,2 people per 100km 2 (Davis et al . 2014).

During the LGM period (25-20 ka) and (23,5-17ka), metapopulation size of Homo sapiens in Western and Eastern Europe estimates between 1400 and 6300 persons at the time due to colder and drier conditions. Some parts of Europe, such as Spain, are estimated to have the largest population in Europe, between 750-3600 persons in the settlement areas, which represents a decrease in population at that time in the Epigravettian period. Maier et al (2016) show a decrease of population in the Epigravettian period in comparison to Gravettian and Aurignacian period. One of the reasons for the decline in Homo sapiens populations in the LGM period was probably the reduction of species diversity which resulted in significant demographic changes in human population (Morin, 2008).

During the Pleistocene period (2,6 million years BP- 11,700 years BP) extreme climatic and environmental changes occurred, caused by repeated cycles of warm and cold stages which continuously impacted not only *Homo sapiens* but also other species such as red deer (*Cervus elaphus*) and red fox (*Vulpes vulpes*). In the LGM period (27,000-24,000 cal. yr BP) red deer were restricted to Iberia, South-Western Asia, Italy and the Balkans, during at the end of the LGM red deer expanded to Central and Northern Europe. Due to broad climatic tolerances, red deer survived during this period (Meiri et al., 2013). One of the most widely distributed carnivores in the world is red fox (*Vulpes vulpes*) whose dispersal reached across Asia, North America and Europe 300-10ka. Like with red deer, red fox has high mobility and adaptability to different habitats and climates. The European fossil record shows the large influence of *Homo sapiens* on red fox dispersal and their postglacial demographic growth, where male red foxes disperse more than females (Kutschera et al., 2013).

Lahr et al. (2003) have suggested that initial *Homo sapiens* colonisation of Europe was in a warmer period in Marine Oxygen Isotope Stage 4 (50-46 ka BP), the most prolonged phase of climatic stability and later during a colder phase 2 (30-26 ka BP). The climate records used are based on fluctuations in the stable isotope of oxygen (δ 18 O) derived from marine cores. Part of phase MOIS3 (45-40 ka BP) was characterized with a greatest level of climatic instability.

Around 25,000 BP, a major phase of climatic deterioration occurred which we call the Last Glacial Maximum or LGM, as mentioned earlier. Between 20,000 and 18,000 BP, ocean surface temperatures were at their minimum and continental ice sheets reached their greatest extent. Northern and central Europe in that time experienced very low average temperatures, long winters, permafrost formation, and high winds. For humans the habitation places were increasingly harsh, characterized by a decreasing abundance and diversity of plants and animals. Northwestern Europe was described as a polar desert between 25,000 and 14,000 BP, where fauna and flora decreased their productivity between 95% and 90% from the early glacial to the glacial maximum period (Milisauskas, 2011).

Southern Europe was much less affected by these climatic changes and many species of plants and animals persisted during the LGM in places like Italy, Spain, Greece and Balkans, which made Southeastern Europe more productive and attractive than northern and Central Europe in that time. These environmental changes had an impact on demographic changes as well, which showed evidence of continuous occupation throughout the glacial maximum in Southeastern Europe, while large areas of northern and central Europe were abandoned and used sporadically by populations on a seasonal basis. Milisauskas (2011) has outlined what the demographic response of humans was in this part of Europe to the LGM.

In the Balkans, many archaeological sites date to between 29 to 12 ka BP (Hughes et al., 2013), spanning the earlier part of the LGM, defined globally by peaks in sea-level, marine oxygen isotope records and defined as the MOIS2 period with cooler and drier climates and low temperatures that resulted the significant reduction in human population in Europe up to 60%.

Using solar insolation data Maier et al. (2020) were able to reconstruct regional climate models in Europe not only during the LGM but also during the period between 42-15 ka. The point of their research was how much solar energy can be generated up during one year and how populations of humans and animals depend on this, and what are the differences in demographic developments in this region during all five stages of the Paleolithic period.

The Aurignacian period (42-33 ka cal BP) was the time when the first AMH spread into Central and Western Europe with an estimated mean population size 1,500-1,800 persons in core areas, followed by increase of solar insolation during growing season, with sizeable increases in population size in that period. In the period from (33-29 ka cal BP), the Early Gravettian demographic expansion continued in the region of South and Southeast Europe with population size 2,800-3,700 in Core Areas, followed by higher solar insolation. The Late Gravettian period (29-25 ka) was characterised with sudden decrease of population size from 1,000-1,500 persons in Core Areas in Western and Central Europe due to maximum loss of solar energy and solar insolation, sharply dropping the temperatures and very large delay and shift in growing season.

The Late Glacial Maximum (LGM) period from (25-20 ka) was a period of none expected increase of population size of 3,100-3,200 persons in Core Areas but only in Western Europe due to fast growing solar insolation and growing season.
The Epigravettian period (20-15 ka) counts a population size of 7,700 in Core Areas mostly in Southwestern Europe, Western Europe and western part of Central Europe with increased solar insolation and growing season, where terrestrial herbivores play the most important role for humans providing useful row material such as bone, antler and ivory. The main conclusion is that anatomically modern humans arrived in Europe during a period of medium intensity solar insolation.

Due to colder and drier periods in MIS2 it is very important to find out what were the temperatures during summer and winter time in this period. For die estimation of summer temperatures during MIS2 period, colleges (Radakovic et al., 2023) were using the Malacothermometer July Paleotemperature (MTJP) method which consists of reconstructing temperatures by analyzing the shells of land snails (malacofauna) found in sediment layers from past periods like MIS2. The principle of the method works is that snails are only active and their shells are only deposited when temperatures and humidity conditions are suitable for them. Knowing the types of snail species, their distributions, and the characteristics of the sediment, colleges could estimate the mean July temperature of a past climate in the Balkans Region.

The results showed that MIS2 period 21-18 ka in July was 16,5 °C while during the period between 26-22 ka cal BP, the temperature was between 19,6 °C and 18 °C.
The winter temperature was between -19 °C and -27 °C in the Balkans and southern Europe, while the Mediterranean region was warmer with -3 °C and 2 °C, by research from (Adams, 1998). Globally during the Last Glacial Maximum (around 21,000 years ago) temperatures were 3,1 °C to 5,9 °C colder than in the Holocene, according to (Annan et al., 2012), during the research from (Rehfeld et al., 2018) shows that in summer period was a warming period of 3 °C-8 °C from the LGM to the Holocene.

Due to all these circumstances the Balkan region has a few sites demonstrating climate, flora, fauna and found tools from that period that we are going to describe in my research.
I concentrated on the Gacko region of modern day Bosnia and Herzegovina and specifically on the archaeological site of Ruzina Pecina Cave, a Paleolithic site of note.

Stone tools or lithics are one of the visible and characteristic elements in the Palaeolithic archaeology. I will now describe some of a key lithic technocomplexes in the region which I studied. There are a few places in Bosnia and Herzegovina and neighbouring Balkan countries which have very similar patterns of faunal and human remains and tool techno-complexes which are characteristic for the Epigravettian Culture.
The Epigravettian is characterised as a late Upper Paleolithic techno-complex archeological industry with associated human tradition , succeeded from the Gravettian and the Aurignacian across Europe in eastern and southeastern regions spanning from 26,500 to 15,000 cal BP. Geographically we find the Epigravettian culture according to our findings in eastern and central Europe like Poland, Moravia, Carpathian Basin and Lower Austria, then in Balkans, the Adriatic hinterland and northern Italy (Lengyel et al., 2021).

In southeastern refugia, specifically Balkans, the Epigravettian culture began around 26,500 cal BP, during in northern part of central Europe like Poland, the Epigravettian started around 23,000-20,000 cal BP, researched by (Ruiz-Redondo et al., 2022).
Also inside the Epigravettian we have three chronological clusters: initial LGM (26.5 - 24 cal BP), local LGM (24-20 cal BP), and post-LGM (20 –14.7 cal BP), according to (Lengyel et al., 2021).

By the Epigravettian culture, their mobile hunter-gatherer groups with very specific patterns of settlements with specialized kill sites and short term camps are showing short occupations lasting days or weeks who were adapted to dynamic post-glacial environments characteristic with rapidly changing ecosystem and landscape found from faunal and human remains where cold -season based camps showing mostly mammoth bone dwelling, during warm-season camps are consisted with open-air locations without permanent structures which were featured with different faunal remains, shown by (Shydlovskyi et al., 2022).

During the second chronological cluster of the Epigravettian (24,000-20,000 cal BP) called the local LGM, the Epigravettian economy was focused on hunting and exploitation of large herbivores such as bison, reindeer, horses and mammoths (Kitagawa et al., 2018), while during the third chronological cluster of the Epigravettian (20,000-15,000 cal BP), called the post-LGM the focus of hunting was centered on red deer and ibex,which was the most hunted species in western and southern Europe (Yaworsky et al., 2023). The hunting strategy consisted of making backed bladelets and shouldered points that served as projectile armatures for efficient pursuit tactics against preys like rein deer, red deer and horses (Niţă et al., 2012). A very common hunting technique was used of spears hafted with microlithic points to target migrating herds researched by Kitagawa et al. (2018).

The coastal Epigravettian sites indicating exploitation of red deer together with marine resources, showed by (Jones et al., 2020), so that the Epigravettian diet was high in protein from terrestrial herbivores, marine resources in combination with seasonal plant resources like berries and roots Oxilia et al. (2020).

The Epigravettian coastal culture is subdivided into two main phases based on lithic typologies, environmental correlations, and radiocarbon sequences in the Adriatic region: the Early Epigravettian (approximately 26,500–17,100 cal BP), characterized by shouldered points and retouched blades, and the Late Epigravettian (17,600–12,000 cal BP), featuring smaller backed bladelets and retouched points, with some regional traditions extending into thumbnail endscrapers and elongated backed points (Ruiz-Redondo et al., 2022).

For better and more successful exploration of prehistoric hunter-gatherers on the Dalmatian and the Adriatic coastline, their hunting habits and social networks, lithic raw material plays a key role. According to (Vukosavljević et al., 2017), autochthonous radiolarite outcrops with preserved pebble rind, cherts from the Lower Eocene limestone, cherts from the Middle Eocene, limestone cherts from the Upper Cretaceous limestone and black cherts represent the universal hunting tool in that region during the third chronological cluster of the Epigravettian, called the post-LGM (20-15 cal BP).

During the rock-shelter in Montenegro, Crvena Stijena who is around 64 km away from the Adriatic coastline and 50 m away from the Trebisnjica river, shows stratigraphic sequence from the Gravettian to the Epigravettian occupations from (27,000-15,000 cal BP) with very rich assemblage including shouldered points, burins, cherts and faunal evidence of ibex and red deer (Kozlowski et al., 2004).

One of the most important facts in the life of the Epigravettian humans was the way they were preparing and how they were cutting the meat from animals like ibex, wild horses, rein deer, red deer. It was very important for researchers to find out and to investigate human behaviour of the Epigravettian man. In general most Paleolithic sites have findings of bones with cut marks, which represents a way of usage of stone tools and a way of cutting the meat for further preparation and consummation. According to Braun et al. (2016) recorded cut marks on bone surfaces can represent potentially changes in the diets of early *Homo sapiens* and their usage of abundant chipped stone artefacts.

It has been known that early *Homo sapiens* fashioned sharp-edged stone tools to cut meat and tissue off the bones that would produce the cut marks which could have cross-sectional shape, V-shaped or U-shaped, so the archeologists are tending to classify the marks as cut marks or tooth marks. When a sharp object like flint or basalt has been drawn across the surface of a bone, it can create a groove on the surface of the bone.
Researched from Bello (2011), cuts on the roots of teeth on the incisors of red deer and horses from the Upper Paleolithic sites have been attributed as a butchery activity. Presence of a scratch internal or lateral micro-striation and Hertzian cones are described as an incisions made by stone tool edge.

In conclusion we can observe that cut marks provide information of cognitive ability of early *Homo sapiens* and that one of the prehistoric butchery strategies was one of the most behavioral patterns in evolution of the Epigravettian man behavior.
Not only the cut marks can be a very important sign of cognitive ability of early *Homo sapiens*, but also the Paleolithic art can be regarded as one of the first expressions of symbolic and cognitive thought, researched by Mac Curdy (1924). The Paleolithic cave art across Europe (Italy, Spain, Germany, France, Austria) was presented with animals and human models, mostly mammals like red deer, horse, bison, wild goat, reindeer and mammoth. Mostly as a cave art was used ocher where the walls of rock shelters were painted representing hunting scenes from the Paleolithic life of *Homo sapiens.*

By explanation of (Medina-Alcaide et al., 2017), there are three forms of the Paleolithic cave art : anthropomorphic (human figures), zoomorphic (animal figures) and signs which are seen as complex geometric signs, simple signs or finger lines. In some southeastern Paleolithic caves, some anthropogenic and zoomorphic marks of red parietal paintings were discovered. In western Europe, in Spain (Malaga-Nerja Cave) were found the same red marks and paintings of 8 deer, 9 horses, 6 caprids and 254 signs of 32 figurative motifs, which play main role in the Paleolithic cave art of the third chronological cluster of the Epigravettian, called the post-LGM.

By Ruiz-Redondo (2024) appearance of the Paleolithic art presents a major milestone in human evolution with expressions of symbolic and cognitive thought in human history, that`s why decorated caves have acted as a territorial marker and ritual places from human groups from 25,000 BP onwards. In Bosnia and Herzegovina in 1974 a rock shelter of Badanj was found with engraved features together with some lithics from the Paleolithic age which represents the first discovery of the Paleolithic art in that region.

Inside of the cave wall were found features of a horse, unfortunately, (Ruiz-Redondo et al., 2020) and other colleges were questioning the interpretation of a horse features with following explanations that the engravings barely evoke the rear part of an animal, that the style of this representation does not correspond with any other style from the Upper Paleolithic and that the lines supposedly depicting the back and the leg of the animal are disconnected and that many of the engravings are interpreted as 'filling' this silhouette go beyond its outline. For better understanding and interpretations of the Paleolithic art cave in Bosnia and Herzegovina would be needed more research and more similar discoveries in that region than we have at this moment.
One of the most important parts of scientific research of the Paleolithic period and their culture is isotope analysis and determination of dieting habits not only of Neanderthals, but also of AMH and animals. Therefore with isotope analysis we can with good precision know if the diet was carnivore (animal diet), herbivore (plants diet) or omnivore (animal and plants diet).

According to some of researches like (Richards et al., 2009), Neanderthals who were living in period between (120,000 to 37,000 cal BP) in a different regions of Europe , the isotopic evidence indicates that they were top-level carnivores and most of their dietary protein was from large herbivores, during dietary of early modern humans (40,000-27,000 cal BP) has a wider range of isotopic values, that indicates aquatic (marine and freshwater) resources. Further isotopic analysis of early humans shows consumption of large herbivores and plants. We can say that dietary of early humans was more rich and varied in range than from the Neanderthals. Our conclusion is that the Neanderthals were more limited in their hunting habitats, which consists of drier and colder weather, lack of sources and imperfection of hunting, while early modern humans had more developed hunting tools, milder weather and habitats with plenty of food resources.
In general we can say according to (Richards et al., 2001), that isotope analysis provides direct information about average dietary protein intake by prehistoric consumers over an approximately 10-year period before their deaths.

The isotopic analysis of archaic humans and animals consists of analysing the 13C and 15N values of collagen extracted from Neanderthal, early modern humans and animal bones in a time span from 40,000 - 20,000 cal BP and more.
My project consists of faunal and human remains from two different cultures, partly the Gravettian and partly the Epigravettian Culture, a period around 27,000 - 19,000 cal BP. A few Paleolithic places in the Balkans are having a mixture between these two different Paleolithic Cultures. I would like to describe similarities between those few paleolithic places and their culture.

We don`t see often in the Balkans, specially in Bosnia and Herzegovina real bone determination and possible art of fauna with the help of ZooMS and radiocarbon dating methodology. This project represents the first real isotope analysis and radiocarbon analysis in the history of anthropological and archeological science in Bosnia and Herzegovina. With this project my aim is to explain the previous archeological method of determination of stone tools and faunal and human bones, in compare with nowadays technology and new ways of more precise and technological advanced methods for more accurate results that can help the researchers in having much more scientific information for better reconstructing the history of that part of Balkans (Bosnia and Herzegovina), together with neighbouring regions.

In the 1980s the archaeological research was held by a sudden report of village people that they found some artefacts or some human bones on the sites. After reports, an archeological museum would be invited to inspect the site. In our case the family Mandic, who was having a big garden and inside the garden was a small cave called Ruzina Pecina, reported some strange findings that should be looked at and examined carefully. On their report, the team from National Museum Sarajevo, led by curator of the National Museum of Sarajevo, Zilka Kujundzic-Vejzagic, in the 1990s came for further research and excavations.

The excavations were led until 1992, until the war in Bosnia and Herzegovina began. Vejzagic and her team managed to excavate VII Layers and G-P terrace, bringing the whole artefacts and the bones from the site Ruzina Pecina to the National Museum of Sarajevo. Some artefacts were described on the site from Vejzagic, while the bones were examined from famous Croatian zooarchaeologist, Mirko Malez. During my research of the artefacts I was trying to find the anatomically written examination of the bones from Malez`s daughter Vesna Malez who is a well known Croatian archaeologist, but unfortunately without any success.

So I stayed without an original and anatomical description of the faunal bones, that should be a good help and indicator for my research. After the artefacts and the bones were examined from zooarchaeologists and archaeologists from Croatia and Bosnia, just one publication came out in 2005 by Vejzagic (2005) Ruzina Pecina - Paleolithic station near Gacko which led me through the whole project. I was relaying my whole project on Vejzagic findings, researching the stratigraphy of the site and the stone tools that were described, hoping to find the proof of Neanderthal presence together with a presence of anatomically modern humans (AMH).

While working on a project I noticed some small unfinished things like: I don`t have anatomically detailed descriptions of the bones which were found in Ruzina Pecina Cave. Apparently, the archeologist Mirko Malez, who described the bones forty years ago, did not publish it and I could not reach him or his team for other consultations. Definitely I can not for sure say how the cut marks on the bones were produced and in which way they appeared, I hope I will successfully describe and give interpretation of the cut marks on the bones. Another very important thing is the description of the tools of early modern humans from Ruzina Pecina Cave.

In my work on a project I can not make comparison between tools from the region, but I can only mention the period they belong to and some small characteristics which are used in already published literature.
For sure I can say that Ruzina Pecina Cave needs more attention and scientific work and excavation to reach the goal of every scientist, were there Neanderthals in Ruzina Pecina Cave, how I can prove their existence and why first excavator Zilka Kujundzic-Vejzagic thinks that Ruzina Pecina Cave is much older and even belongs to the older period Aurignacian where I can find Mousterian and Levallois tool points which represent the presence of Neanderthals in Bosnia and Herzegovina.

5.0 Methods

In this chapter of my project, I will explain the site of Ruzina Pacina and findings from the site, that will be presented and methodology I used for determination of faunal and human remains by ZooMS, determination the age of faunal and human remains by using the properties of radiocarbon dating, together with isotopic analysis for determination of their dietary habits. How did I come to make a project about the Ruzina Pecina site? The idea was born from Douka-Higham Lab with a desire to find the first Neanderthals of Bosnia and Herzegovina.

My goal was to visit the National Museum in Sarajevo to obtain permission for working on bones from the Bosnian Paleolithic sites. After the search for the best site to research, I decided to work on a small site from Eastern Herzegovina, called Ruzina Pecina. With permission from archeologists and a curator from the National Museum of Sarajevo, I started the journey of scientific research with hope to find the first Neanderthals in Bosnia and Herzegovina and with the wish to get very good results from faunal and human remains that I was analysing.

Unfortunately, my expactations were not reached, but the project became the first AMS radiocarbon dated site in that region of Bosnia and Herzegovina and this project represents only continuum of work and legacy from Zilka Kujundzic-Vejzagic, the first excavator of Ruzina Pecina site. My focus on that little-studied Paleolithic site of Ruzina Pecina, which was first discovered in 1981 was my attempt to unlock the mystery of the Paleolithic period and life in Bosnia and Herzegovina. The location of the site is located in the village of Mandići in Pusto polje, Eastern Herzegovina, on the southern side of a long ridge that encloses the southeastern part of the Gatačko Polje and separates that field, as a slightly sloping plateau, extended towards the border of Montenegro, in the direction of the Paleolithic site Crvena stijena (Vejzagic , 2005).

The cave has very small dimensions 0-1 meters bright and 0-5 meters deep but has seven discrete layers which are well stratified. Before the first layer (Layer I), it was a very visible upper Platou on the Terrasse (Platou G-P) where two small human natal bones were found in humus soil. The first layer (Layer I) is archaeologically sterile and comprises soil humus and topsoil. The second layer (Layer II) is a deposit of reddish clay with no archaeological remains. The third layer (Layer III) comprises a light brown debris and larger pontian stone, an animal horn tool was found which has similarities to those found during the Aurignacian period, which dates from ~42,000 - 35,000 cal BP in Europe and is linked strongly with early *Homo sapiens*.

There are some other artefacts which are reminiscent of the youngest part of the Aurignacian, with smaller laminal flakes and cores. Layer IV contained a few tools and one animal bone. Layer V was much richer and contained many unretouched flakes. Layer VI was characterised by a dark brown soil with no animal bones, only cores and stone tools made from river pebbles. The lower stratum of layer six is related to layer seven where the Mousterian stone tool was found according to Vejzagic (2005).

The most important layers with archeological remains were layer III, IV and V and Platou G-P for my project. For sure determination of faunal and human remains I was using ZooMS (Zooarchaeology by Mass Spectrometry), a peptide mass fingerprinting method, which was used to identify the bone collagen extracts to species or genus level. This was enabling us to identify the bones, teeth and antler to determine biological species. Another methodology I was using was AMS radiocarbon dating (Accelerator Mass Spectrometry) which represents a highly precise method that directly counts Carbon-14 (^{14}C) atoms in a sample to determine its age, like bones, and sediments, with determination how long ago the organism died. For the description of cut marks on the bones I was using pictures of the bones and interpretation of marks on the bone surface. The description of stone tools was already made on a site during excavations in 1990.

5.1 Radiocarbon Dating

One of the most important natural elements in biochemistry is Carbon. In my case it is about radiocarbon 14C, who is a naturally occurring isotope of carbon who interacts with nitrogen atoms in the upper atmosphere. It is an unstable isotope who enters the terrestrial food chain by photosynthesis. When an organism dies it ceases to take up radiocarbon. Over time the proportion of 14C of the dead organism decreases. By measuring the proportion that remains, the elapsed time since death can be estimated, according to (Bayliss et al., 2004).

Libby, Anderson and Arnold (1949) were the first to measure the rate of this 14C decay. They found that after 5568 years, half the in the original sample will have decayed and after another 5568 years, half of that remaining material will have decayed. The half-life (t 1/2) is the name given to this value which Libby measured at 5568±30 years. This became known as the Libby half-life. After 10 half-lives, there is a very small amount of radioactive carbon present in a sample. At about 50,000-60 000 years, then the limit of the technique is reached and beyond this time, radiocarbon dating won't be possible (Housley, 1990).

For accurate radiocarbon dating, only that part of the organism when it died should be measured, avoiding foreign carbon that can enter the sample. For much more accurate and more direct method for measuring the 14C is used Accelerator mass spectrometry (AMS), which enables smaller samples of 1g of bone being measured rather than 200g of bone. After the radiocarbon activity of the sample, it has been measured and it is possible to say how old a bone sample is, according to (Bayliss et al., 2004).

In the AMS technique, sample carbon is chemically separated from the original sample, converted to graphite, pressed into a cathode (sample target holder) where it forms a solid graphite plug , and is then placed into a sputter ion source of an accelerator. This methodology outlines the general graphite sample preparation (chemistry) and AMS counting procedures at Beta Analytic Inc. for organic and carbonate samples. Through this process, the carbon dioxide produced from carbonaceous raw materials is cryogenically purified (separated from non-combustible gases) and reduced to solid graphite for measurement in an AMS, described by (Housley, 1990). The radiocarbon dating method can be used to determine the ages of many types of carbonaceous material of up to about 50 ka in age, thats way AMS radiocarbon dating is of value to multiple areas of Quaternary research like archaeology, oceanography, hydrology, geology, and paleoclimatology (Linick et al., 1989).

The historical sites present an ideal place where this method can be employed for two reasons: the first is the increasing precision and accuracy of radiocarbon dating with the use of accelerator mass spectrometry (AMS), and the second is the use of Bayesian modeling of dates which represents the ability to incorporate a priori information that can aid in modeling, evaluating, and constraining probability distributions, explained by (Thompson et al., 2018).

For my project I took 18 bone samples for radiocarbon dating. The first steps in the lab were measuring the initial weight of the bone samples and cleaning the bones with air abrasion with aluminium oxide powder (in this case I took whole bone fragments). I took 500-550 mg of bone, crushed it with a pestle, then transferred it in a tube and measured the used weight for a radiocarbon pretreatment chemistry. The samples were treated with 0,5 M HCl (3-4 rinses over 18 hr), 0,1 M NaOH (30min), and 0,5 M HCl (15min) with thorough rinsing with ultrapure water between each reagent.

The crude collagen was gelatinized in pH3 solution (10ml) at 75 °C for 20 hours and the resultant gelatin solution filtered using a cleaned Ezee-filter. The filtrate was transferred into pre cleaned ultrafilters and centrifuged until 0,5-1,0 mL of the >30 kD gelatin fraction remains. The gelatin was then removed from the ultrafilter with ultrapure water before being freeze dried. The aim of freeze drying is to remove all water from the samples, and freeze solid for 48 hours (or until fully dried), (Brock et al., 2010).

Then I prepared the collagen to be graphitized. I made a transfer of the collagen to a treff tube (1,5 ml plastic tube) and weighed the total collagen yield (tear the empty tube on the scale, then transferred and measured), then I opened a clean tin capsule and tore it on the scale. The sample was around 3 mg of collagen and weighed it in the tin on the scale, then I closed the tin, folding the four sides and placing the tin in a 96-well plate for graphitization.
The samples were combusted and graphitized at the VERA facility (Vienna Environmental Research Facility), Faculty of Physics.Combustion & Graphitisation. Collagen was fully combusted to gas: N_2 and CO_2, CO_2 is then trapped in a vial and H_2 is injected, so the graphitization happens at 500°C for 6 hours: $CO_2 + H_2 \rightarrow C$ (graphite) $+ H_2O$.

After graphitization, graphite was pressed into a target and mounted on a wheel before being loaded into the accelerator mass spectrometer (AMS) at VERA, which is a 3MV Pelletron tandem accelerator Vockenhuber et al., (2003), Steier et al., (2004a), Kutschera (2005). Each target is shot with a beam of cesium and carbon is focused in a beam through magnets. The three isotopes of carbon (12C, 13C, 14C) are separated by mass and end up on distinct detectors which count the number of atoms and the ratio is used to calculate a calendar age.

The AMS enables the user to separate rare isotopes with very low abundances from a large background, which was previously impossible. Another advantage of AMS is that it only requires very small amounts of material for measurement. An important application of this process is radiocarbon dating because the rare 14C isotopes can be separated from the stable 14N background that is 10 to 13 orders of magnitude larger.
Only small amounts of the old and fragile organic samples are necessary for measurement according to (Miller et al., 2014).

5.2 Calibration of the radiocarbon results

The Bayesian approach is the most ruling approach in archaeology where the research layers of archaeological excavations can be measured, dated and represented by modelling. The Bayesian approach represents the estimation of the transit time between a sequence of archeological layers where any theory that researcher has in addition to the radiocarbon data, is in a simple way introduced. Therefore archaeologists say that the Bayesian approach is simple, intuitive, and natural. The standard statistical packages used in archaeology are Bayesian: The OxCal and the BCal. Ritov et al. (2018). In my project I used OxCal and the INTCAL20 curve and calibrated the results. I did not build a Bayesian model because of variation in the results and the lack of confident stratigraphic/contextual information. Calibrated dates are presented in a calibrated year (cal BP).

5.3 Zooarchaeology by mass spectrometry (ZooMS)

One of the methods that I was using in my project was ZooMS (Zooarchaeology by mass spectrometry). According to (Wang et al., 2024) zooarchaeology is a scientificaly discipline used in a research of animal remains from archaeological sites with a purpose of answering archaeological questions from the past.
With a new method of sediment screening which can provide enlarged faunal assemblages, archeologists can improve zooarchaeological studies together with other complementary archaeological techniques like ZooMS, isotope analysis and radiocarbon dating.
In 2009, a paleoproteomics method, ZooMS (Zooarchaeology by Mass Spectrometry), was introduced as a taxonomic identification tool (Wang et al., 2024) and has been used for diverse applications in archaeology and paleontology, ecology and conservation, and cultural heritage (Richter et al., 2022).

Due to its low cost, ZooMS offers very fast and precise taxonomical identification of faunal remains from archaeological sites by speciating collagen materials not only from bones but also from ivory and leather. Collagen is the major organic component (~90%) in the bone of vertebrates, and its survival could be very long lasting (Wang et al., 2024).
Collagens are an abundant class of structural proteins essential for life in animals, from sponges to humans. There are nearly 30 different collagen proteins, of which type I collagen (COL1) is among the most ubiquitous and abundant, comprising 80% of the bone proteome. COL1 is the major component of animal connective tissues.
It is highly abundant in skin, tendon, ligament, and fish scales and it is also found in bird and reptile eggshells, invertebrate shells, and a wide range of other animal-derived tissues (Richter et al., 2022).

ZooMS involves extracting Type I collagen (COL1) from a sample and generating tryptic-digested peptide mass fingerprints via MALDI-TOF-MS (Matrix Assisted Laser Desorption Ionization Time-of-Flight Mass Spectrometry), which represents
rapidly growing analytical technique in the fields of archaeology, ecology, and cultural heritage. It leverages the high abundance and long-term preservation of collagen in bone and other animal tissues with the analytical power of mass spectrometry (MS) in order to provide robust taxonomic identifications using minimally destructive methods (Richter et al., 2022).
The automated use of a matrix-assisted laser desorption ionization (MALDI) mass spectrometer (MS) is described for image analysis of samples through implementation of new software for instrument control, data acquisition, and data analysis.

The software permits automated acquisition of MS MALDI spectra to form an ordered data array and contains display features to provide images at one or more mass-to-charge ratio values. The technique can be used to scan tissue samples, blotted samples, gels or other sample surfaces where the image analysis of that sample is required. The program achieves a time of typically 1s per image point, permitting an analysis made up of large numbers of points with high spatial resolution up to 850 dpi, described by Stoeckli et al. (1998).

A big advantage of the ZooMS is finding a new and unexpected taxa and good faunal estimation when anatomically description is not possible or available. It has been specially used to help identify remains in museum collections in cases where the associated metadata have been lost (Richter et al., 2022). For the ZooMS taxonomic identification analysis I was applying a similar method to (Vegh et al., 2024). The 18 bone samples and second set of 25 bone samples were made as small bone chips (15-25 mg) after each bone surface was cleaned with AlO2 powder. The first set of 18 bone samples collagen we got already after (Brock et al., 2010) collagen extraction, during the another set of 25 bone samples the collagen extraction underwent by following the extraction protocol by (Vegh et al., 2024).

The 25 bone samples obtained had been pretreated with 500ll of cold (4 °C) 0.6 M HCl and left to demineralize in the fridge (4°C) for 1–2 days.
The acid supernatant was removed, and the samples were rinsed 3 times with 200ll of 50 mM pH 8 ammonium bicarbonate (NH_4HCO_3; AmBic). Then humic acid was removed by adding 200ll of 0.1 M NaOH, and 200ll of 50 mM AmBic (pH 8) three times, which brought the solution to get neutral pH. Then 100ll of AmBic was added to each sample after it was put for incubation in an oven for 1h at 65°C and put on centrifugation.

The 50ll of the resulting supernatant was incubated with 1ll of trypsin solution Pierce TM (0.4ll / lg), (ThermoFisher Trypsin Protease) at 37°C for 12–18h. After tryptic digestion, the samples were centrifuged and were acidified to 1ll of 5% trifluoroacetic (CF_3COOH) acid (TFA) and the peptides were purified and extracted with a 100ll C18 resin ZipTipVR pipette tip with conditioning solution, composed of 0.1% TFA in 50% acetonitrile, and washing buffer solution, composed of 0.1% TFA in ultrapure MilliQTM water. Samples were eluted with 50ll condition ing solution.
Bruker peptide calibrant standards were spotted (0.5ll/spot) on a ground steel 385-spot MALDI target plate along with diluted (1:10) tryptic collagen peptides in 0.5ll/spot triplicates. Samples were spotted on ground-steel MALDI plates in triplicates mixed with 0.5ll of a-cyano-4-hydroxycinnamic acid matrix solution. Analyses were run on an in-house Bruker Autoflex Speed MALDI-ToF-MS (Bruker Daltonics).

5.4 Isotopic Analysis

Isotope evidence is a powerful tool for reconstructing past human diets and subsistence adaptations, where human bone collagen is an indicator of the main sources of dietary protein consumed over a number of years. With calculation of carbon isotope ratios (13C values) researchers could indicate the source of dietary protein as a marine resource or terrestrial resource, researched by (Richards et al., 2009).
For Roberts (2022) isotope analysis represents an ever-present methodology applied to the study of past human diets, mobility and environments.

The study of isotope analysis is on its pathway to prominence in an archaeological context, being followed by the joint application of stable carbon and nitrogen isotope analysis to bone collagen with a goal to look at changes in food sources and trophic level and the stable carbon isotope analysis of tooth enamel bioapatite to explore hominin diets and environments from the past time. According to (Richards et al., 2001) with isotopic analysis is possible to assess the relative proportion of aquatic resources in the diets of prehistoric humans and coexistent animals through analyses of bone collagen carbon (13C) and (nitrogen /15N) stable isotope values, providing direct information about average dietary protein intake by prehistoric consumers over an approximately 10-year period before their deaths.

With the research of (Richards et al., 2009) it is shown that isotopic analysis provides information about the sources of dietary protein over a number of years and it does not measure the caloric contributions of different foods, while the method only measures protein intake, many low-protein foods that may have been important to the diet, like honey, underground storage organs, and essential mineral and vitamin rich plant foods are simply not traceable with this method. During the procedure of isotopic analysis from the same region, the same time and the same place where the humans and animals bones were found, there is always one conclusion by the researchers, the herbivore isotope values are similar.

So we have 15N value from *Capra* (ibex), (average 2,6 %), *Cervus Elaphus* (red deer), (average 5,4 %), the carnivores wolf (average 11,5 %), hyena (average 11,1 %), red fox (average 7,3 %-10 %). By the research from (Baumann et al., 2020) the high δ15N fox niche value (7,0 %-10 %), and the large carnivore group of the Middle Palaeolithic overlap to a high degree with the Aurignacian niches (niche overlap about 55 to 60 %), suggesting similar conditions for the feeding possibilities of these predators across the Middle and the Upper Palaeolithic.

Omnivore values can fall between the ranges of carnivore and herbivore values depending on the amount of plant or animal protein in their diets. By comparing the isotope values of omnivores such as humans to the isotope values of herbivores and carnivores from the same site or region, we can determine whether they obtained their proteins from mainly animal sources or plant sources or a mixture of both Richards et al. (2009).

In my project, I was obtaining stable isotope evidence from the carbon and nitrogen isotopes to provide direct information about protein intake by fauna and humans (I selected two bones for AMS dating which was identified as infant humans and other 16 animal bones) over a 10-year period before their deaths. Carbon and nitrogen stable isotope values of bone collagen can sometimes yield information telling us whether the dietary protein was coming from a terrestrial or aquatic food chain system.

The consumption of aquatic foods can show much higher levels of nitrogen 15N, in a bone collagen than the consumption of terrestrial plants and herbivores during the consumption of some plants can show higher levels of carbon stable isotope values (Richards et al., 2001).
I was weighing samples of collagen (~0,21-0,32 mg) into clean tin capsules and measured them for their stable isotopic composition and carbon and nitrogen content and sent them to Isotope Ratio Mass Spectrometry (IRMS).

According to (Muccio et al., 2008) Isotope Ratio Mass Spectrometry (IRMS) is a specialized technique used to provide information about the geographic, chemical, and biological origins of substances and it is widespread and used in archaeology, medicine, geology, biology, food authenticity, and forensic science. In order to measure the average isotope ratios for non-volatile liquids or solids, the bulk sample can be lowered into a combustion furnace through an autosampler carousel, at which time the sample is combusted at elevated temperatures under a flow of oxygen into NOx, CO2, SO2 or H2O.

In carbon isotope ratio analysis the combusted sample is carried by a helium gas stream into a reduction chamber where nitrous oxides are converted into N2 and excess O2 is removed. The analyte is next carried through a chemical trap to remove water that was produced from combustion and then into the gas chromatograph where separation of CO2 and N2 is performed. Effluent from the elemental analyzer is then sent to the IRMS where the intensity of the gases are read and analyzed.

5.5 Cut marks

During my visit in the National Museum of Sarajevo and my work on finding specimens for the project, I was watching the cut marks on chosen bone samples in order to present human activity on the bone from the past. In science the presence of cut marks on the bones is mostly associated with ancient stone tools from that past time. For better description of cut marks morphology, very important roles are playing the properties of stone tools and properties of bones itself. Hardness of tool edges significatelly affects cut mark morphology, in the same way hardness of bones very deeply affects cut mark morphology too.

For example, it is already known that bones of animals that recently died reacting differently to plastic deformation than bones of animals that have been dead for several days and in zooarchaeology it is refered as ‘fresh’ compared to ‘dry’ bones explained by the results from (Braun et al., 2016) and in a same way showed that rock type and bone portions influence the shape and prevalence of cut marks on animal bones which brings important investigation and question are the archaeologists able to diagnose the actor (carnivore versus hominin) and effector (stone tool edge versus carnivore tooth) that produced these marks. Marks inflicted by the edges of stone tools are usually diagnosed based on their cross-sectional shape, more V-shaped than U-shaped. Some archaeologists tend to classify the marks on the surfaces of bones into categories as cut marks and tooth marks.

For Bello (2011) cut marks observed on fossil bones represents important source of evidence in the reconstruction of prehistoric butchery strategies and with a usage of a 3D composite image, vertical variations in the surface structure can be used to interpret differences in the mechanical impact caused by different types of tools and different butchery techniques. For a further investigation on butchery techniques it is needable new technology and new methodology that we could be able to interpret and explain cut marks on the bone surface.
In my project not all 18 bones had visible cut marks on the bone surface. Six of them have visible cut marks, some of them are tool cut marks, some of them are teeth cut marks, some of them are human modified bones.

5.6 Tools

The Epigravettian in Bosnia and Herzegovina and in the Balkan region is characterised by stone tools like backed bladelets, microgravettes, and shouldered points together with end-scrapers, thumbnail end-scrapers and burins used mostly for hunting. The time span goes between 26-25 ka cal BP to 17-11 ka cal BP, considered as the Early and the Late Epigravettian. For (Ruiz-Redondo et al., 2021) distinction between the Late Gravettian and the Early Epigravettian lithic assemblages is often problematic, as the material presents many similarities. Typologically, some tools are frequently found in the Early Epigravettian assemblages, such as shouldered points, large retouched blades, and long scrapers on blades with retouched edges.The Late Epigravettian in the Adriatic area is characterised by integrated blades-bladelets production systems and increasing in innovations in lithic production, especially for the time span between 15 and 11,5 ka cal BP, small backed points as hunting tools, called ‘microgravettes'.

The most characteristic and widespread lithic tools from this period are short endscrapers on flakes or small blades (known as ‘thumbnail endscrapers’), circular endscrapers, and truncated bladelets from the beginning of the Late Epigravettian.
By radiocarbon dating it is seeable overlap between periods up to 1784 years, therefore the lithics were hard to estimate in some places. The most present stone tools from the Epigravettian period in Bosnia and Herzegovina, researched from Montet-White (1993) are shouldered points stone tools which were found in Kadar (Bosnia and Herzegovina), Croatia, Slovenia and in the Adriatic Basin. Also in Kadar were found blades, chips, cores and flakes too.

For Vukosavljević et al. (2018), the Early Epigravettian lithic assemblages of the Balkans have been interpreted as a marker of cultural influence and as population movement from central Europe to southern Europe during the (LGM) so that their appearance and similarity relied on Italian classification, having the Early, Developed and the Late Epigravettian with shouldered points as indicators of the Early Epigravettian.
The newest results of radiocarbon dating and the earliest appearance of shouldered points and shouldered pieces in the eastern Adriatic and their appeariance in lithic assemblages until the Late Glacial Interstadial Bølling-Allerød, representing a long period of around 10 000 years, out of these results we know that the shouldered points were reaching much longer period than only the Epigravettian.

We can say that the Early Epigravettian shouldered points were surely part of the Epigravettian hunters toolkit. According to (Monnier et al., 2021) the Gravettian and the Epigravettian has been found in Montenegro at Crvena Stijena with endscrapers, burins, retouched blades, notched pieces, truncations, straight backed bladelets, and points, during at Medena Stijena (Montenegro) has been found the Final Epigravettian tools consisting of curved backed bladelets, truncated backed bladelets, and geometrics, retouched blades and notched pieces, endscrapers, burins and small thumbnail endscrapers.

Badanj Cave (Bosnia and Herzegovina) contains the Final Epigravettian lithic industries as well as an osseous industry consisting of bone and antler harpoons, awls, needles, and pierced shell and tooth ornaments and characteristic limestone boulder. Boric et al. (2021) the site harbors one of the rare occurrences of the Upper Palaeolithic parietal “art” in southeastern Europe in the form of a large rock engraving. Another aspect of the site is the presence of engravings on portable objects made from bone and a large number of personal ornaments made primarily of marine gastropods, scaphopods, and bivalves, and red deer canines, barbed points, and the large extant collection of ornamental beads were also found at the site.

According to (Dogandzic et al., 2021) very similar Epigravettian assemblage was found in Bukovac Cave (Croatia) with high frequency of backed bladelets and a bone point contains traces of burning with the presence of charcoal, burnt bones and lithics and fewer retouched flaking pieces. In Orlovaca Cave (Bosnia and Herzegovina) was found a small assemblage with a core, backed bladelets and endscraperpoint.
Anhang from reasearch of (Mihailovic, 2024), relatively diverse assemblage of cores and tools implies a longer stay at the site Crvena Stijena (Montenegro) where they found clear evidence of burned artifacts, suggesting a temporary rather than transitory occupation.

6.0 Results

6.1 The Gravettian and the Epigravettian (radiocarbon analysis)

After I finished a lab part of the project, I got results from the facility VERA (Vienna Environmental Research Accelerator). As I said previously, I was expecting results closer to the time of the Neanderthals around 40,000-50,000 cal BP, but unfortunately I got much younger bone collagen results. I had 18 bone samples and from 18 bone samples I got a bone collagen which was between 22,201 years BP and 16,038 years BP (animal bones), two neonatal human bones were 217 and 214 years old without calibration. After I did calibration the results were from 26,900 cal BP-19,515 cal BP. The results from neonatal human bones were not calibrated.

By finishing calibration I made a Calibration model of the radiocarbon dating results of my project that is shown in a figure 1, which put my project directly in a time of the Gravettian period (35,000-22,000 cal BP), the Epigravettian period (21,000-10,000 cal BP) and the LGM (The Last Glacial Maximum) period (26,000-20,000 cal BP) in the Balkan region (Bosnia and Herzegovina). With my project I did not find the presence of the Neanderthals as I expected but I found the presence of anatomically modern humans (AMH). Very similarly the colleges from the USA and Serbia (Stiner et al., 2021) got results from the Serbian site Velika Pecina.

The site preserved the LGM components and the time of occupation radiocarbon dating from 24,500-19,600 cal BP, showing the Gravettian and the Epigravettian presence in neighbouring countries, that put a more clear picture of that time in the Balkans. That small cave Velika Pecina with only IV layers showed temporary human occupation with rich faunal remains of red fox, red deer, cave bear, lynx, leopard and the Epigravettian tool assemblages which give us a similar picture of the Paleolithic life in Bosnia and Herzegovina and Serbia at almost exact time span. By Croatian researchers (Farbstein et al., 2012), results from the site Vela Spila (Island Korcula) in Croatian Dalmatian Coast showed big similarities with our site. Occupational time from the Late Upper Paleolithic (the Epigravettian) till younger time. The cave Vela Spila gives us evidence of radiocarbon dated animal bones of red fox, red deer, roe deer, lynx, hare, wild cat aged (19,500-14,500 cal BP) from a series of layers with abundant archaeological bone and tool assemblage.

At the site of Crvena Stijena in Montenegro researched by (Mihailovic, 2024), in a layer X of a very large cave, there were found a bones from red deer radiocarbon dated (the Late Gravettian, the Early Epigravettian) period between 28,500-13,600 cal BP (MIS 2) with very large tool assemblage in the whole layers (X-XXXI). Some Bosnian scientists and archaeologists like Zilka Kujundzic-Vejzagic are opinion that Crvena Stijena rockshelter was a long-term place for anatomically modern humans, possible the Neanderthals (the other layers in Crvena Stijena are much older and radiocarbon dated till 52,000 cal BP, MIS 5a and possible older MIS 6) who would come across the border of Bosnia and Herzegovina, 20-30 km to site of Ruzina Pecina for hunting reasons, where they would stay temporarily and then came back to rockshelter Crvena Stijena. Zilka Kujundzic-Vejzagic (the first excavator of the site Ruzina Pecina) connects the site Ruzina Pecina and the site Crvena Stijena due to her own archaeological experience and research. Another very popular cave from the region of Bosnia and Herzegovina, Badanj, researched by (Boric et al., 2021), has very large amount of red deer bones and antlers from Level 6 and onwards and very small collection of red fox bones together with marmot bones, ibex, wild boar bones. The tool complex has been made from bones and antlers and from snail arts. The AMS analysis puts Badanj cave in the Epigravettian period around 22,000 cal BP and a period of the Late Glacial Maximum (LGM) which is very similar to our site with osseous tool manufacture with the recognizable Epigravettian style. From another neighbouring county, Italy, the Epigravettian period was recorded in many shelters and caves across the Apennine peninsula and the whole periods of the Epigravettian were mostly called by Italian nomenclature. In a work of (Rossini et al., 2025) I found a lot of similarities with my cave, together with the presence of tools and animal bones from a period between 24,000-18,000 cal BP. In a layer O in Grotta della Cala faunal remains resemble very much to the site Ruzina Pecina. The presence of red deer and red fox is very similar, but there is also presence of other species such as lynx, wild boar, roe deer, hare. Due to bone assemblage it can be assumed that in layer O human occupation, hunting activities were mainly focused on ungulates, rather than on large carnivores or mesomammals, during in Ruzina Pecina site I can assume that their hunting activities were partly focused on ungulates and partly on mesomammals which puts the Ruzina Pecina site very near to the other Italian Epigravettian sites. Unfortunately the site Ruzina Pecina is not excavated enough for deeper reconstruction of the Paleolithic culture and their period. One month ago, a team from Bosnia and Herzegovina, Italy, Canada and Serbia started further excavations of the site Ruzina Pecina, hoping for new results and deeper reconstruction of the Paleolithic period and the culture on that site. Hopefully our united results can bring more answers and light on the Paleolithic period in the site and generally in the Paleolithic research in that part of a region of Bosnia and Herzegovina and the Balkans.

6.2 Calibration of the radiocarbon results (26,900-19,515 cal BP)

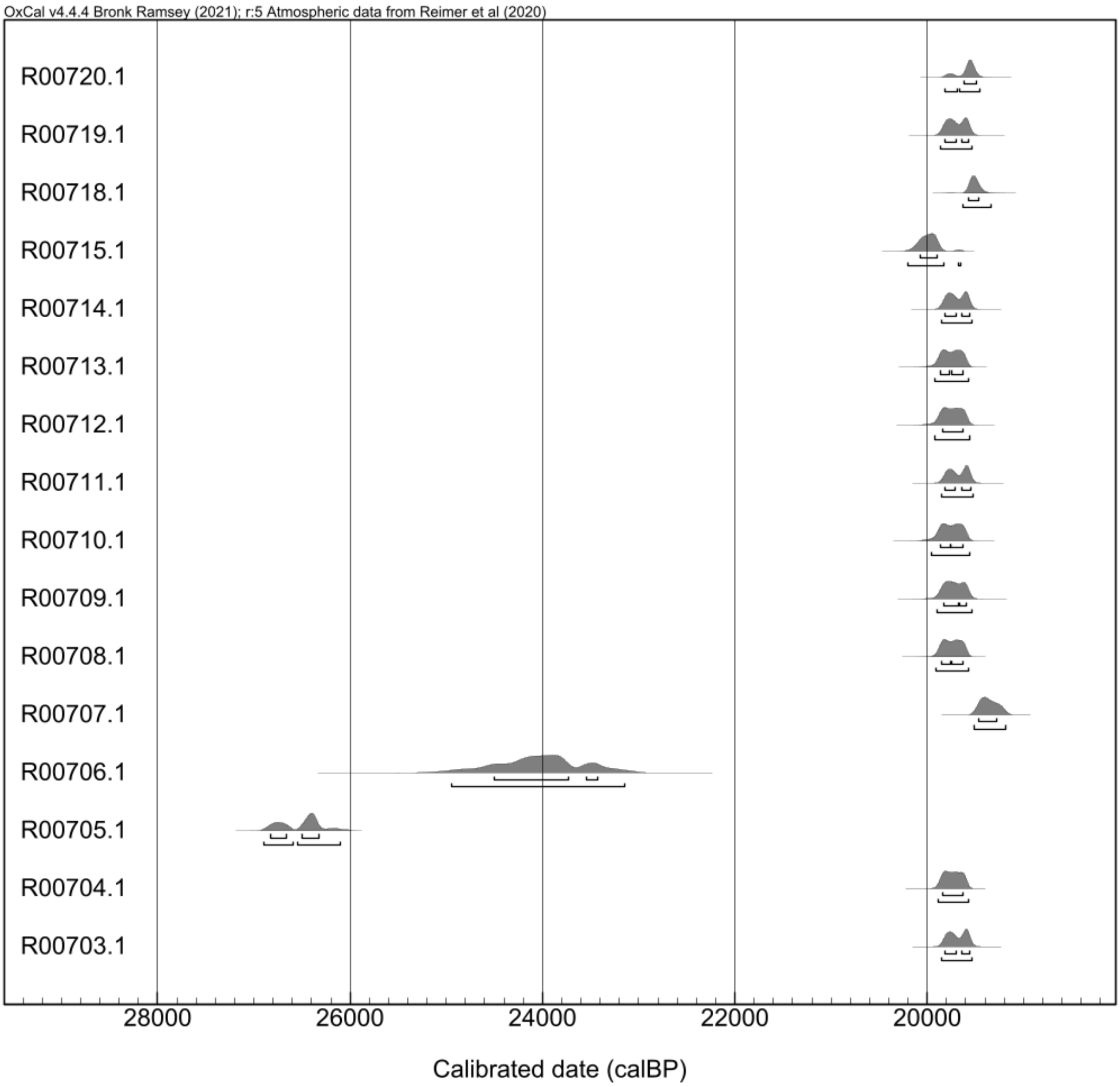


Figure 1: calibrated ages (cal BP) of the radiocarbon determinations obtained in this dissertation.

6.3 Paleodiet

After I got results from isotopic analysis for my project, I could explain the results in two different ways. The first way will be a written description of the results that I got and another way will be everything represented in a scheme or diagram for better understanding and explaining of my results. First of all, the whole isotopic analysis of bone collagen was presented with a δ13C and δ15N values. We can see that δ15N values are between 6,5 % and 3,3 % and δ13C values are between -19,2 % and -20,5 % from animal bones. From the bones of neonate the values of δ13C are between -19,0 % and -18,9 %, and values of δ15N are between 10,1 % and 10,2 %.

My results are showing that the diet of animals was more concentrated on plants than on meat or fish, with one specific result from neonate where it is very seeable that the diet was more carnivore than herbivore, knowing that anatomically modern humans are omnivore. According to (Ganiatsou, 2023) neonates are in a weaning phase at a higher trophic level than their mothers. By analyzing hairs and nails from mother-infant pairs have shown a difference in δ15N values by approximately 2-3 ‰.

Nitrogen value is the most frequently known and used element in the isotopic reconstruction of breastfeeding and weaning. With analyzing the values of tissues that were synthesized during infancy and childhood, we can estimate the ages when the protein contribution of weaning food began, when that of breast milk ceased, and the tempo of weaning, while carbon values in infant collagen during exclusive breastfeeding, are increased by approximately 1 ‰ and have been used auxiliary to identify breastfeeding and weaning patterns. Carbon isotope ratios are expected to be elevated during exclusive breastfeeding and decrease throughout the weaning process.

By study of human hair and nails it is shown that there seems to be an approximately 0,4 ‰ increase of δ13C values in fetal compared with maternal ones. One of other indicators of higher δ15N lever is that mothers milk has more proteins (casein) that give us a picture of higher level of δ15N value and puts neonate as a more carnivore than herbivore, even having more higher level of nitrogen and carbon than his own mother, according to (Stefanovic et al., 2019).

By the carbon results of red deer researched from (Craig et al., 2010) is seeable that δ13C values of mammals in the range between -19,0 % and -21,3 % are characteristic of animals feeding on plants with a C3 photosynthetic pathway which is characteristic with our mammals too, where red deer was feeding on depleted woody shrubs, and open dwelling species (such as aurochs) on relatively enriched grasses. By plants growing under the dense, closed canopy are known to exhibit lower 13C abundances compared to the same plant groups growing in anthropogenic landscapes, generally composed of mosaics of meadows and species-rich small woodlands, researched from (Schnitzler et al., 2018) and very importantly the carbon isotope signature is used for tracking the presence of dense forest through time.

When 15N and 13C values exibit large values and 13C values are crossing the value of -22 1⁄2 %, represents an indication that animals were aging under a closed canopy. After the valuation of 15N and 13C values from the red deer bone collagen, it showed that dominant forest types like beech, oak and hornbeam forests were animal feeding plants. From research of (Sommer et al., 2008) red deer has a broad tolerance of different habitats and their fossil records shows presence in interglacial / woodland and glacial / steppe faunal complexes. The red deer is found in Western Central and North-Western Europe and the Balkans with a wide distribution of preferred food plants such as birch, willow and poplar.

In the work from (Baumann et al., 2020) red foxes are omnivores and usually fed from small mammals and some plants. Their isotopic carbon and nitrogen values are shown in different three levels. We have red foxes with high level of δ15N values range from +7 % to +10 %, than we have red foxes with intermediate δ 15N values range from +3,7 % to + 6,7 %, and red foxes with low level of δ15N values range from +1,0 % to +3,0 %. By the low level red foxes δ 13C value has a range from -21,4 % to -21,1 % and intermediate δ15N fox group has a range of δ13C values from -20,5 % to -19,4 %. The red fox from Ruzina Pecina cave belongs to the intermediate red fox level where δ 15N level is +5,7 % and δ 13C level value is -19,7 %.

In further research (Baumann et al., 2020) was seen that intermediate δ15N values red foxes was more specialized on “rodents” and “reindeer” while low δ15N foxes feed primarily on “rodents”. That result from their research was very important for my site, because we have δ 15N intermediate red fox level in the site of Ruzina Pecina where I “found presence of rodents” and red deer, so we can assume that red fox from Ruzina Pecina site was fed primarily from red deer and rodents.

In his other research Baumann (2020), intermediate δ 15N red foxes and high level δ15N red foxes were fed not only from reindeer and rodents, but with mammoth and horses during the Gravettian period. In his work Monchot et al. (2009) suggested that fox skins were more important than fox meat for anatomically modern humans during the LGM period, due to butchering patterns and cut marks on the red fox bones.

From radiocarbon analysis we know that bones from a III-IV layer were between 26,900-24,940 cal BP, this layer is assumed to be the oldest in comparison to layer V and layer G-P. The two bones we found there were not so close by age, while the other seven bones we got from layer III were between 19,953-19,515 cal BP and even closer to each other by age. The layer V had a seven bones calibrated age between 20,196-19,890 cal BP which were relatively close in age with each other.

The two neonatal bones were aged without calibration between 217-214 years in a G-P layer. At all animal bones we can see by isotopic analysis that they were all similar in their diet and that they are coming from similar ages. Even the oldest animal bones, which are almost 7,000 years older than the other bones are showing similarity in diet which can give us a picture of time and life in that period (the Gravettian), and the LGM period in Bosnia and Herzegovina.

6.4 Faunal and human (ZooMS)

For identification of the bone samples I used Zooarchaeology by mass spectrometry (ZooMS) method. As I previously wrote, I analysed two sets of bones. The first set of 18 bones were radiocarbon and isotopic analysed and identified using a ZooMS method, while the second set of 25 bone samples were only identified using ZooMS method. For those 25 bones we don't know their real age or their dieting habits, but we know the species and from which layer they are coming from.

From the first set of 18 bone collagen samples I got results that from only one animal bone collagen was red fox dated by ZooMS, with a calibrated age of 19,851 cal BP from the layer V. All other animal bones were from layers III, IV and V and they were from red deer aged 26,900-19,515 cal BP. For two small human bones which were already identified on a site as neonate from layer G-P, my results proved that two small bones are from humans, aged 217 and 214 without calibration.

From the other set of 25 collagen bones results were a little bit different. The whole bones belong to a layer III, unknown calibrated age and dietary habits (assuming around 19,000 cal BP). From the samples, twelve of them belongs to red deer, another twelve to unknown species (rodents), probably marmots (we do not have markers for marmots, but unknown species is very similar to otter, further explanation are in discussion), and there was another bone left that unfortunately I could not make determination out of one thing, there is no markers for that animal, who showed characteristics similar to rodents and mammals (similar to *Nesophontes major* and beaver, further explanation in discussion). The whole results of ZooMS and radiocarbon dating from 18 bones are represented in figure 2.

According to (Stiner et al., 2021), similar results in their research were shown from analysis of Velika Prcina cave in Serbia. It is one of rarely radiocarbon dated places from the Late Glacial Maximum (LGM) or MIS 2 period, where the collagen bone results are dated between 24,000 and 20,500 cal BP with faunal remains from red deer, red fox and rodents. By (Sommer et al., 2006) and their research from the 47 European LGM places which were dated from 23,000-16,000 cal BP are containing faunal remains from red deer and red fox. It is notable that two of those species are found always together in the LGM places across Europe which showed a sign of mammalian glacial refugia in Europe.

By their definition glacial refugia represents findings of faunal and human remains only in a period between 23,000-16,000 cal BP. The whole of those places represent hunter-gatherer stations of the Younger Paleolithic, the Gravettien and the Epigravettien cultures. In their research they noticed that presence of red deer is very dominant in 80 % of the sites, while the second dominant presence of red fox was recorded in 70 % of the sites, but rarely from the Balkans.

From the presence (*Castor fiber*-beaver) of rodents they were rarely recorded across Europe, but mostly they have been recorded during the LGM from the Balkans. From 14 European sites red deer and red fox are recorded on the same site and five of them are from the neighbouring countries of Bosnia and Herzegovina (Ruzina Pecina site), Sandalja II (Croatia), Zmijinac Pecina (Croatia), Pecina Brini (Croatia), Zupanov Spodmol (Slovenia) and Ovca Jama (Slovenia). By the main research from a lot of LGM sites two refugia from that period occurred very important with their presence.

We talk about the Italian Peninsula and Balkan refugia, the two neighbouring LGM refugia which are making hot spot refugia for genetical exchange between faunal assamblage during the period of LGM. From the study of (Morin et al., 2017), the Gravettian and the Epigravettian culture (28,500-13,600 cal BP) from Layer X and Layer IX (Crvena Stijena) Montenegro, red deer dominate not only in Layer X, but in other older layers together with roe deer and marmots. The presence of red deer and marmots could be very similar for the site Ruzina Pecina, unfortunately the red fox is not present in the Crvena Stijena site.

Also in a team work from Serbian colleges (Dimitrijevic et al., 2018) the largest faunal remains were found in Velika Pecina site in Serbia. Togother with mammalian remains of red deer and red fox, there were faunal remains from rodents, birds and fish mostly from the Gravettian and the Epigravettian period (MIS 2). In a project Sommer et al. (2004) it was explained and researched about canid fauna in Europe during the Gravettian, the Epigravettian, the Mesolithic and the Neolithic period.

The main focus of the research was on red fox presence in Iberian Peninsula, Italian Peninsula and the Balkans during 38,000-25,000 cal BP and 22,000-18,000 cal BP. In a period between 22,000-18,000 cal BP the red fox faunal remains were found together with red deer faunal remains not only in Iberian Peninsula, but in another two bonded refugia from the Italian Peninsula and the Balkans. All these findings are representing big similarity to the site Ruzina Pecina and could be a signature for the LGM period not only in central and western Europe but in the whole Balkans.

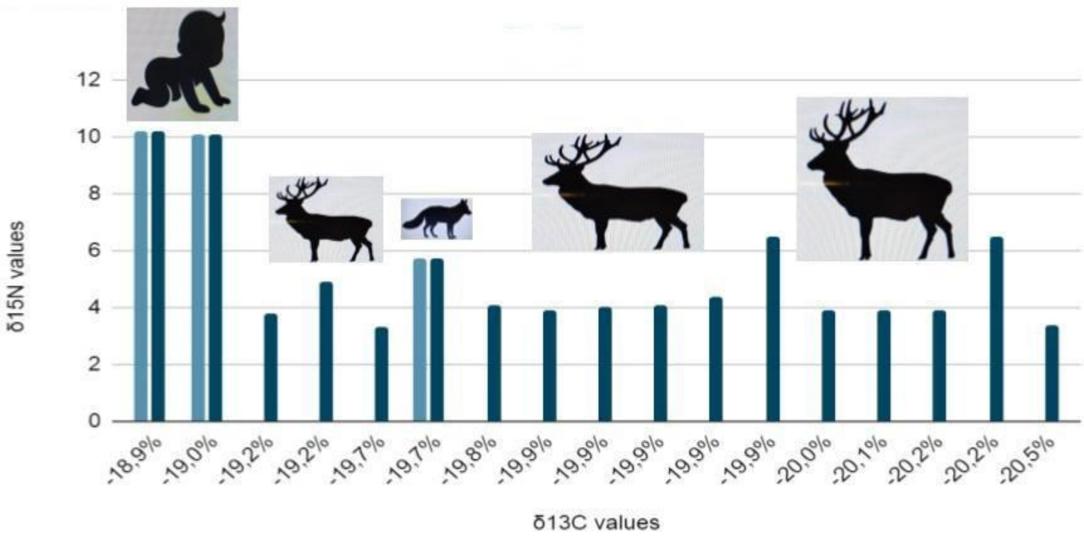


Figure 2: Isotopic analysis and ZooMS results from the project.

6.5 Human modifications (cut marks)

As I wrote in methods, I took pictures of examined bones on the site in the National Museum of Sarajevo, for further explanation of visible cut-marked bones. Not all of them are cut-marked or with cut marks which are well preserved. I took six of them for further investigation and description for my project Ruzina Pecina. In a series of six pictures, presented on page 40, figure 3, it will be shown how the cut marks are looking and which type of actor is involved in making those cut marks. It was visible that some bones were: human modified bones, tools cut marks, teeth cut marks. By isotopic analysis the first cut marks bone was red fox bone (Sample 1), (RO, G3,4/V ; R00703) from the V layer with visible deep cut mark assumingly made from tool and (U-shaped) marks with crooked vertical marks, humanly modified bone with smoothly shaped point.

The second bone was red deer bone (Sample 2), (RO, G3,4/V ; R00704) from the V layer with six deep scratches made parallel on the bone surface, assumingly made by stone tools. The third bone was red deer bone (Sample 3), (RO, DIII-IV ; R00705) from III-IV layer shapely human modified bone with visible small pale cut marks, assumingly done with some sharp tool. The fourth bone was red deer bone (Sample 6), (RO, G3,4/III ; R00708) from the III layer humanly modified bone with oval smooth edges and (U-shaped) cut mark on the surface. The fifth bone was red deer bone (Sample 11), (RO, G3,4/III ; R00713) from the III layer with visible three long sharp scratches, two of them (V-shaped), assumingly done with a very sharp tool, possible butchery method.

The sixth bone was red deer bone (Sample 17), (RO, G3,4/V ; R00719) from the V layer with visible teeth marks (looks more like a human tooth mark done on the fresh bone) and crooked short cut marks, assumingly done with a stone tool. The recognition and description of the cut marks was made according to Braun et al. (2016). According to (Stiner et al., 2021) the most modifications on the bones were on fresh bones that were seeable on their impressions. Mostly they were made on red deer bones with marks of gnawing traces including small and large deep punctures, similarly like on a sample six from Ruzina Pecina cave where we see small deep punctures on a bone surface.

We are assuming that gnawing bone damage occurred from teeth from red fox or from another predator (rodent) immediately after the red deer carcass processing, but unfortunately we don't have a good proof for such argumentation. Like in a (Stiner et al., 2021) project the most of the bones were multi-grooved which occured from cut marks incisions on the bone surface made by stone tools. In the Epigravettian site Crvena Stijena (Morin et al., 2017) were describing cut marks on red deer bones using a 30 x hand lens, examining if the marks were on a dry bone or on a fresh bone, discovering presence of percussion marks and damages on the bone surfaces. The cutmarks on the red deer were extensive and moderate with high frequences on the wide range of skeletal parts. Most of the cutmarks were longer than 2 cm stretching parallel following the bone axis.

The sample 11 shows similar cutmarks. One of the most specific cutmarks were marrow extraction cutmarks and percussion pits, very good seeable on the sample 2 from Ruzina Pecina. On the red deer bones from Crvena Stijena site were present long bone fractures, especially brought in association of a carcasses processing. From sample 2 we can see a fractured bone but human modified and shaped like the top of a knife, probably used as a tool or as a weapon. On the red deer bone collection we see more human accumulated cut marks than from other predators, which can bring us to the conclusion that after animals were hunted and proceeded from humans, other predators were scavenging the rest of red deer meat leaving cutmarks on the bone surfaces.

For Dimitrijevic et al. (2018) butchering marks were recorded on the red deer bone assemblage from Velika Pecina site in Serbia. On the red fox bone assemblage were recorded deep incisions and cut marks indicating processing at the site. On sample 1 on the red fox bone we see cut marks and remodeled and shaped bone, particularly on the top of the bone indicating processing at the site, similarly like on the Velika Pecina site. In a Croatian site Sandalja, according to (Miracle, 2007) during the LGM around 20,700 cal BP animal bones were identified as red fox bones with visible cut marks as a sign of human use of carnivores but this time for ritual consumption because the carnivore was portioned in small pieces suggesting unusual ritual behavior. In my project I did not find any sign of ritual behavior but I can say that red fox bone from Ruzina Pecina site was used or planned to be used for hunting reasons as a bone tool too, which could represent some art of human behavior.

By investigation from (Marín-Arroyo et al., 2023) Šalitrena Pecina (Serbia) with the Layer 4 (the Gravettian) and Layer 3 (the LGM) belongs to one of the similar sites with similar cut mark patterns. The presence of red deer and red fox is distributed in every layer of Šalitrena Pecina site. It is noticeable that large mammals like red deer were brought from humans to the site showing cut marks like defleshing, skinning, dismembering, fracturing, butchering and using fire causing not burning but thermoalterations on the large bones, during small mammal bones like red fox bones were showing gnaw marks caused from other smaller predators.

Our Italian neighbor Ruta (2021) was reasearching Grotta di Pozzo (Italy) and in the Unita III (Layer3) were faunal remains from red deer belonging to the LGM period between 20,000-17,500 cal BP, with butchering activities inside the place (butchering in situ) with scratching traces of rodents. Red fox was found in the Unita IV (Layer4) but belonging to a much younger period 15,000 cal BP than red deer faunal remains.

Sample 1, red fox bone

Sample 2, red deer bone

Sample 3, red deer bone

Sample 6, red deer bone

Sample 11, red deer bone

Sample 17, red deer bone

Figure 3: Photographs of dated samples.

6.6 The Epigravettian (26,000-11,500 cal BP) stone tools

According to (Vejzagic, 2005) the site Ruzina Pecina has characteristic five to six different periods in their VII layers by description of stone tools that were found at the site. The Older Paleolithic, the Middle Paleolithic, the Younger Paleolithic, the Epipaleolithic, the Mesolithic and the Neolithic culture. Unfortunately, by my results from radiocarbon dating I got the Gravettian, the Epigravettian and the LGM periods which gave me different situations and more detailed periods through different layers from the site Ruzina Pecina, more about it in discussion.

After excavating the site Ruzina Pecina, Zilka Vejzagic started determination and description of stone tools at the site, which she wrote about in her published work "Ruzina Pecina - Paleolithic station near Gacko". In her research Zilka Vejzagic makes a description from Layer I and Layer II and there were no findings in those two layers. In the Layer III animal horn tool was found, a spike with an oval section characteristic for the Younger Aurignacian period 33,000-26,000 years ago, the cores and smaller laminae were also found without retouched and preserved cortex on the edge. From the Layer IV where Zilka Vejzagic identifies the stone tools as a pitted scarpers and flint tool material showing Levaloisian technique, characteristic for the Older Paleolithic (2,6milion - 300,000 years ago) or the Middle Paleolithic (300,000 - 50,000 years ago).

The other findings from Layer VI, are described as retouched scarpers with characteristics of Mousterian technique, called micromousterian, usually found in the Middle Paleolithic period. In Layer V, high scarpers were found on small, single-platform cores or river pebbles of small dimensions which are characteristic for the Younger Paleolithic (46,000 - 12,000 years ago). With their specific morpho-technological characteristics, the small pebbles and scarpers were put to the Middle Aurignacian (approx. 35,000 – 25,000 BP). For the one-sided retouched laminae with partially preserved cortex from the Layer VII, there was not known any cultural period out of the presence of such stone tools from the Aurignacian period till the Early Neolithic period. In the G-P Layer were no stone tool findings, only two neonate bones.

6.7 The Epigravettian in Bosnia and Herzegovina

In early 1990 when the Yugoslavia existed as a country, our college Zilka Kujundzic-Vejzagic, was the only archeologist who was making excavations not only in the older Yugoslav Paleolithic stations but in a Bosnia and Herzegovina Paleolithic stations with a goal to describe the Mousterian and the Levaloues culture in the region, hoping to find first Neanderthals from Bosnia and Herzegovina. Unfortunately till these days scientists have not achieved it, so we could say that archaeological hunt for Neanderthals still is going on in cooperation with other international colleges from other countries like Italy, Austria, Canada, UK, Germany and USA. Zilka's achievements were very important for the national heritage of Bosnia and Herzegovina and a lot of Zilkas excavational archaeological items are still kept at the National Museum in Sarajevo, representing the prehistory of that region.

Unfortunately, as Zilka wrote it in her work (Vejzagic, 2005) that initial excavation at the Paleolithic station Ruzina Pecina did not provide enough data for a clear definition of the Paleolithic cultures in that site and that was not enough material to compare it with other international and domestic Paleolithic sites. In her words there was not enough archeological informations for judgement about their age, geological affiliation and there was a problem of dating these cultural remains which stayed for (Vejzagic, 2005) temporarily unresolved, due the lack of proper technological equipment which could help in resolving the mystery about Paleolithic culture in Bosnia and Herzegovina. (Vejzagic, 2005) is opinion that better understanding of the Yugoslavian, Adriatic and Bosnian Paleolithic sites goes through excavational findings and archaeological descriptions from Italy and Greece where the typical Aurignacian and the Middle Paleolithic culture and period shows more possible similarities out of geological closures to Adriatic region.

Zilka finds Italy and Greece one of the closest regions to compare with the Adriatic and the Bosnian Paleolithic sites. Determination of faunal remains were not mentioned in her work, neither compared to any other international or domestic Paleolithic sites which represents one of the disadvantages in Zilka's scientific work. To get the complete and correct picture of the Paleolithic life at the site Ruzina Pecina, Zilka needed the determination of faunal remains, their real date of age and correct determination of the Paleolithic and bone tools which was impossible in that period of time (1990) due to lack of modern technology and implementation of more advanced tools for better resolving the mystery of the Paleolithic in Bosnia and Herzegovina.

7.0 Discussion

The Paleolithic culture in Bosnia and Herzegovina is still unknown due to lack of usage of modern technology and a new knowledge that other western countries are already using in their scientific works and publications. Unfortunately archaeologists from Bosnia and Herzegovina are still using the old methodology to describe and to explain their scientific work. There is a very low usage of modern knowledge, so that everything is still based on old excavations and explanations from over 40 years ago and more. As I came to opportunity to work on this project, I was expecting similar results using modern knowledge and modern technology to explain and describe the project Ruzina Pecina and to put conformation with my results to results from the past scientific work of Bosnian archaeologists (Zilka Kujundzic-Vejzagic) and others who were part of previous examinations of the site, stone tools, human and animal remains.

One of the crucial fact was that there is no prehistoric archaeologists in Bosnia and Herzegovina who are specialist for the Paleolithic period and culture and therefore is very hard to examine all those sites unless someone from western countries would come to excavate and to research the Paleolithic sites supported with international finance fonds for scientific research specially for the region of Bosnia and Herzegovina. Unfortunately my small project Ruzina Pecina didn't get enough attention from international finance fonds and their financial support that could grow in a more researched area, due to lack of interest or finances they would rather invest in some other region with more possibility for finding and discovering Neanderthals across the world. But there is one big signal of hope for that small project.

Colleges from Italy, Bosnia and Herzegovina, Serbia and Canada are joining their forces for further excavation after almost 36 years to research and to examine the site Ruzina Pecina using modern technology and modern knowledge, which has a goal, finding the real time and date of the site, determination of faunal and human remains and a new description of stone tools and bone tools and every item they find at the site. My own research will be just a small contribution to a much bigger research that will be proceeding in the next seven years, how long the further excavation would be lasting and how long their contract for further research would last. Using the new methodology and a new modern knowledge I would like to explain the situation of the first excavator (40 years ago) and my situation (nowadays) researching and analysing the items from the Ruzina Pecina site.

One of the striking things about this small site was the description of the site as the Paleolithic station from the time of Aurignacian (37,000 - 33,000 years ago) with an assumption of the site being older and belonging to the Older and the Middle Paleolithic. I was assuming that this project could be presented as the Aurignacian and the Upper Paleolithic site, but closer to 40,000 - 50,000 years ago or even later, due to the Mousterian and the Levallois description of the stone toolkit, which was characteristic of the Neanderthal culture.

I was hoping that animal remains would be older than 40,000 cal BP which would put the site Ruzina Pecina as the possible Neanderthal seasonal hunting station during summer and winter seasonal time of the Upper Paleolithic period. In a work of (Vejzagic, 2005) no animal remains taxonomy was mentioned, neither their anatomical description, only stone tools, one bone tool and stratigraphy was described. Dating of the paleolithic layers was described thanks to a stone toolkit found on the site. Another striking point in the whole project was stratigraphy and the layers. It seems that some layers were older, some younger or there was a mixture between the layers. It is possible during the excavation that some stone tools were moved from their position so that we got different aged stone toolkits in one layer. By the stratigraphy, layers should be from youngest to the oldest, following the archaeological time and a row from youngest to the oldest which was not in this case.

Another very important point was a missing bone spike from the collection that we could not find, that should bring us more clarification in the project. I was asking for that bone spike which was described as the Mousterian-like (the Mousterian tools were often described in the Aurignacian period) for radiocarbon dating and for the Zooaerheology mass spectrometry (ZooMS) for further investigation and a proof of the Mousterian time and culture.

Unfortunately, I couldn't present the whole set of the toolkits and bone remains, because my project is more concentrated on human and faunal remains (18+25 bones) and the collection was almost five times bigger than the small number of bones that we randomly chose from the whole bigger collection. Another important point was a loss of information about the small human (neonatal) bones who were already identified and described on the site.
In the (Vejzagic, 2005) project there was not a description of two small neonatal bones found on the G-P teracce. With my knowledge of human anatomy I identify the two small bones as a neonatal left and right femur, up to six centimetres (60 mm) long, characteristic for a neonate of 36 weeks probably born premature. Usually the neonate by birth is between 38-42 weeks and femur length is 7,0 - 7,8 cm (70 - 78 mm). Both bones were broken, medically called femoral shaft fracture, that was made post mortem, while the edges of the broken bones were sharp on the both bones, there is no evidence of healing process, was it done from animals or humans we can not make determination. All these facts could have an impact on my measurements (little bit shorter femurs) but again normal for that stage of development.

According to (Pratima et al., 2016), gestational age (GA) begins from the last menstrual period prior to conception. Their project consists of femur length (FL) measurements with help of ultrasound (ultrasonography), where femur length was measured as an accurate parameter to determine gestational age (GA).
In the project of (Carneiro et al., 2016) estimation of gestational age in fetal human remains is important in forensic settings and it presents biological parameter for non-adults, led through anthropological examination and post-mortem radiographs used not only in forensic context, but in archaeological context. It is well known that the lower limb (femur) is very well known as the most well-preserved skeletal element.

By their results femur length was 6,6 - 7,1 cm (66 - 71 mm) by the time of 33 to 36 weeks of gestational age and by 37-40 weeks the femur length was 7,4 - 7,7 cm (74 - 77 mm). The whole project was made of collected records of 257 fetuses with a range between 12-40 weeks of gestational age taken from hospitals.
By the results of (Pratima et al., 2016), in the 32 week of gestational age (8 month of pregnancy), femur length was 6,1 - 6,5 cm (61 - 65 mm), during 36 week of gestational age (9 month of pregnancy), femur length was 7,0 -7,3 cm (70 - 73 mm), and 38 week of gestational age femur length was 7,4 - 7,5 cm (74 - 75 mm).

The collection was made of ultrasonographic results of 200 pregnant women from 13 to 38 weeks of gestation that were examined in a hospital. By these results I can say that the femur length from my collection was 6,0 cm (60mm), and could be connected to premature birth. I just need to say that ultrasound measurements (Pratima et al., 2016) from India and post-mortem radiographs (Carneiro et al., 2016) from abort neonates from Portugal were done in the 21st Century, during two femur bones from my site (Bosnia and Herzegovina) belong to much older time (with calibration, even to the Neolithic period between 7,000 to 3,000 years ago), which give us information that maybe, the neonates in the Neolithic period were little bit shorter than the neonates from the 21st Century.
In page 46, with three figures we can see that : a) and b) the neonate bones that I examined in comparison with a figure c) anatomically neonate femur with growth examples.

Neonate bone (a)

Neonate bone (b)

Neonate femur with growth examples (c)

Figure 4 : Photographs of dated samples with growth examples.

In my results from the bone identification analysis (ZooMS), I would like to explain the results of the bones that we could not make a determination out of missing markers. First after the bone collagen analysis and reading the results, I could not find the fitting match for the results of almost 13 bones (12 bones had the same protein signals and one bone showed a different protein signal, other 12 bones were from red deer) from the second set of 25 analysed bones, marked as (Z1-Z25). One thing was very important to notice, there was a picture of a rodent that we took at the National Museum of Sarajevo and by my analysis it could be the mandible of a marmot that we took a picture of and one small part of the bone from the mandible, marked as a (Z4, from the set of the Z1-Z5) was taken too.

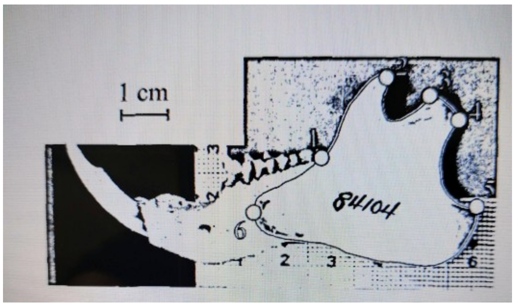
According to Cardini et al. (2004), species marmots (*Marmota marmota)* are known from the Miocene period (9,5 Myr ago), out of their possibility to live in harsh environments from mountain habitats to the meadows. The Marmots are large hibernating mammals, supposedly they existed till the Holocene period (11,700 years ago till these days). In the project of (Cardini et al., 2004), research was based on a geometric-morphometric analysis that should bring more closure for proper identification of marmot mandibles. In the project it was used in Elliptic Fourier Analysis (EFA) which enables it to provide size, orientation and location in the morphometric applications.

The mandible is 6,0 cm (60 mm) long, similar to the bone from my collection. Six anatomical landmarks were also employed to study the posterior region of the mandible as 1. intersection of the dental ridge with the dorsal portion of the masseteric ridge (base of the coronoid process), 2. tip of the coronoid process (region of insertion of the temporalis), 3 and 4. the anterior and posterior tip of the condyle, 5. the posterior extremity of the angular process (region of insertion of the superficial masseter) and 6. the masseteric ridge (region of insertion of the anterior deep masseter), pictured on page 48. Unfortunately, due to the incomplete bone that I have in my collection I can not properly investigate the whole six geometrical marks but I can say that other parts of the mandible like 1, 2, 3. the diastema, 4. the masseteric ridge, 5. the part of the coronoid process, 9. the mental foramen, horizontal ramus and incisive alveolus showing very similar patterns, during points like 5.- 6. the incisura mandibulae, 7.- 8. the condyle and the angular processes are missing (figures a, b, c) on page 49.

In my collection I had another bone which was analysed and characterised as a rodent and mammal (via ZooMS) that could not be anatomically analysed out of the missing picture of the faunal remains and also missing ZooMS markers for the bone collagen, and it was marked as Z20 in my collection. My limitation in description is not only correlated with missing pictures of the faunal bones, but out of my specialisation. The best results and anatomical description can come only from a specialised zooarchaeologist that I unfortunately could not find while working on my project.

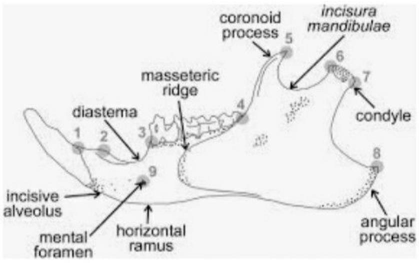
This was one of the biggest limitations and disadvantages connected to my project. I would not go deeper in anatomical explanation, but I would just mention the reason for my inability to make the determination of the bone remains. After my examination of the mandible that I assume is marmot, I can not put it as a final result, but only as an assumption that my analysis of the mandible was correct. Without the zooarchaeoecological mass spectrometry analysis (ZooMS) and matched markers I can not say for sure that that mandible belongs to marmot.

With the project of (Cardini et al., 2004), I am just describing the mandible and explaining some similar points for the project to make a closure to my assumptions. In the next chapter, I will explain my limitations and conclusions about the whole project and the work which was very important for archaeology and prehistory of the Balkans. I hope that my work with the Austrian team and the team from Italy would help in a bringing a closure of the Paleolithic life in Bosnia and Herzegovina and much more interest for the Paleolithic sites from the county with almost 200 not researched Paleolithic sites in the whole region of Bosnia and Herzegovina.



a) Cardini et al., (2004), (*Marmota marmota)*

b) dated sample



c) anatomically sketched examples
(*Marmota marmota*)

Figure 5 : Photograph of dated sample with bone markings on geometric morphometric and anatomically sketched examples.

8.0 Conclusion

By the final consideration of (Vejzagic, 2005), the initial excavations at the Paleolithic station Ruzina Pecina did not provide enough data for a clear definition of the researched Paleolithic culture, their physiognomy and possibility of comparisons with the other Paleolithic sites in Bosnia and Herzegovina and the other sites outside of the region. It was not possible to give a final judgment of their age and their geological affiliation, so according to (Vejzagic, 2005), dating these cultural remains stays temporarily unresolved. By this research from 1990´s it was opinion that after discovering and excavation of the site Ruzina Pecina, the mixture of the Middle and the Younger Paleolithic culture was not known in Bosnia and Herzegovina until the final examination of the site.

For the archaeologists from that period (1990's), the site Ruzina Pecina was the first site where it was seen the development of the Younger Paleolithic culture (50,000 - 12,000 years old) from the Middle Paleolithic culture (300,000 - 50,000 years old). Their opinion was that the site Ruzina Pecina was very significant site for solving the problem of transition of the Paleolithic populations from cultures with elements of the Middle Paleolithic heritage to cultures of the oldest stage of the Younger Paleolithic not only in the region of Bosnia and Herzegovina, but in the area of the Adriatic-Mediterranean region.

Unfortunately, the time period and transition between the Middle Paleolithic and the Younger Paleolithic was not the case in the site Ruzina Pecina. With my results I got a transitional period between the Late Gravetian Culture (29,000 - 24,000 cal BP) and the Early Epigravettian Culture (26,000 - 18,000 cal BP) which are the part of the Younger Paleolithic period, also the site was not from the Aurignacian period and culture (43,000 - 33,000 cal BP), what was opinion from the 1990´s project (Ruzina Pecina-Paleolithic station near Gacko) published in 2005. In the near future it will be needed to find a way to describe the tools which were found at the site for a better clarification and better understanding of their shape and determination. As I previously wrote, some similarities with the tools from the Late Gravettian and the Early Epigravettian from Italy, Adriatic coast, Croatia and Serbia could bring some conclusion in comparison with the site Ruzina Pecina.

In the research from (Kaczanowska et al., 2018) leaf and shouldered points, microgravettes, geometrical inserts (triangles, segments) and presence of microburin technique represents the Epigravettian tradition. Very specific was the presence of the long Epigravettian sequences on the eastern coast of the Adriatic, where the site Crvena Stijena (Montenegro) shows presence of discoidal and subdiscoidal end-scarpes and truncations in the layers VIII, VII, VI and V. In the other Adriatic site Medena Stijena (Montenegro), the layers VII to V show the presence of backed pieces and geometric microliths (triangles), then flake industry with end-scarpers, retouched flakes and single trapezes. In the Slovenian site Vrbicev Hrbec a few kilometers from the Adriatic coast, arched backed pieces, scalene triangles and truncations made on regular blade blanks were collected and estimated as the Epigravettian culture. A similar presence was found in the site Ruzina Pecina, described by (Vejzagic, 2005).

Referring to (Vukosavljevic et al., 2017), the appearance of shouldered points was recorded in the Sandalja (Croatia) and the Kastritsa (Greece) sites, approximately 20,000 - 19,000 years ago, during in the Vrbicka cave (northwest Montenegro) in the Adriatic hinterlands shouldered points were found and estimated (28,000 - 27,000 cal BP) which belongs to late the Gravettian period, similarly to the site Ruzina Pecina. Fragments of shouldered points or shouldered pieces were also discovered at another Slovenian site in the Ovcja jama cave in layer 4 whose age is approximately 19 000 uncal bp. Shouldered points were found in the Kadar (Bosnia and Herzegovina) dated on the basis of thermoluminescence dating method around 20,000 BP - 16,500 BP, the similar shouldered points were found in the Salterina cave (Serbia), dated between 25,000 - 21,000 years BP.

Mihailovic at al. (2023) refers to the Gravettian industries with a repertoire of tools limited to abruptly retouched points, endscrapers on blades and flakes, and retouched blades also occur in the early Epigravettian of the Velika Pecina and Pecina kod stene sites with a common microgravettes and truncated backed bladelets. The final Epigravettian industries with geometric tools (segments and triangles), short and thumbnail endscrapers have been well documented mostly in the coastal zone and less known or found in the Central Balkans. With the research from (Alex et al., 2019), the Pešturina and the Hadži Prodanova cave (Serbia) shows characteristic flint tools and quartzite-dominated the Gravettian assemblage with chipped stone tools, retouched blades and flakes, sidescarpers and some denticulates dated from (22,000 - 16,000 cal BP), close to the site Ruzina Pecina.

According to (Stiner et al., 2021), the Gravettian and the Early Epigravettian sites such as the Šalitrena Pecina (Layer 3), the Pešturina, the Hadži Prodanova Pecina, and the Meca Dupka in Serbia, show the presence of secondary “pebble”cortex and the frequencies of cores and rarer fine-grained flints, may have been very similar to the Ruzina Pecina site. In an examination of (Marín-Arroyo et al., 2023) the Šalitrena Pecina site has two very important levels which could be the discousion points in comparison to the Ruzina Pecina site. Level 5 of the Šalitrena Pecina has the very pronounced Aurignacian industry with local flint tools, various core types such as bladelet cores with carinated and nosed endscarpers, burins and pointed blades, which could be similar to the description from the Ruzina Pecina site.

In the Gravettian level, magnesite flints were used in tool production, with burin cores, microbladelets, endscarpers, burins and backed tools, double truncated bladelets, shouldered points and flakes. In the work of (Vejzagic, 2005) the similar occupation of the Aurignacian assemblage was described as in the work of (Marín-Arroyo et al., 2023), unfortunately the level 3 of the Šalitrena Pecina that belongs to the Gravettian period was very similarly described, which bring me to conclusion that the Late Gravettian and the Early Epigravettian culture in Bosnia and Herzegovina is very similar to the Aurignacian and the Gravetian culture in Serbia.

Further examination should be necessary for the better determination of tool assemblages and comparison of two sites. Another point was very important and the question is very seeable: “ Is Epigravettian from the Adriatic coast very similar to the Epigravettian from the Ruzina Pecina site, are we talking maybe about the same or very similar tool assemblage, or the Epigravettian from the Ruzina Pecina site belongs to very specific tool assemblage which can be the mixture from the Aurignacian, the Gravettian and the Epigravettian culture, found and dated as the Late Gravettian and the Early Epigravettian?” We need to say that the Ruzina Pecina site in the village Mandici near Gacko is very close to Bosnian part of the Adriatic coast (125 km), it is close to the Croatian part of the Adriatic coast (107 km) and close to the Montenegro`s part of the Adriatic coast (118 km) and from the site Crvena Stijena in Montenegro (20 - 30 km) away via cross paths over mountain passes, according to (Vejzagic, 2005).

As we can see from (Kaczanowska et al., 2018) the belt of the eastern Adriatic coast opens up to the Adriatic Sea and the Adriatic islands, while on the other side it is separated from the Central Balkans by the latitudinal range of the Dinaric Mountains. This range, up to 1,500 meters above the average sea level, sometimes approaches and sometimes lies farther from the coast. In some areas, for example in Montenegro, the Dinaric range is intersected by canyon-like valleys which connect the river valleys flowing from north to south and the Adriatic, which plays a very important role in a settlement processes and economies in that region of the Balkans.

My assumption is that the Aurignacian, the Gravettian and the Epigravettian humans were travelling from the Adriatic coast to landparts of Bosnia and Herzegovina, Croatia and Montenegro bringing and exchanging their economies and culture.
So we have very various assemblages in this region of the Balkans that could not be precisely distinguished between them, so we have such a situation where the Epigravettian and the Gravettian assemblages were understood and were taken for the Aurignacian culture.

Another point was very important in a publication from (Mihailovic at al., 2023) where many authors believe that the Epigravettian of the Mediterranean should be distinguished from the Epigravettian of the Central and the Eastern Europe, and it was once assumed that the Mediterranean Epigravettian spread from the coastal region to the interior of the Balkans at the end of the LGM. My opinion is that the Mediterranean Epigravettian was spread from the coastal region to the interior of the Balkans much earlier, even before and during the Late Glacial Maximum, which the Ruzina Pecina site is pointing to with results, presence of assemblages and geographical position.

According to my results from the radiocarbon dating I can say that with great precision I estimated and dated the human and faunal remains. The isotopic analysis gave me very good results about the dietary habits of the prehistoric animals and the human neonates. Unfortunately, I could not estimate some faunal remains out of missing markers, missing zooarchaeological and zooanatomical descriptions of the faunal remains and probably out of similar protein signal by ZooMS where some results were misleading, where it was impossible to make determination of the bone collagen (assumption of contamination) during the lab work.

I can put the bone Z20 without determination out of possible contamination during the lab work. Other 12 bone samples and their collagen results came from the same taxa (*Marmota marmota*) with the same collagen signal but unfortunately not possible to make determination because of missing markers. It was tried to make an estimation due to the presence of photographed bone samples, but it will be a needable opinion of the zooarchaeologist to make determination of the samples.

Unfortunately, my project didn`t bring results of the Mousterian or the Levallois culture and the neonate bones were not the Neanderthal neonate bones, but according to my results I solved the unsolved mystery from the past with radiocarbon dating, I found out which culture was present at the site Ruzina Pecina and which kind of faunal remains I have after successfully collagen determination by the ZooMS analysis. I can proudly say that I have very good results and that my project can help other scientists in their scientific work.

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