University of Évora

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ERASMUS MUNDUS MASTER IN ARCHaeological MATerials Science

Study of paleodiet from the context of the rotunda church in Bribirska Glavica, Croatia

Merita Dreshaj
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(Supervisor)

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I Abstract

This work focuses on the study of paleodiet of selected burials and fauna from Bribirska Glavica, Croatia via stable isotopes of carbon and nitrogen. Carbon stable isotopes in bone collagen can distinguish between two types of plants (C_3 and C_4) whilst nitrogen isotopic composition gives an estimation of the trophic levels and the amount of protein consumed. The results are compared to several factors such as the burial context, health, time period, social status, trauma, sex and age. An attempt was made to understand the impact of these factors on stable isotopic values and, hence, the choice of diet, contextualising the results within known historical and archaeological data. This research is compared to the study done on the area of Ravni Kotari, geographical area where Bribirska Glavica is situated, extending the paleo-dietary data range to Late Medieval period in the hinterland of Dalmatia.

KEY WORDS: paleodiet, carbon isotopes, nitrogen isotopes, Bribirska Glavica, Ravni Kotari

RESUMO (Estudo da dieta paleo no context da "rotunda" igreja em Bribirska Glavica, Croácia)

O presente trabalho foca-se no estudo em paleodieta, realizado em ossos humanos e animais selecionados de um sitio arqueológico em Bribirska Glavica (Croácia), através do estudo dos seus isótopos estáveis de carbono e nitrogénio. Os isótopos estáveis de carbono presentes no colagénio dos ossos permite distinguir entre 2 tipos de plantas (C_3 e C_4) ao passo que a composição isotópica de nitrogénio fornece uma estimativa dos níveis tróficos e na quantidade de proteína consumida. Os resultados têm em consideração diversos fatores tais como o próprio contexto funerário, a saúde dos indivíduos, o período de tempo, o estatuto social, trauma, sexo e idade. Uma tentativa para a compreensão do impacto destes fatores nos valores dos isótopos estáveis e a escolha da própria dieta foi realizada, contextualizando desta forma os resultados obtidos com dados históricos e arqueológicos já conhecidos. Os resultados obtidos neste trabalho de investigação são ainda comparados com um estudo prévio realizado na área de Ravni Kotari, área geográfica onde se situa Bribirska Glavica, estendendo desta forma o intervalo de dados em paleodieta até ao período medieval tardio na região da Dalmácia.

Palavras-chave: paleodieta, isótopos de carbono, isótopos de nitrogénio, Bribirska Glavica, Ravni Kotari

II ACKNOWLEDGMENTS

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CHAPTER ONE

1. Introduction

This chapter discusses the main aims, objectives and the reasons for choosing this particular site. A brief remark on the current academic environment and the state of isotopic research in Croatia is mentioned, circled up with the main questions addressed in this work.

1.1. <u>Choice of case study</u>

The importance of studying diet has been recognized as having social and economic implications which are essential for understanding past societies.[1] It comes from the assumption that food has a social component and reflects the culture and social status, both in history and nowadays.[2] Hence diet, being culturally determined, can also represent the identity, as it is in many religions and communities today.[3]

Having that in mind, the importance of applying stable isotope analysis as a powerful technique in understanding the subsistence of past societies has been used to analyse 35 individuals and 9 faunal remains from burials around and within the rotunda church in Bribirska Glavica.

The reason for choosing this particular site is biased by the author's involvement into the archaeological research and the need to clarify the rising questions on the Late Antiquity, Early and Late Middle age in Dalmatian hinterland. In the context of Croatian academia, the mediaeval period (especially Early Medieval) has a strong political echo since the arrival of "Croats" falls into that specific time range and therefore is a compelling topic. The issue is emphasized by the turbulent history of Western Balkans. From the first establishment of the Croatian state in middle ages [4] till the fall of Yugoslavia there was an intense demand for creation of a strong national identity.

The term Oldcroat's history (Starohrvatska povijest) has been used widely in literature even though it has not been officially accepted by unbiased researchers since it doesn't stand on strong grounds. It derived from the theory that Croats were a distinct group of Slavs, having a unique culture witnessed by the material that resembles Slavic one with influences from antiquity.[5] This was an important idea that gave fuel to the establishment of a modern

[1] Schoeninger, Moore 1992: 249.
[2] Douglas 1972: 61, 63, 66.
[3] Lightfoot 2009: 7.
[4] Evans 1996; Evans 1989.
[5] Evans 1989:113.

independent Croatia. Nationalistic Archaeology (Nacionalna arheologija) was especially important in the period of the fall of Yugoslavia in 90s and the war that was proceeding it. Since the arrival of Croats (or Slavs) falls into Early Middle Ages, as mentioned before, medieval Archaeology is largely influenced by those political assumptions. Hence, author assumes that theoretical interpretations of various scholars might be strongly influenced by the questions of national identity and the political situation in the moment of publication. The need for involving archaeometrical methods in discussing problematics in such a sensitive context is getting more and more recognized.

Even though the interest in involving new methods has been growing over last several years, the position of Archaeometry in Croatia is still in its developing mode, relying heavily on international initiatives. Hence every possibility to work on the material coming from Croatia can have a huge significance.

There are several works done on stable isotopic research solely: mostly by Dr Emma Lightfoot[6], Dr Mario Novak[7] and Dr Clea Paine[8] and their importance is tremendous in understanding the questions of diet and migration in archaeology and re-questioning the established theories. The results brought up in this study are here to complement the research done so far and extend the assemblage of isotopic data from Early to Late Middle age.

Thus, having a significant work done by other scholars on the stable isotopic technique in the surrounding area and the intriguing results from the recent excavations - the choice of Bribirska Glavica seemed somehow logical.

[6] Lighfoot 2015, 2014, 2012, 2011, 2010, 2009 (phd thesis)
[7] Novak 2016.
[8] Paine et al, 2009.

1.2. Objects and main questions

Figure 1: Trench 11, inside the modern Orthodox church, after the removal of the floor, revealing remains of the rotunda / V. Ghica

This research focuses on the isotopic study of selected burials uncovered during 2014-2017 excavation season under Varvaria-Breberium-Bribir project.[9] The burials are coming from the context of a recently discovered rotunda under the modern Serbian Orthodox church in Bribirska Glavica, Croatia (fig.1). The chronostratigraphy of the rotunda church and its surrounding architecture is still under question but recent radiocarbon results dated its foundations to 3rd century (*terminus a quo*), OSL results to beginning of the 6th century whilst the oldest grave (GR 17) within the context of the church is dated into mid-6th century[10], completely shifting previous relative dating to 9th century[11]. Furthermore, the unearthed material suggests Bribirska Glavica might have had contact with Northern Europe at some stage.[12] The results of the research have been indeed surprising and suggested the need for re-questioning established interpretations. Thus, the emphasis in the research shifted to new methods, specifically archaeometrical ones. This particular study relies on the study of burials and their paleodiet, in order to grasp a tiny glimpse of life of people buried on the site.

Understanding the subsistence of the studied population is usually approached through archaeo-botanical remains, animal bones, human teeth, faecal material, residue analysis and, indirectly, material culture. Stable isotope analysis is considered to be the most powerful method in understanding diet as it gives the insight into the diet of an individual thus allowing to understand differences between aspects such as gender, age, social status etc.[13] The study of paleodiet might even imply migration since the choice of food is usually affected by the environment.[14]

[9] http://www.varvaria-breberium-bribir.org/
[10] Ghica et al 2016: 33, 34.
[11] Jurković 1995.
[12] Ghica et al 2016.
[13] Fogel et al 1997: 284.
[14] Lightfoot 2009: 10.

In total 35 human individual and 9 faunal remains have been studied in order to obtain isotopic signals from carbon and nitrogen. The data have been interpreted within known archaeological, historical, anthropological and archaeometrical data.

There are two main questions which this thesis aims to answer:

1. What was the paleodiet of people buried in Bribirska Glavica?
2. What is the relationship of the paleodiet with chronology, burial context, social status, gender and pathology?

An attempt to answer this questions is based on the interpretation of stable isotopic results, taking into account all the possible variables. The approach to data is a twofold one: on the individual and the population level, both seeking patterns and observing the relationship of the individual isotopic signature to their own context.

CHAPTER TWO

2. CONTEXT OF THE SITE

This chapter aims to provide an overview into several aspects of the site: starting from the brief description of the position and the environment, the history or the research and the current situation, general historical background and archaeological remains followed by a brief introduction to the discoveries that inspired this thesis work. Moreover, published anthropological data are brought up in order to understand the burial context of samples.

2.1. THE ENVIRONMENT AND THE POSITION OF THE SITE

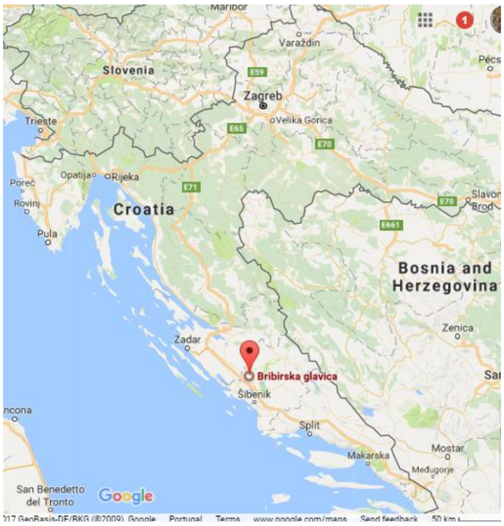

Figure 2:geographical position of Bribirska Glavica/ https://goo.gl/maps/iNirHbRDhTr

Bribirska glavica (ancient *Varvaria*), is set in the hinterland of Dalmatia, a region in the coastal Croatia, around 15 km from Skradin and 20 km from Šibenik. (Exact coordinates 43.925939, 15.842463. fig.2). It is a natural hilltop, 305 meters high, overlooking the fertile valley in the middle of a karstic Mediterranean landscape surrounded by a chain of mountains of Dinara in the horizon.[15] It stretches towards South-East as a relatively even natural plateau. (fig.3) On the Western side it contains a spring source of Bribirčica stream which irrigates the surrounding fertile land. This hill naturally dominates the flat surrounding area – overlooking Ravni Kotari and Bukovica, with mountains on one and the Adriatic coast with Šibenik archipelago on the other side.[16]

[15] Milošević 2015, 2.
[16] Krnčević 2005: 179.

Figure 3: aerial view on Bribirska Glavica /www.varvaria-breberium-bribirg.org

Ravni Kotari is considered to be a geographical area in the Northern part of Dalmatia. It is a level platform, around 150 m below sea level and within 25km by 35 km surface area. It stretches from Benkovac and Bukovica till Zadar and Skradin and is considered to be the most fertile area of Dalmatian karstic landscape. Thus, it has been extensively settled since Neolithic period and the area contains many significant archaeological sites. Because of the continuous human activity, the whole area is covered by deciduous oak in the inland, montane and sub-Alpine beechwoods near the area of Velebit mountains and evergreen forest on the coast and islands.[17]

The climate is mainly Mediterranean, characterised by hot and dry summers and cool and wet winters with the mean temperature value going rarely below zero degrees. The presence of water is rather seldom, except in the area of river Krka and Bribirčica stream (both near Bribirska Glavica – Krka within 15km and Bribirčica within 200 meters), ensuring constant water supply for irrigation. In autumn, the lower altitudes have floods due to heavy rains.

Most of the area sits on Cretaceous limestone and Tertiary sedimentary rocks covered by *terra rossa*; redish, clayish arable land perfect for pastures. The main cultivated species nowadays are olives, figs, vines, nuts and, on the lower altitudes, cereals. Transhumance is still practiced in modern days[18] and is indeed believed to be practiced on a much bigger scale in the past.

Bribirska Glavica as a site contains distinct archaeological remains dominated by recently restored medieval fortifications and ruins dating from Iron Age till 16th century and a Serbian orthodox cemetery around the modern church of St. Joachim and Anne. Most of the wall structures are conserved, some of them restored and the surrounding vegetation and touristic pathway is regularly maintained by the Museum of Croatian Archaeological Monuments and Šibenik City Museum, located in Split and Šibenik, respectively.

[17] Chapman et al. 1996: 33.
[18] Moore et al. 2007.

2.2.HISTORY AND STATE OF THE RESEARCH

Figure 4: excavation of the roman ruins on Tjeme, 1895. / http://www.varvaria-breberium-bribir.org/

The scholarly interest began in 19th century when F. Bulić[19], D. Alačević[20] and S. Frankfuter[21] wrote about the site. Following that, L. Marun announced in 1985 his goal to find the burials of the old royal Šubići family which were suspected to be in Bribirska Glavica. The excavations started in 1910 (fig.4) on the southern edge of Glavica plateau but were soon interrupted by World War I.[22] Because of the complex political situation, the excavation did not continue until 1960, this time led by S. Gunjača, director of the museum of Croatian Archaeological Monuments. His work continued until his retirement in 1977, consisting of a systematic exploration and conservation of the major parts of the Dol (Southern) area, together with the monastery, St Mary's Church and the fortifications. Moreover, Gunjača organised small rescue excavations on different areas of the plateau. Šibenik City Museum joined from 1980 along with the Museum of Croatian Archaeological Monuments in Split in the role of the maintenance of the site.[23]

Figure 5: trench 9, between the rotunda's apses walls, season 2015 / V. Ghica

In 2014 started a currently active excavation project which is concerning the area of the modern Orthodox Church of St. Joachim and Anne. (fig.5) It is a joint international project (Macquarie University Sydney, School of Theology

[19] Bulić 1882; 5: 65-6.
[20] Alačević 1882; 5: 147.
[21] Frankfuter 1884; 8: 154-5.
[22] Milošević 2015, 3-4; Milošević 2016: 50.
[23] Milošević 2015, 3-4.

Oslo, Archaeores Perugia, Rathsman arkitektkontor, Filozofski fakultet Zagreb, Museum of Croatian Archaeological Monuments Split and Šibenik City Museum). The main goal of the project is to understand Late Antiquity and Early Middle ages in the hinterland of Dalmatia, that is yet fairly unknown. The research echoed in Croatian media and Bribirska Glavica became one of the most famous archaeological sites in the country. The most prominent news were recent finds that imply possible presence of Norse-men,[24] therefore giving wind to the theories that "Vikings" reached and even settled Dalmatian hinterland in Early Middle Ages. That changes the whole understanding of the movements of Norse-men throughout Europe and challenges established theories. However, these speculations, together with the understanding the chronostratigraphy of the rotunda church are still hanging in the air.

2.3.BRIEF HISTORICAL BACKROUND OF DALMATIA (Late Antiquity and Middle Age)

Romanisation of Dalmatia spread steadily throughout 1st century AD via establishment of colonies and military camps, especially in the area where Bribirska Glavica is situated. [25] Urban structures were largely influenced by Romans, deeply reshaping settlements of the autochthone community – Liburnians.[26] Dalmatia was connected by the net of military roads which were used as trade routes.[27] The Romanisation lasted untill 3rd century, shaping majority of the areas except of the more remote ones.[28] How much the area was truly Romanised and how much it maintained the "Illyrian character" is still a matter of debates: from theories of a complete romanisation[29] till claims that the autochthone character still prevailed.[30] During 1st century AD Christian missionaries reached this area. However, archaeologically, the first evidence of Christianity dates back to 3rd century AD, mostly in Salona where the first churches were erected and first bishop started his service.[31]

The first significant turbulence happened in 4th century, during the division of the Empire in AD 395 and the occurrence of first barbaric invasions in Dalmatia, which was then

[24] Ghica et al. 2016.
[25] Zaninović 1999: 69.
[26] Wilkes 1969: 214, 366.
[27] Kuntić-Makvić 1999: 79.
[28] Wilkes 1969: 290.
[29] Evans 1989.
[30] Fine 1991:13.
[31] Jeličić-Radonić 1999.

part of the Prefecture of Illyricum in the Western Empire. Goths invaded the coast and some cities had to be abandoned due to the threat. The beneficial factor in the landscape of Dalmatia was a chain of mountain Dinara that made Goths slow down and fail in complete raiding. Hence all the refugees rushed towards Dalmatia and the area became crowded so that even the official supervision of the movements of people was issued in AD 419.[32]

Dalmatia wasn't under a tight control from either East or West Empire and became politically independent, especially from AD 454. During the Gothic conquest, Emperor Julius Nepos was ruling from Dalmatia and got murdered in AD 480. Following that, Odovacar, the kind of Italy, invaded Dalmatia. Zeno, the emperor of the East, realised he cannot really prevent Odovacar so he settled for the pledge of loyalty from him.[33] Later, he made a plan with the Ostrogothic leader Theodoric to fight against Odovacar and create an Ostrogothic kingdom which gathered West Balkans, Istria, Dalmatia and partly Pannonia under one rule. In that time many Goths settled Dalmatia.[34] Apparently the coexistence of locals with Ostrogoths wasn't peaceful, and those two groups couldn't settle well.[35] After Goths left, the area was partly destructed and vulnerable which made future invasions more successful. There is not much knowledge about Gothic settlements in Dalmatia, mostly due to the lack of study of Late Antique rural settlements.

During Emperor Justinian (AD 527 to 565) the Balkan area and Dalmatia were restored from invasions till AD 537. But, because of so many raids and higher taxes during 40 years wars, many peasants left their land and escaped, causing lack of money input via taxes, needed for maintaining wars. Hence Justinian couldn't hold the defence against incoming Slavic raids and he didn't give enough attention to Persians threating from the East.[36]

The Slavs are first mentioned in 5th century as a community north from the Danube River. However, it is still unclear if they were a homogenous group and if they even had a feeling of ethnic identity.[37] It is very possible that the term was artificially created by historic sources, the same as Romans classified most of the tribes in Balkans as "Illyrians".

Interesting is the coexistence of the two groups: Avars and Slavs and how they conquered and settled the lands. Seems that Slavs moved to Dalmatia due to population pressure

32 Wilkes 1969: 419.
33 Fine 1992: 21-22.
34 Evans 1989: 20.
35 Wilkes 1969: 424.
36 Fine 1991: 23.
37 Pritsak 1983: 414.

and the search for fertile land to farm around AD 550, a decade before the Avars.[38] They weren't so organised in conquering as Avars and rarely took over the cities with defensive fortifications. They mostly just settled the land and farmed it. However, when Avars arrived, fleeing the Turks in Central Asia, their conquering was more aggressive and efficient.[39] With them came many tribes besides a Slavic one, having Bulgar and Huns with additional smaller alliances. Interestingly, not much is known about Avar's religion, even though their burials were quite elaborated, buried with full equipment – weapons and horses. They most certainly did not adopt Christianity.[40]

Only after the Persian war ended in AD 591, Emperor Maurice managed to focus on defeating Avars[41]. Eventually, Slavs were the ones who actually settled the conquered areas, not Avars.[42] Procopius wrote about Slavs being a community without leaders, deciding everything in public gatherings and having a religion that believed in the God of lightning to whom they sacrificed the cattle, accompanied with nypmhs, demons etc. They lived in poor huts and were constantly moving.[43] Hence their settlements are not easy to detect and study.

It is assumed that Avars and Slavs reached specifically Ravni Kotari around the time of the fall of Salona which is suggested to be around AD 614[44] or AD 630.[45] Urban centres like Narona were destroyed with these raids but most of coastal Byzantine cities remained under Byzant and weren't conquered. How Avars and Slavs settled the area is again unclear. In *De Administrando Imperio*[46] it has been written that Avars did indeed settle the region.[47]

Early Medieval period is considered to be Old-Croat's even though the term is rather problematic. It is not yet clear if Croats existed as a separate group, as a subgroup of Slavs and if they even had their own identity. The neutral attitude is taken by international scholars, claiming that it is a culture with a mixture of Slavic influence and the Late Antique one.[48]

[38] Procopius VII. XL. 34
[39] Fine 1991: 30.
[40]Daim 1998: 83; Pritsak 1983: 397; Curta 2006: 65.
[41] Ibid. 32.
[42] Evans 1996: 295.
[43] Procopius: VII. XIV. 24.
[44] Fine 1991/Gimbutas 1971.
[45] Marović 1999.
[46] Written by Constantinus VII Porphyrogenitus (AD 908-959) in AD 950, dedicated to his son.
[47] Fine 1991.
[48] Evans 1989: 113.

The only contemporaneous historical source mentioning Croats[49] is *De Administrando Imperio*. According to it, the Croats were invited to the region by Emperor Heraclius (AD 610 – 641) to defeat the Avars under Byzantine. It is assumed that the Avars were defeated then and Croats and Slavs settled the area. However, when continuing to read another chapter, the story is changed and is mentioning 5 brothers and 2 sisters (without mentioning Emperor Heraclius anymore) coming from somewhere beyond Carpathians, from so called "White Croatia" and defeating the Avars in a seven year war. This story is rejected as a later input and was considered not to be written by Constantinus Porphyrogenitus.[50] Perhaps this historical occurrence has been manipulated throughout *De Administrando Imperio* to justify the rule of Byzant over the area.[51] Having in mind that there are some errors in the text, scholars have been rejecting it as a reliable source.[52] However, some historians do see it as reliable with some incorrect details mainly due to mentions of White Croatia in other sources.[53]

So, there are three main models describing arrival of Croats: First one claiming *De Administrando Imperio* tells an accurate story, meaning Croats came around AD 630.[54] Second one rejects the previously mentioned historical source, claiming that Slavs were settling the area and Croats arrived much later, in the end of 8th century since all mentions of Croats come from only after 9th century, when they were fleeing Franks. They are briefly under their rule before they free themselves and create their own states. That means Avars ruled 150 years longer (which is not supported in sources) and that all that is today connected to Old-Croats culture is actually a Slavic one.[55] And the third model suggests that Croats came with Avars in the 6th and 7th century. After Avars were defeated in the battle in Constantinople, Croats attacked Avars and freed themselves. And later on, during the Frankish campaign Croats could have been gradually developing as a community with a Croatian identity. This theory is supported by the lack of archaeological evidence for migration and any new import or change in a lifestyle. [56]

One is certain - the term Croats doesn't exist in any sources from the time of their apparent arrival. The earliest mentions come from AD 852 calling Trpimir 'the Dux of

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[49] It is interesting that while Croatis are mentioned only in this source, other contemporaneous sources do mention Avars and Slavs.
[50] Lightfoot 2009: 43.
[51] Chapman et al. 1996: 297.
[52] Curta 2001: 66; Evans 1989.
[53] Fine 2006: 18.
[54] Supek 1999.
[55] Klaić 1988; Margetić 1999; Evans 1996: 297.
[56] Evans 1989; 1996: 298.

Croats'.[57] The goal of this thesis is not to enter too deep into the discussion about the arrival and origins of Croats but rather to provide a concise historical background before approaching the interpretation of the results. Hence the discussion about the origins of Croats will stop here.[58]

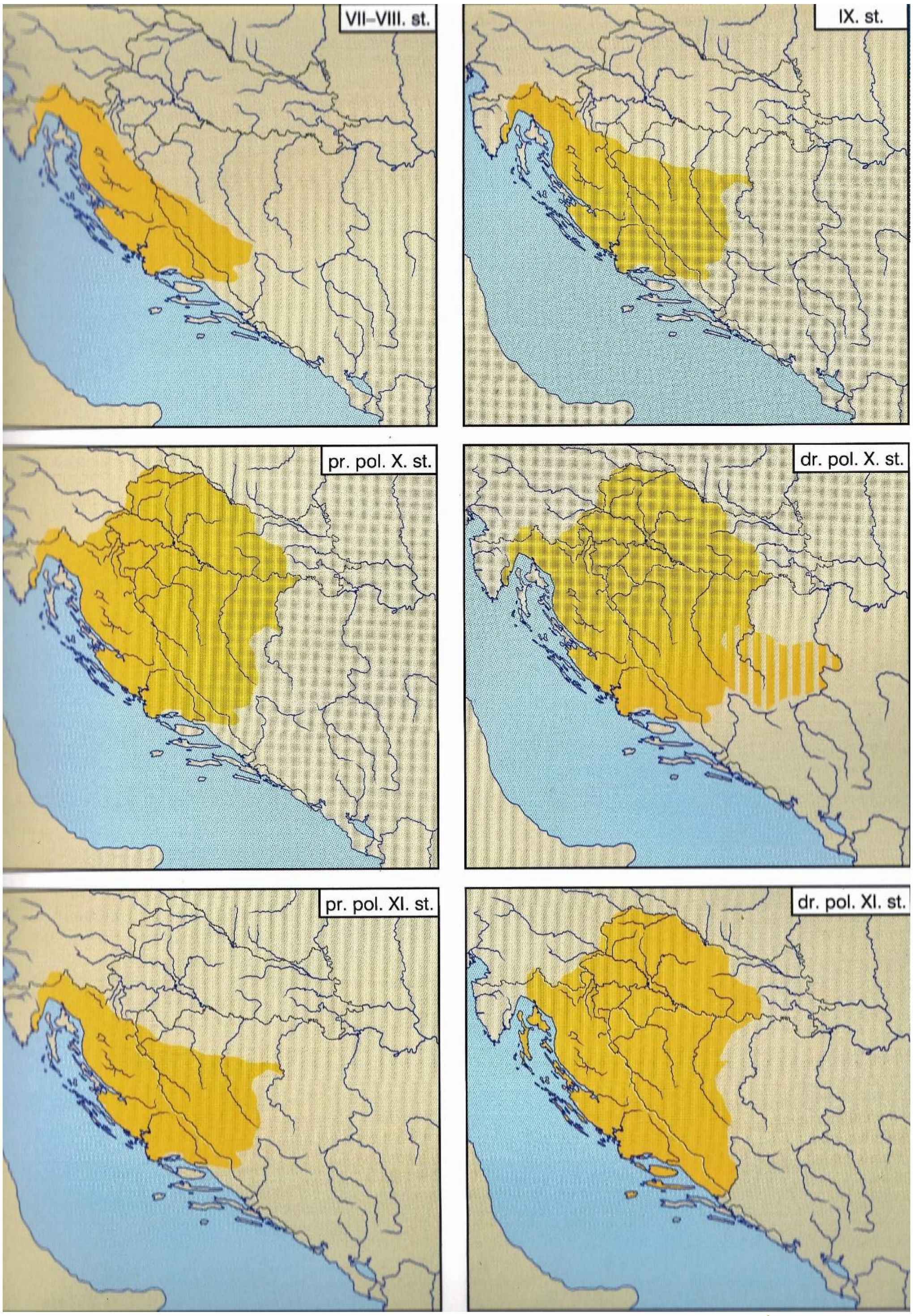

Figure 6: spread and formation of the area assumed to be settled by Croats, 7-11th century / Regan, Kaniški 2003.

[57] Fine 2006: 28.
[58] For further research see Fine 2006, Evans 1989, Margetić 1999 etc.

Franks were ruling over Dalmatia between AD 820 and 840 and that is considered to be the time when Croats settled and were Christianised. In that time, from middle of 9th century AD Slavs started settling within cities (not only empty land and mountains) and creating peaceful coexistence with locals. [59] Dalmatia was under Italian rule in AD 843 whilst in AD 875 the area came under Carloman, king of Franks. However, there was a certain independence led by a local ruler and when Carloman wanted to take over the rule, he was successfully fought back and Croatians became independent for the first time in history, in AD 876, led by prince Domagoj. The Croats created Croatia, sharing the rule with two princes, one in Pannonia and one in Dalmatia, divided into eleven counties.[60]

Tomislav, King of the Croats (AD 910-928) is considered the most important historical figure since he united Croatia for the first time, in AD 925, adding Pannonia under his state and creating the Kingdom of Croatia. (fig. 6) This unification was strengthen during the reign of the king Petar Krešimir IV (AD 1058-1074) who was considered to be the ruler of Croatians and Dalmatians. In that period all the cities in Dalmatia, formerly Byzantine, were slowly getting Croatianised. New cities such as Šibenik and Biograd were established and the capitals of the area were Nin, Biaći, Split, Knin and Solin. Significant was the fact that Croatian noble families had the right to choose their ruler amongst themselves. It was the period of strengthening of Croatian identity and independence.[61]

However, that didn't last long. As soon as Byzantine protection disappeared, Croatia was left vulnerable. Hence they made alliance with Venetia whose main goal was to keep the power of Croatian navy and army dependent on them and asked for big tributes from the cities.[62]

Hungary was also trying to get their hands on Croatian land. They defeated the last Croats king in AD 1097 and the Hungarian king Coloman continued to conquer Dalmatia during AD 1102-1105. During 12th century Dalmatia was under constant juggling of political dominance between Venice, Hungary and Byzantium. During the Fourth Crusade in AD 1204, the Byzantium power completely ceased and Dalmatia wasn't under their rule anymore. In 13th century Mongol invasion weakened Hungary so much that their king Bela IV had to hide in Dalmatia in AD 1241, in the fort of Klis. Mongols followed him and raided Dalmatia, but not for more than several years. Because both Hungary and Byzantium power over Croatia ceased,

[59] Raukar 1999: 184.
[60] Lightfoot 2009: 46.
[61] Praga et Luxardo 1993; Fine et al 2006.
[62] Fine et al 2006.

the local noble families had their authority and dominance additionally strengthen.[63] Most notable is the Šubići family from Bribirska Glavica that were considered to be the uncrowned kings of Croatia. [64]

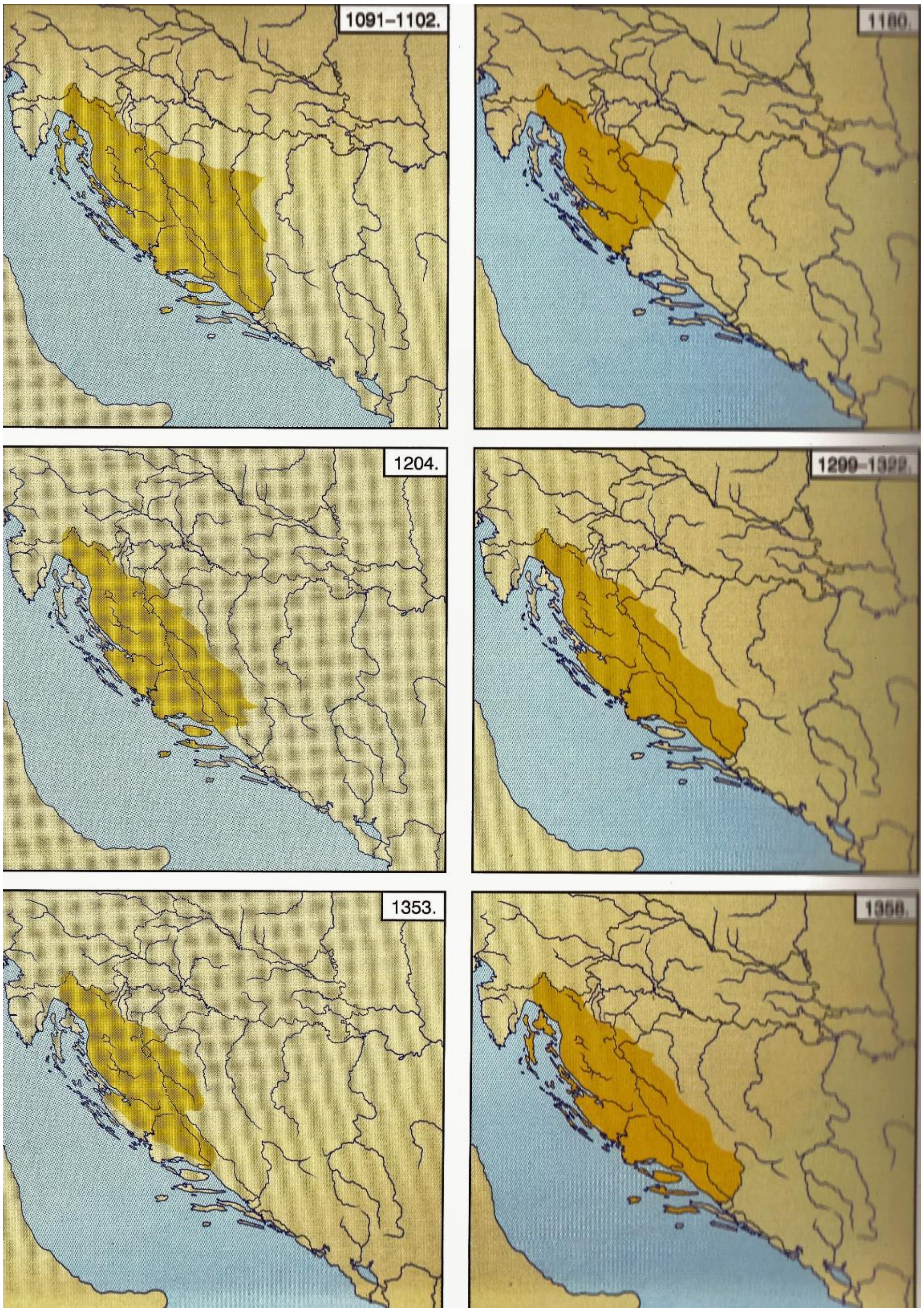

Figure 7: Area assumed to be settled by Croats 11-13th century / Regan, Kaniški 2003.

[63] Curta 2006; Fine et al 2006; Fine et al 1991.
[64] Jakšić 2009: 1.

In AD 1345, Dalmatia was struck by Black Death, one of the biggest pandemic events in history. It is estimated that 75 to 200 millions of people died in Europe and Asia due to this plague. This disease kept coming during next centuries but never in such a magnitude. That was the difficult period in Dalmatia, not only because of the disease but also economically. Interesting is the fact that on Bribirska Glavica there are several burials with signs of severe pathologies (both depicting leprosy and malnutrition) which will be discussed later.[65]

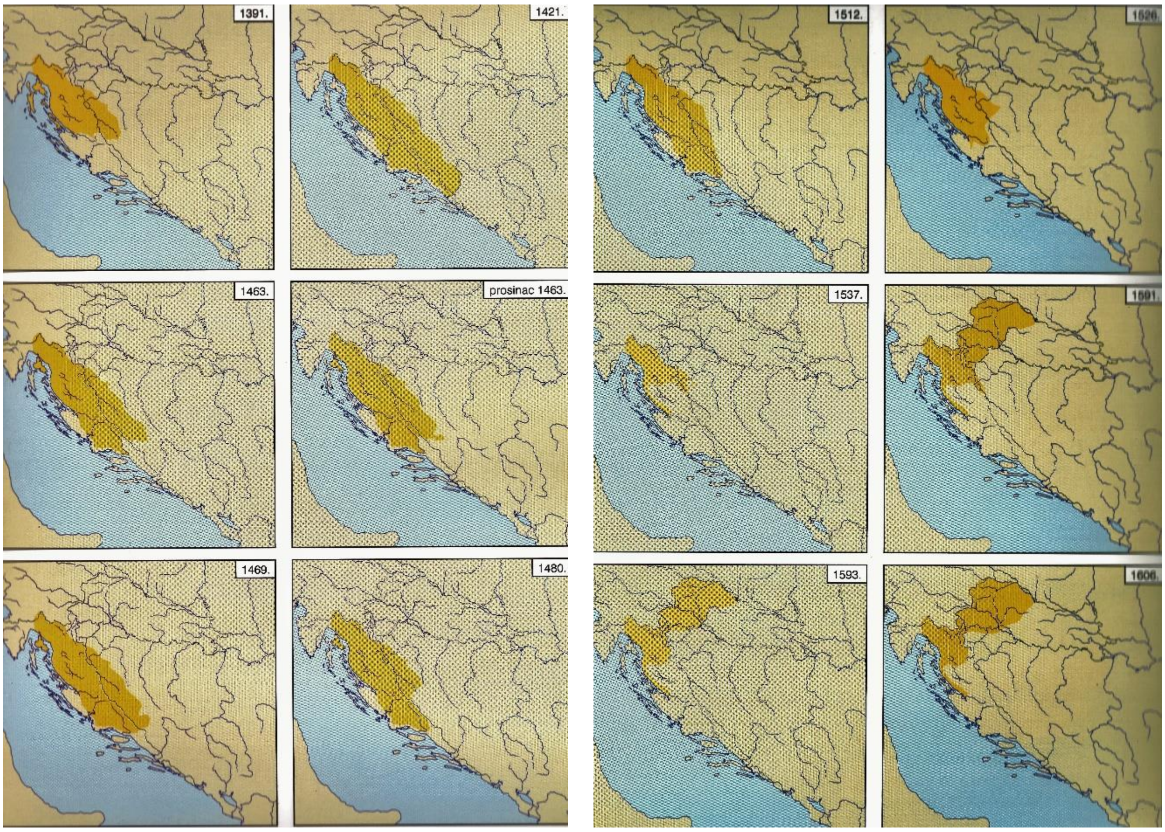

Figure 8: the area assumed to be settled by Croats, 13-16th century / Regan, Kaniški 2003.

Croatia lost its independence slowly, and in 14th century was even under the short rule of the Bosnian kind Stjepan Tvrtko. After his death in AD 1391, Croatia was constantly between Hungary and Venice. Shortly a noble family from Naples ruled over Dalmatia but they eventually sold their lawful rights over the land to Venice which continued to dominate from AD 1420 till AD 1797.[66] (fig. 8)

[65] Ravančić 2004.
[66] Praga et Luxardo 1993.

2.4. ARCHAEOLOGICAL AND HISTORICAL CONTEXT OF THE SITE

First signs of human occupation on Bribirska Glavica are recorded in Bronze Age (2500-800 BC)[67], even though the surrounding area has been settled since Neolithic period (6000-3000 BC).[68] The area has favourable conditions, with fertile land, spring source Bribirčica flowing through the valley and a natural uphill that gives a visual dominance over the area.

During the Bronze Age, autochthone community known under the name of Liburni settled the area and built first fortifications. There are remains of several burials from this period depicting rich grave goods and a highly developed urban society that were trading with Greek, Phoenician and Apennine communities. Liburnians were known for their thalassocracy (dominance over the sea and the strong navy)[69] over the Eastern Adriatic coast so there is no surprise that the city of *Varvaria*, as was called back then, became multicultural and prosperous during Iron Age (800-150 BC). Pliny wrote that the Liburnian community was divided into 14 civitates and Varvaria was the center of one of them[70]. It is not clear what the relations between those divided areas was but it is assumed that they were never completely unified, unless there was a threat and a common enemy.[71]

Varvaria was considered to be one of the most important Liburnian city and it never lost that significance during the Romanisation.[72] They established an alliance with Romans very early, in 2nd century BC, because they were threatened by neighbouring communities of *Delmatae* and by Greeks who came to colonise from the sea. That was the period when Roman legions extensively fought to conquer Delmatae, using Varvaria as a strategic point since it was lying in the area of the boundaries between those two mutually hostile communities.[73] These conflicts were described by Appian.[74]

The remains from the period of Classical Antiquity (7th century BC – 3rd century AD) include many ruins of villas and city houses decorated with frescoes and paved with polychrome mosaics. The archaeological material recovered from excavations range from metal objects, jewellery, glass, pottery, coins, and architectural decoration (very often with expensive

[67] Milošević 2015: 5.
[68] Krnčević 2005: 179.
[69] Pseud. Scymn. 370-376; N. Dam, Jacoby, FGrH ,93, App. Bell. Civ. II 39; Strab. VII.5.
[70] Nat.hist.III.
[71] Fine et al. 2006.
[72] Milošević 2015: 6. Illyr. 12 i 25; Čače 1898, 87..
[73] Ibid. 7;
[74] App. Bell. Civ. II 39.

Figure 9: stone sculpture of a dove, Bribirska Glavica (today lost) /Milošević 2015.

imported marble) to artefacts made of imported expensive material such as ivory. Moreover, there have been many remains of diverse cults discovered at the site, both from autochthone cult of Silvanus, Roman cults and oriental one such as Magna Mater[75] and Isis[76]. It clearly reflects *Varvaria* being a prosperous Romanised city with highly developed urban infrastructure in Antiquity and a high frequency of migration and trade.

Varvaria got the status of a *municipium* presumably in the time of Late Roman republic (ending 27 BC) as it is implied by the funerary epigraph of *T. Allius Saturninus* found nearby, in the Roman military camp *Burnum*. That meant that the Varvarians had more legal rights and the city was a self-governing one.[77]

Period of Late Antiquity (3rd to 7th century AD) is still vaguely understood. There have been scarse findings that imply existence of a church and remains of a mausoleum with two sarcophagi typologically dated to 4th -6th century.(fig.10) In that mausoleum a stone sculpture of a dove resembling the style of Justinian period has been found (and stolen later). (fig.9) It is assumed that it was a part of the roof decoration of the mausoleum, symbolising a Christian tomb. Other finds from this period include the bottom of a glass vessel with a Christogram, coin from Justinian era and a Gothic S-shaped pendant.[78]

Figure 10: opening one of the Late Antique sarcophagi in the mausoleum, season 2014 / V. Ghica

Early middle ages are a specifically interesting period for Croatian scholars since the arrival of so called Croats falls into 7th -8th century. This was the turbulent time of great migrations featured as a visible layer of destruction in Bribirska Glavica – both in high abundance of charcoal and in the way later architecture doesn't follow the previous one, implying that most of the site was demolished by that time. However, a mediaeval fortified

[75] Miloševoć 2015: 8.
[76] Kuntić-Makvić 1982. 156.
[77] Milošević 2015: 8.
[78] Ibid. 9.

burg, *castrum*, started to develop above previous ruins gaining more and more significance during Early Middle Ages.[79]

Name "Bribir" is mentioned for the first time in 10th century in *De administrando imperio* by *Constantinus Porphirogenitus* where he described the division of Croatia into 11 districts (županija) and referred to Bribir as being the centre of *Berbera* district.[80] This is one of the hints on the importance of the city at that time. The rotunda church that is now a focal point of this research is presumed to exist in that time and probably earlier too. The theory proposed till the recent excavation finds is that the rotunda church dates to 9th century and was used throughout Middle Age, based on the typology of architectural decorations found in previous years, before the *Varvaria-Breberium-Bribir* project.[81]

There are written mentions of the existence of the Bribir archpresbyter in 1229.[82] The patronage of the church and the whole medieval burg of Breber was in hands of the royal Šubići family, established in 11th century. They were referred to as *nobiles/comites/principes Breberienses* in the written sources[83] and gradually expanded their influence over the entire coast[84]. When Pavao Bribirski received (AD 1312) the title of the Lord of Bosnia, the Šubići family became the most powerful people in Croatian kingdom.[85] Pavao was an independent ruler (and the uncrowned king) of the whole Croatia. Thus Bribir became the main chancellery which even minted its own coins.[86] The research done on Bribirska Glavica revealed luxury late medieval materials, especially on the area of the monastery and the church of St. Mary in Dol where rich sculpture and other architectural decorations were uncovered. There were many sherds of pottery and glass imported from Italy and Spain, implying trade and demand for luxury goods. The main palace of Šubići has not been revealed yet. The fortifications were still following the Classical and Late Antique plan. The only novelty were circular towers added in 15th century and during the Ottoman period. (fig.8) Their purpose was to reinforce the protection during the period of wars with Turks, Hungarians and Venetians in 15th and 16th century when *Breber* was again demolished and its citizens took flight to the North of Croatia.[87] Since then Bribirska Glavica remains a dominant natural plateau with voiceless ruins overlooking the entire valley.

[79] Ibid. 11.
[80] Gunjača 1968: 207.
[81] Milošević 2015: 12.; Jurković 1995; Čače 1989.
[82] Karbić 2004: 4.
[83] Ibid.
[84] Curta 206: 397.
[85] Jakšić 2009: 11.
[86] Milošević 2015: 14.
[87] Ibid. 14.

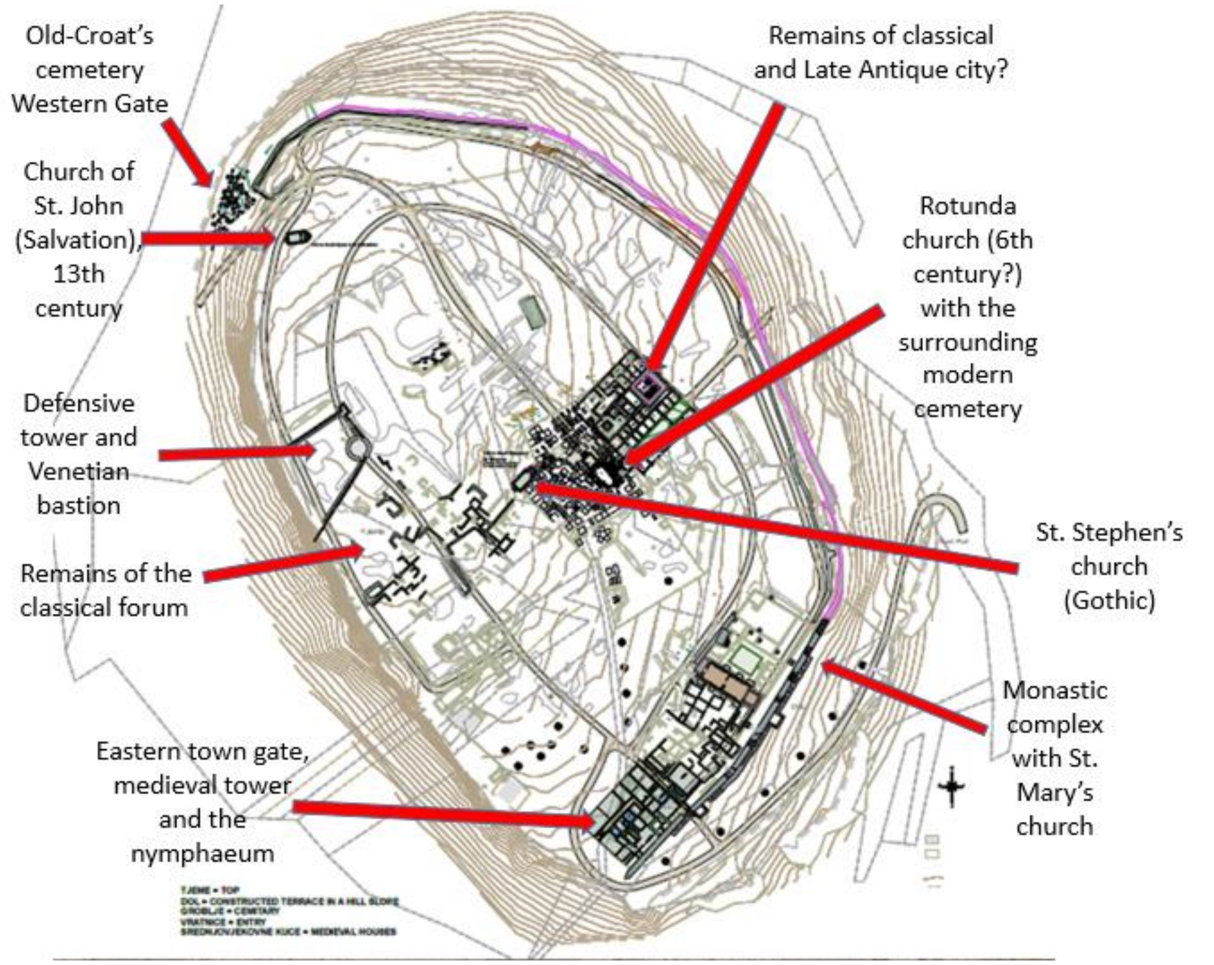

Figure 11: plan of Bribirska Glavica with main structures / P. Rathsman, explained by M. Dreshaj

2.5. REINTERPRETATION OF THE ROTUNDA CHURCH

Recent excavations (2014-2017) were focused around the visible remains of a rotunda church under the modern Orthodox one, surrounded by a Serbian cemetery. (fig. 11) From the first campaign, it started to be clear that the research will show unexpected results and re-question established theories.

Main idea was that the rotunda was built and used during the period from 9th until 11th century, in the so called Pre-romanic period, as it is stylistically classified by art historians. [88] It was considered to be a private *oratorium* of the royal Šubići family, established in the 11th

[88] Jurković 1995; Marasović 2009.

century.[89] However, what was confusing was the presence of a Late Antique *memorium* with two sarcophagi right next to the church, seemingly contemporaneous.[90]

During the excavations in 2015, the modern floor of the standing church was demolished and the team excavated till the bedrock, uncovering several different building phases of the church, the foundations of the rotunda and lots of burials in a complex stratigraphy. [91]

Figure 12: a fragment of an altar screen with inscribed "ieri rogavi" / M. Dreshaj

The attempt to date the rotunda church and understand its chronology is relying on typological assessment of architectural decoration, uncovered material and archaeometrical methods when possible. Relative dating via pottery sherds in archaeological layers proved to be unreliable since the assemblage showed diverse chronology – from Roman till Late Medieval period.[92] Architectural decorations gave an insight into relative chronology but yet remained debatable.

Thermoluminescence dates of the foundation of the rotunda church showed puzzling and very early date, being 3rd century AD. The orientation of the rotunda corresponds to Roman period buildings, implying that the church was incorporated into the the Roman urban fabric. Moreover, the oldest grave connected to the rotunda and dated via C^{14} method pointed to 6th century, therefore providing a *terminus ad quem* period of Late Antiquity. [93]

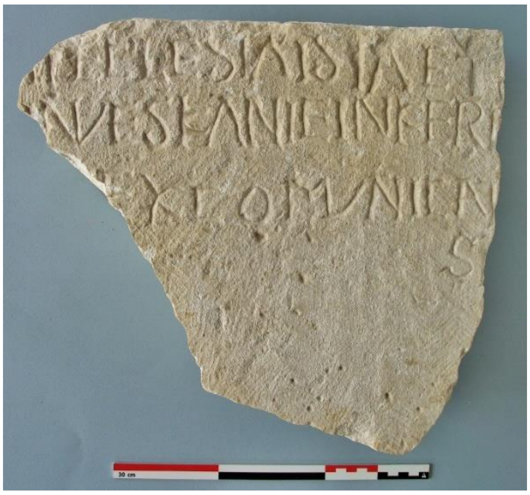

Figure 13: inscription mentioning *Skania inferior* and the Croatian duke Branimir,/ M. Dreshaj

Based on fragments of architectural decoration (fig.12) it has been suggested that the destruction of the rotunda church falls into 11th century, as a *terminus a quo*. However, that is still debatable.[94]

[89] Jurković 1995: 236.
[90] Bakulić 1996: 37.
[91] Ghica et al. 2016.
[92] Ibid. 19.
[93] Ibid. 33
[94] Ibid. 20.

A significant find in Croatian archaeology is an inscription with the name of a famous Croatian duke Branimir (9th century)[95] discovered as a reused stone block for a sarcophagi wall and also containing the mentioning of *Skania Inferior*, as the area of lower Scandinavia was called in Middle Ages[96], today modern Sweden (fig 13).[97] Interestingly enough is the fact that this inscription could be almost surely dated into 9th century and was most likely a dedicatory one, part of a longer text that was later reused.[98]

Following that, there has been another peculiar context that could be correlated to the inscription. Grave 17, sitting on the bedrock and placed next to and parallel to the wall connected to the rotunda church, has been assumed to be the oldest grave in this context. It contained a minimum of 10 individuals and had surprising finds: On the outer face of the only wall of this grave two identical triangular bronze bowls were found. Moreover, in the fill of the grave, a salt container made from an antler bone was uncovered together with the Byzantine golden earing (fig.14).[99] Interesting enough is the fact that the only parallels for the triangular bowls noted so far are the one found in Kilgulbin, Ireland[100] and in a female burial in Skei, Steinkjer, Norway, dated to 8th century and interpreted as an import from Ireland.[101]

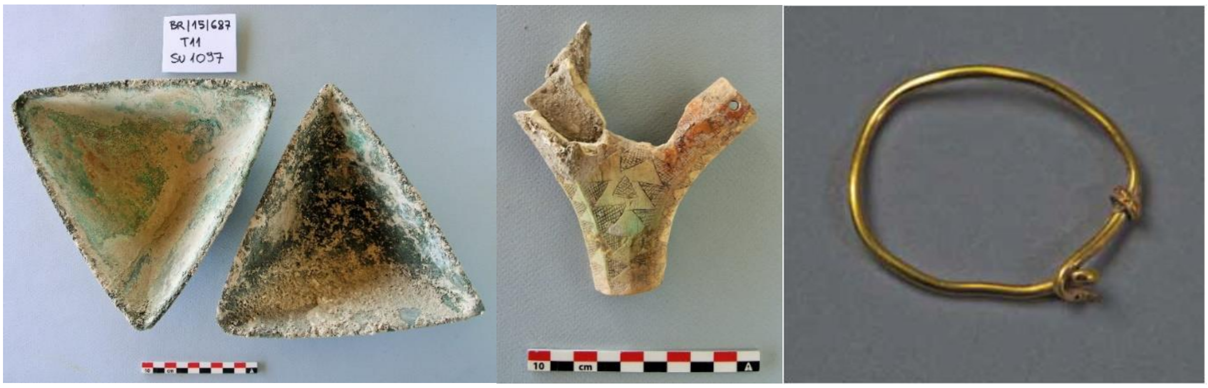

Figure 14: finds from grave 17: triangular bowls, antler container and a byzantine earing/ M. Dreshaj, A.Z.Alajbeg

Previous rotunda churches have been mostly classified based on the methods of relative chronology[102] and dated into a period of 8-11th century, as previously mentioned. However, the possibility that their roots lie in the early Christianity has not been discarded.[103] In total, 11

[95] Quite similar inscription has been discovered in Lepuri, Croatia, with the same style of carving: Jakšić 2000: 218-219.
[96] It is still debatable is it refers to the province of Skåne.
[97] Ghica et al 2015: 22.
[98] Ibid. 36.
[99] Ibid. 26.
[100] Graham-Campbell 2001:29.
[101] Heen-Petterson 2014: 14, fig. 14.
[102] Mainly by typology of the liturgical furniture and sculpture: Jurković 1995: 230-232.
[103] Jurković 1995: 230.

rotunda churches are discovered in Dalmatia with the one from Bribir having a unique planimetry.[104]

The connection of the rotunda church with Late Antiquity has been proposed via parallels such as *cella Septichora* in Sopianae/Pecs[105] and Ulpiana in Gračanice, Kosovo[106], dated to 4th and 5th century.[107]

To conclude - rotunda church in Bribirska Glavica shows the need of a complete shift in understanding this type of architecture in Dalmatia that has been so far dated three centuries later. Moreover, the finds implying the contact with Skandinavia and Northern Ireland have been ground-breaking and emphasise the need for more research.

To understand more the connection of the rotunda church and the surrounding urban fabric, next year campaign will most likely concentrate on the Eastern slope containing the Late Antique and Roman settlement. (fig.15)

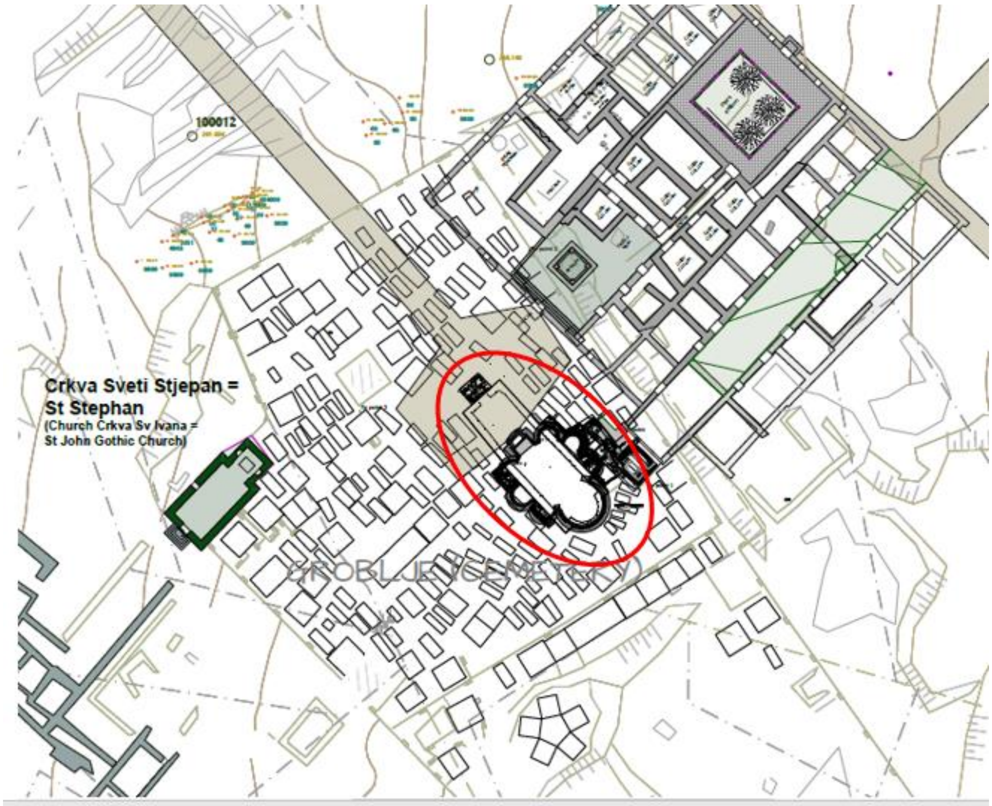

Figure 15: plan of the modern cemetery with the uncovered rotunda church. Within the red circle is the excavated area (seasons 2014-2017) /P. Rathsman

[104] Jurković 1995: 225, 226.
[105] Fülep 1984: 57-59./ Pozsárkó et al. 2007:84-90.
[106] Teichner 2011: 271-275. / Teichner 2014: 271-275. / Teichner 2016: 85-89./ Çetinkaya 2015: 67-78. / Çetinkaya 2015(b): 99-116.
[107] Ghica et al 2015: 35.

2.6. ANTHROPOLOGICAL AND BURIAL CONTEXT

Figure 16: example of a burial drystone structure, trench 8 / M. Dreshaj

Burials are organised in a cluster of either individual or overlapping graves and ossuaries. (fig.16) Mostly they consist of drystone structures or simple stone lining. (fig.17) There are signs of rearrangements and multiple use of tombs.[108] Most of burials have poor abundance of grave goods, usually consisting of metal belts and simple jewellery, except of few rare cases (GR 17, 16).

In total 35 human individuals are studied in this work. The choice of samples was biased towards the ones that are radiocarbon dated and representing various stratigraphic areas – from the earliest to the latest ones. Most of the graves come from season 2015 since those have been studied by anthropologists. The rest was chosen on basis of radiocarbon dating, crucial burial context and preliminary assessments of severe pathology.

So far, burials from Bribirska Glavica have been studied by Dr Željka Bedić, Dr Vlasta Vyroubal and Anita Adamić under the supervision of Dr Mario Šlaus from the Department of Anthropology within Croatian Academy of Science and Art (HAZU). The results from anthropological research on bones from 2014 and 2015 excavation season have been presented on a recent conference held in May 2017 in Bribirska Glavica.[109]

Figure 17: uncovered grave structures, trench 10, inside the rotunda church, season 2015 / V. Ghica

So far, only 2014th and 2015th osteological material has been studied and published so this subchapter will be limited to those data. However, this study also involves burials from 2016 and 2017 excavation seasons.

108 Ghica et al 2016: 12, 13.

109 5th Gunjača's days, Colloqium on Bribir II, May 5th-6th 2017.

The demographic image of the burial assemblage showed an unusual ratio – a huge majority consists of male and sub-adult individuals while female percentage is in a significant minority. As taken from the 110 distinguished analysed individuals - 38 were sub-adults, 20 females, and 52 males hence showing unequal ratio 0.73:0.38:1. Moreover, unusually high was the percentage of signs from animal activity (rodent gnawing), being 28.2%, the highest ever shown in Croatian context. These bones have either been exposed or shallowly buried before they were placed in respective burials.[110]

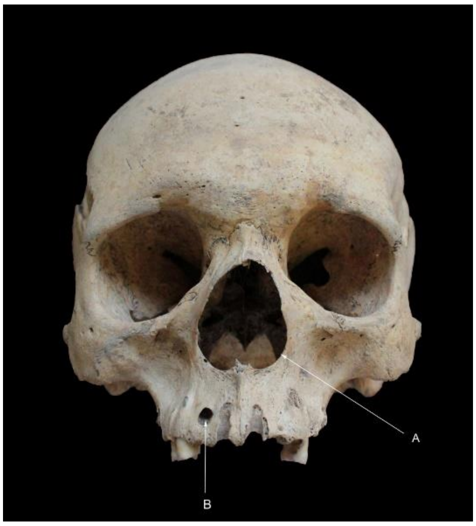

Figure 18: skull 1 from ossuary E1 showing signs of leprosy - A (widening of the nose opening), B (inflamation and hard tissue changes in the mandibula)/ V.Vyroubal, Ž.Bedić 2015.

There is a relatively high frequency of pathologies: 60% of linear enamel hypoplasia, 40% of nonspecific periostitis and 25.8% of cribra orbitalia. This suggest that individuals were living in poor conditions, with a significant amount of stress factors during the childhood and low health standards. Eleven individuals (E1) represent a certain or possible case of leprosy (fig.18) while one case shows signs of tuberculosis (Gr11/D). [111]

Statistical overview on the percentage and the nature of traumas shows that studied burials exhibit significantly higher trauma frequencies then those recorded in composite Late Antique and Medieval series in Dalmatia[112], as well as fractures. Furthermore, there is a high abundance of craniofacial injuries and *perimortem* fractures[113], showing also a clear positive distinction between sexes - meaning that males have higher frequency of injuries. Compared to another sites in Croatia, Bribirska Glavica dominates in number of injuries and reflects a pattern of previously noticed signs of increased violence on burials from Late Antique and throughout Medieval period.[114]

[110] Bedić, Vyroubal 2017; Ghica et al 2015: 46.
[111] Bedić, Vyroubal 2017.
[112] Dalmatia has been regarded as a relatively peaceful area during the Late Antiquity and the reign of the emperor Diocletian, as opposed to continental Croatia: see Novak et al. 2010: 1240. Bribir shows unusually high percentage of trauma even in that period.
[113] Perimortem fractures are the ones that are direct cause of death, showing no signs of healing.
[114] Adamić, Šlaus 2017.

When looking at the nature of traumas, it is important to note that high percentage of craniofacial fractures are indicators of deliberate violence[115] and in case of Bribir, parietal bones are the second most frequently affected areas.[116]

Figure 20: antemortem fracture with complete penetration in the frontal bone, Gr 10, B / V.Vyroubal, Ž.Bedić, 2016.

There were several antemortem fractures, being fractures that show signs of healing and are not direct cause of death, and one shoulder dislocation (GR2) featuring accidental injuries (E1, GR5, GR 11, GR12, S mausoleum), most likely because of the rugged terrain of the site. However, quite a significant amount of the recorded traumas on the frontal and parietal bones, skull fractures, are clear indicators of interpersonal violence (GR10/A, GR 12/C, D, GR 11/B,D, GR 13/E, GR14/B, sub-adult, E5, E6(2skulls), E11(2skulls) SU 1098(A)). There was, in grave 14, a case of an oblong fracture on the left side of the frontal bone on one sub-adult aging around 3 years and a triple fractured skull. Moreover, in E5, E6 and E11 there are 3 female cranial fractures.[117] Female individual from grave 12, T10/T13 is considered to be a possible case of domestic assault, as she has signs of 3 *antemortem* craniofacial fractures and several fractures on her chest, arms and around the knees.[118]

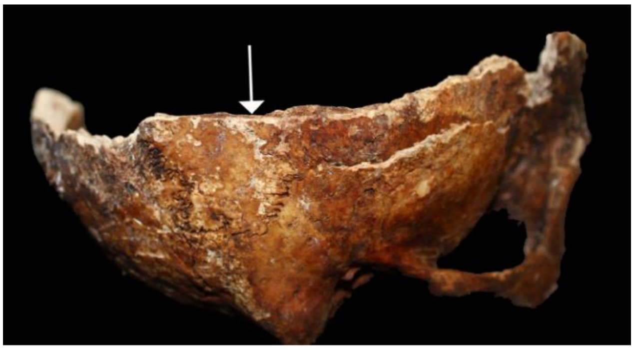

Figure 19: sharp parietal injury in the skull of a female individual, GR 3, T 9 /V.Vyroubal, Ž. Bedić 2016.

Perimortem fractures, the one that were a direct cause of death and don't show signs of healing, were also frequent. In the case of GR3 there is a long fracture on the parietal bone, partly going through the skull, (fig.20) Gr 7 displays seven *perimortem* injuries on legs and arms, GR 11 has injuries on the second cervical

Figure 21: osteochondroma on the posterior-medial side, left tibia (benign tumour on bones) / Vyroubal, Bedić 2016.

115 Walker 1989, 1997.
116 Adamić, Šlaus 2017.
117 Ghica et al. 2015: 45.
118 Adamić, Šlaus 2017, proceedings from the 5th Gunjača's days 2017.

vertebrae, Gr 14-E8 on second, third and fourth cervical vertebrae. Moreover, individual from Gr 16 has injuries on posterior-lateral side of left ulna and radius.[119]

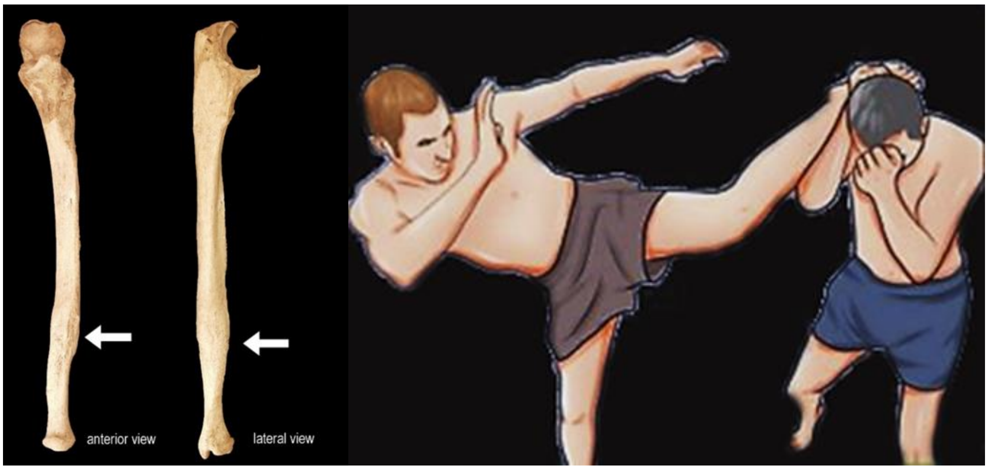

Figure 22: example of the "Parry" fracture - defensive wound on the ulna, GR 13, T11, B /A. Adamić, 2017.

Figure 23: sharp-angled gibbus on the vertebrae, case of tuberculosis, GR 11, T11, D / Vyroubal, Bedić 2016.

The data presented in the following table were extracted from the anthropological report of Vlasta Vyroubal and Željka Bedić, done under supervision of Mario Šlaus from Croatian Academy of Science and Art.

[119] Ghica et al.2015: 45-46.

Table 1: List of samples with anthropological assessment 0

No. of sample	Context	Observation, notes[120]
BRH 01	GR 05, T7	Male, 50-55 years **Pathology**: periostitis as inflammatory response – potential tuberculosis, leprosy, treponemal disease **Trauma**: antemortem fractures on distal third of the shaft of the right fibula and 5th, 4th and 6th right rib; rhomboid fossa[121], pronounced muscle attachments on *teres maior*, *pectoralis maior* and *deltoideus* on both humeri
BRH 02	GR 7, T 10, A	Male, 25-35 years **Pathology**: Stafne defect [122] and linear enamel hypoplasia[123] **Trauma**: 7 perimortem sharp edged injuries (acute edge on the distal part of the anterior side of the right femur due to the contact of the blade with the bone; same on the proximal half of the shaft of the anterior side of the left tibia; injuries on hands as smooth polished surfaces on the left capitate, left hamate and the head of metacarpal bone, thin layer of bone cut off on the anterior side of the intermediate middle phalanx and 1 antemortem (lateral angular deformity and overlap on the proximal phalanx) + ossification of the quadriceps ligament and Ahilles tendon (usually only in advanced age)
BRH 03	GR 17, T11, E11 *[124]	Not enough material for anthropological assessment C14 dated to mid 6th century

[120] Taken from the anthropological report of dr Željka Bedić and dr Vlasta Vyroubal.
[121] A benign defect along the medial end of the clavicle, usually due to intensive physical activity of muscles in shoulder girdle.
[122] Depression of the mandible on the lingual surface, uncommon defect that is not represented as a pathological lession. Usually developed between 11 and 30 years and due to systemic physiological stress.
[123] Developes due to increased amount of stress in childhood, when the enamel is formed.
[124] The burial context was too disturbed and this individua could not be identified based on age and sex. However, the context is very important since it contained unique burial goods. (see page 20)

BRH 04	GR 49, T9, HRU 1217B	No anthropological study available C14 dated to 885-995 AD
BRH 05	GR 16, T10, skeleton I	Male, 40-50 years **Pathology:** osteochondroma (fig.21) in the posterior-medial side of the left tibia (benign tumors on bones); mild degenerative OA[125] in the hips and knees **Trauma:** squatting facets on tibias *Chalice and paten
BRH 06	GR 17, T11*	No anthropological study available
BRH 07	GR 11, T11, B	Male, 45-55 years **Pathology**: mild degenerative OA in the right wrist and both knees **Trauma:** round antemortem fracture in the frontal bone of the skull, complete penetration, remodelled edges with no signs of inflammation
BRH 08	GR 11, T11, C	Male, 45-55 years **Pathology**: moderate degenerative OA on lumbar vertebrae; mild degenerative OA in shoulders, elbows, hips, knees, sacrum and 5th lumbar vertebrae; active periostitis on the left tibia **Trauma:** antemortem fracture on distal right tibia
BRH 09	GR 11, T11, D	Female, 45-55 years **Pathology:** 3rd lumbar vertebrae completely resorbed, 2nd vertebrae wedged; ankyloses of the 2nd, 3rd and 4th vertebrae making a sharp-angled gibbus (possible sign of tuberculosis); lytic lesion on the 1st lumbar vertebrae; mild degenerative OA in the right and left shoulders, both elbows, hips and knees **Trauma:** antemortem fracture on the left parietal bone

125 Osteoathritis

BRH 10	GR 60, T15, SU 1234	No anthropological study available (burial goods: spurs)
BRH 11	GR 12, T 10, SU 1116, B	Male, 40-50 years **Pathology**: mild degenerative OA in the right temporo-mandibular joint, mild healed periostitis in both fibulae, *Torus palatinus* (bony protrusion on the palate), severe degenerative OA in the right temporo-mandibular joint **Trauma:** antemortem fracture on the distal part of the left fibula with signs of healing
BRH 12	GR 47, HRU 1198	No anthropological study available
BRH 13	GR 12, T10, SU 1116, lower level, D	Female, 20-30 years **Pathology**: linear enamel hypoplasia **Trauma:** 2 antemortem craniofacial fractures in the frontal and one in the right parietal bone (fractures with no signs of inflammatory process), possible case of a domestic assault; pronounced muscle attachments for *teres maior* and *pectoralis maior* on the right humerus
BRH 14	GR 23, T7, HRU 1164, 1	No anthropological study available
BRH 15	GR 70, T18/E18	No anthropogical study available
BRH 16	GR 13, T11, B	Male, 40-50 years **Pathology**: antemortem lesion on the left side of the maxilla, penetrating the bone; mild inflammatory process on the maxilla and sinuses; severe degenerative OA on thoracic vertebrae; lytic lessions on medial sides on both tali (possible case of osteochondritis dissecans) [126]; mild porosity on nuchal arches, tali, calcanei, palatine and zygoma and skull bones; linear enamel hypoplastic defects on the mandibular canine

[126] It occures due to repetitive micro-traumas connected to vascular impairment. Symptoms are progressive ankle pain and dysfunction in skeletally immature and young adults.

		Trauma: antemortem "parry" fracture on the left ulna (fig.22)
BRH 17	GR 13, T11, C	Female, 35-45 years Pathology: mild healed ectocranial porosity[127] on both parietal bones; moderate degenerative OA in the left knee; mild degenerative OA in the left shoulder, right elbow and right hip Trauma: no.
BRH 18	GR 13, T11, D	Male, 30-40 years Pathology: lytic lesion on the right glenoid fossa; mild ectocranial porosity, mild degenerative OA in the hips; mild healed periostitis on the left tibia and fibula, osseous exostosis on the distal part of the left tibia Trauma: no.
BRH 19	GR 13, T11, E	Female, 35-45 years **Pathology**: mild degenerative OA in the right knee **Trauma:** antemortem fracture on the left side of the frontal bone with no obvious sign of inflammatory process; antemortem "Colle's" fracture on the right radius
BRH 20	GR 13, T11, F	Male, 35-45 years **Pathology:** mild healed ectocranial porosity, mild degenerative OA in the left shoulder, right elbow and both knees **Trauma:** no
BRH 21	GR 13, T11, G	Female, 25-30 years **Pathology**: mild healed periostitis on the medial side of the left tibia **Trauma**: no
BRH 23	GR 14, T11, SU 1078	Male, 20-25 years, **Pathology**: no **Trauma**: no

127 Usually sign of malnutrition and deficiency in vitamin A, D, C and anemia.

BRH 24	GR 15, T11, E10, B	Female, 15-18 years **Pathology:** mild ectocranial porosity; dental pearl on molar **Trauma**: squatting facets on tibias
BRH 25	GR 15, T11, E10, C	Female, 15-18 years **Pathology**: mild ectocranial porosity; schmorl's nodes[128] on thoracic and lumbar vertebrae **Trauma**: no
BRH 26	GR 15, T11, E 10	No available anthropological data
BRH 27	E24, T7	No anthropological study available Massive ossuary at the entrance of the cella of the hypogeum
BRH 28	E24, T7	No anthropological study available Massive ossuary at the entrance of the cella of the hypogeum
BRH 29	T7, SU 1283	No anthropological study available
BRH 30	GR 76, T18, HRU 1285	No anthropological study available Chalice and paten*[129]
BRH 31	E2, SU 1005, scull 2	No anthropological study available Possible case of leprosy[130]
BRH 32	E2, B1, SU 1005, scull 1	No anthropological study available Possible case of leprosy
BRH 33	GR 12, T10, SU 1116, A	Subadult, 9-10 years Pathology: mild porosity on the maxilla Trauma: no
BRH 34	GR 54, T9, SU 1232	No anthropological study available
BRH 35	GR 54, T9, SU 1231	No anthropological study available

[128] Usually associated with big physical stress. See Rajčić, Ujčić 2003: 806.
[129] Chalice and paten as burial goods are mostly found in graves of priests.
[130] Assessment for BRH 31, BRH 32 and BRH 36 was made by archaeologist during the field work. The anthropological expertise hasn't been conducted on those burials yet.

BRH 36	GR 77, T 21, HRU 1293	No anthropological study available Possible case of leprosy

Figure 24: sorted bones from Bribir, HAZU/ A.Adamić

Taking into account that all the burials were buried either inside or in the close proximity of the church, the common practice is that only the significant strata in society gets this opportunity as that area is considered to be a holy ground. That would explain odd demographic image and high percentage of interpersonal violence amongst male individuas. However, high level of pathologies such as cribra orbitalia and ectocranial porosity are suggesting the opposite – people buried in Bribir had problems with malnutrition and deficiency of vitamins A, D, C and anemia. Linear enamel hypoplasia, detected in more of the half of the analysed population suggests high levels of stress factors during childhood.[131]

[131] Rajić, Ujčić 2003: 806.

CHAPTER THREE

This sub-chapter provides the overview on the basic principles of stable isotopic technique applied to archaeological materials. Since the material studied in this research is bone, the structure and chemistry of it is discussed. After introduction to the technique and the material, the variations and potential impact on the results are discussed.

3.1. BONE STRUCTURE

Bone is the most occurring material on archaeological excavations, after pottery. Due to its durability, it remains as the only witness of the individual's life. The amount of information it can provide is impressive; from age, gender, pathology, diet, migration, water consumption and so on.

It consists of two phases: organic one that is the protein in the shape of a collagen (1/3rd of the bone) and the inorganic mineral phase, being biological apatite (calcium phosphate, 2/3rd of the bone).[132] Organic part gives the elasticity whilst mineral part provides strength and rigidity. Visible are two types of bone structure: compact (cortical) on the surface and spongy (cancellous) bone forming the interior. (fig.25)[133]

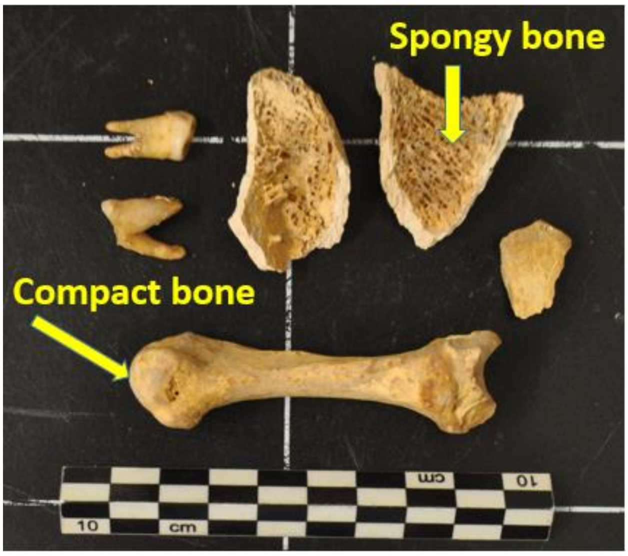

Figure 25: example of the compact and spongy part of the bone / M.Dreshaj

Bone consists of three main types of cell (according to their functions): osteoblasts which induce bone formation, osteoclasts which disintegrate bone tissue and osteocytes regulating daily metabolism.[134]

The mineral part of the bone, biological apatite, is a naturally occurring mineral hydroxyapatite with a chemical formula $Ca_{10}(PO_4)_6(OH)_2$.[135]

[132] Tortora 1989; Burton 2008.
[133] Turner-Walker 2007.
[134] Tortora and Nielsen 2012.
[135] Krueger and Sullivan 1984; Merwe 1991, Lee-Thorp et al. 1989.

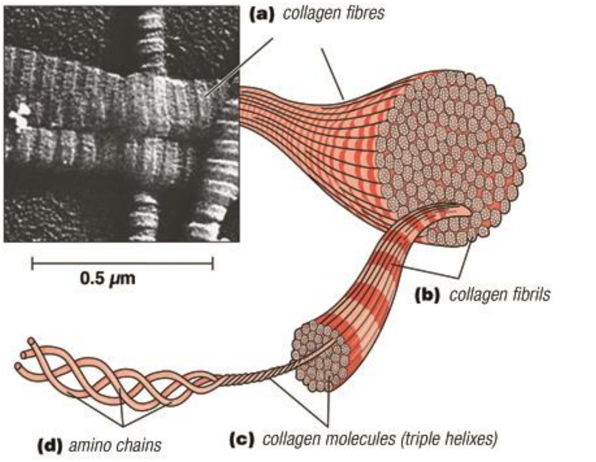

Figure 26 structure of collagen fibres / https://www.scitecnutrition.com/en/catalog/guide_to_vitamis/images/guide_to_vitamins-05.jpg

Organic part of bone is made of collagen, a structural and insoluble fibrous protein consisting of three polypeptide strands composed of three types of amino acids: glycine, proline and hydroxyproline. Triple helices are twisted into a larger molecule or fibrils of collagen and collagen fibers. (fig.26)[136] Collagen consist of 90% of type I collagen and 10% of NCP (non-collagenous protein) and mucopolysaccharides.[137] Amino acids can be divided into essential and non-essential ones, both deriving from consumed protein. However, non-essential amino acids can be synthesized by the body and not be directly connected to the diet which is a quite important aspect in paleo-dietary research.[138]

Collagen reflects only the protein intake, not the whole diet like bioapatite. However, its relative resistance to degradation and contamination makes it a desirable source for paleo-dietary research.[139] Collagen preservation 0is usually indicated through C/N ratio and %N content of the whole bone whilst for hydroxyapatite usually ratio of carbonate to phosphate peaks and level of crystallinity from FTIR and XRD are observed.[140]

Bone is a living tissues and it changes over time, going through overall turnover every several years: changing shape, size and structure as a response to physiological demands. In this way it regenerates and repairs the damage from everyday stress, replaces the parts that are not fit for its function anymore and provides calcium during the pregnancy and breast feeding. Even though the generally accepted rate of turnover is considered approximately ten years, it has been suggested that it isn’t uniform but depends on sex and age[141] and very likely from the part of the skeleton.[142]

136 Patte 1994, Lightfoot 2009.
137 Burton, 2008.
138 Katzenberg 2008.
139 Schoeninger, Moore 1992.
140 Ambrose 1989.
141 Hedges et al. 2007: 815.
142 Manolagas and Jilka 1995: 305.

3.2. BASIC PRINCIPLES OF STABLE ISOTOPES METHOD

Everything we eat and drink, together with the environment we live in leaves a chemical fingerprint in our bodies. This is reflected in the bone via isotopic ratios, allowing us to have a deep insight into the life of past communities.

Isotopes are atoms of the same element, same number of protons but different number of neutrons in their nucleus, giving them a different atomic weight. Despite having almost the same chemical, their physical properties are different. This difference causes fractionation - the process which depicts a ratio of heavy to lighter isotope different to that of the reactant, depending on the metabolic processes. Two types of fractionation occurs: thermodynamic and kinetic. Thermodynamic is a temperature depended reaction and occurs in environments that are in equilibrium while kinetic ones occur in incomplete and unidirectional reactions, mostly in biological reactions. The lighter isotopes tend to be more mobile. Moreover, bonds in heavier isotopes have higher dissociation energies and it is more difficult to break them than the ones in lighter isotopes.[143] Isotopes can be stable, having constant number of protons and neutrons or radioactive and decay over time. In assessing paleodiet, stable isotopes are used.

Analysis of tissue (in this case bone) provides data on the consumption pattern and the results are depicted as a fractionation pattern (either enrichment or depletion) between isotopic composition of the diet and the consumer tissue.[144] This stepwise enrichment following the food chain (from primary producers to top consumers) is called a trophic level. The isotopic results reflect the diet over a longer period of time, so the short term dietary variations are not recorded in the isotopic signal.[145]

$$\delta X = \frac{R_{sample} - R_{standard}}{R_{standard}} \times 1000$$

Equation 1: formula for obtainind stable isotopic ratio according to the comparison of sample and the international standard

The delta (δ) notation symbolises the isotopic composition of an element and the unit of measurement is per mil (‰). (equation 1) The measured values have to be compared to international standard.

Positive δX means that the sample has a higher ratio of heavy isotopes while the negative value represents a lower ratio than the standard. (equation 1)[146]

[143] Lightfoot 2009: 53.
[144] De Niro, Epstein 1978: 502.
[145] Lightfoot 2009, 1.
[146] Craig 1957: 135.

For isotopes of carbon, the international standard is PDB (Peedee belemnite) which is a cretaceous limestone containing more ^{13}C then all dietary sources on this planet.[147] The standard for Nitrogen is AIR, being the natural abundance of $\delta^{15}N$ in the atmosphere, having the assigned value of zero.[148]

Carbon from the bone collagen is used to distinguish C_3 and C_4 types of plants and between marine and terrestrial diet. Nitrogen isotopes are used to estimate the trophic levels and the amount of protein intake.[149]

3.3. CARBON STABLE ISOTOPES

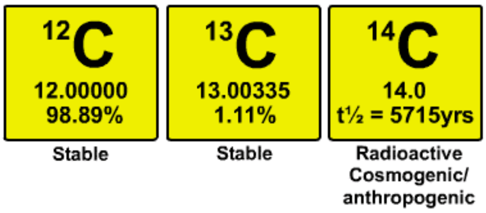

Figure 27: isotopes of carbon / http://web.sahra.arizona.edu/programs/isotopes/images/carbon.gif

There are two stable isotopes of Carbon: the more abundant ^{12}C and less abundant ^{13}C. (fig.27) Plants obtain carbon via CO_2 from the atmosphere through photosynthesis. The isotopic ratio depends on the isotopic fractionation during the absorbance, the amount and isotopic composition of CO_2 and how much of it is lost during the respiration process.[150] All flora contains less ^{13}C than the atmosphere due to discrimination against heavier isotopes during the uptake of CO_2. Precisely this discrimination reflects the metabolism of the plant and in which environment did the process occur, distinguishing so called, different photosynthetic pathways which are then reflected in the consumer's tissue, allowing a dietary reconstruction.

There are three groups of plants according to the uptake of CO_2:

1. C_3 (Calvin-Benson) group having $\delta^{13}C$ values between -35 and -21‰.
2. C_4 (Hatch-Slack) group with values between -20 and -6 ‰.[151] (fig.28)
3. CAM (Crassulacean Acid Metabolism) group having values between C_3 and C_4, with the range of -14 to -33‰.[152] These plants are rarely included into archaeological interpretation because plants like cacti, agaves and euphorbias are

[147] Craig 1957: 135.
[148] AIR: Mariotti 1983.
[149] Katzenberg 2008.
[150] O'Leary 1988.
[151] Ibid. 329.
[152] Bender et al. 1973.

usually not part of the subsistence within European archaeological context. Hence they will be only mentioned and not discussed further.

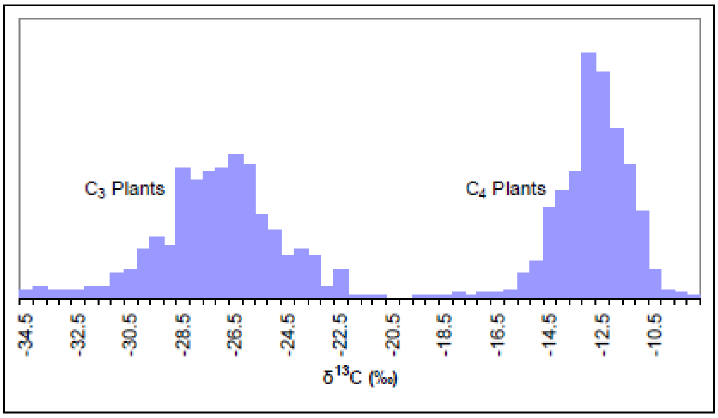

Figure 28: isotopic ratio for C3 and C4 photosynthetic pathways /O'Leary 1988.

C_3 and C_4 plants got their names because of the different enzymes used in fixing carbon dioxide which result in forming molecules with either three or four atoms of carbon in the initial stage of photosynthesis.[153] C_3 plants are 90% of the world's vegetation, consisting of trees, shrubs, herbaceous plants, grasses, legumes, wheat, rice etc. These plants are typical for European environment while C_4 plants, being mainly sorghum, millet, maize and sugar cane originate from savannah and tropical areas. In this case, only millet can be of relevance.

3.3.1.C_3 PHOTOSYNTHESIS

Having a C_3 isotopic signal in the context of European archaeology is the most common as most of the local plants use C_3 photosynthetic pathway.

Carbon dioxide from atmosphere enters through stomata (openings in the leaves), dissolving in the cell and diffusing into the chloroplast where carboxylation occurs. It is a reaction where carbon dioxide is combined with ribulose bisphosphate. Isotopic fractionation happens during the diffusion of CO_2 through boundary thin layer of air on the leaves, going through stomata into the internal air space and finally carboxylation which is an irreversible process.[154] Since the amount of carbon dioxide uptake is more determined by the carboxylation then the rate of diffusion (which partly influences), the fractionation during that process is significant on establishing isotopic ratio.[155]

There are several things that might influence the fractionation and therefore an isotopic signal: the amount of CO_2 [156] and the carbon isotopic ratio in the atmosphere,[157] water

[153] Sharp 2007; Schwarz, Schoeninger 1991.
[154] O'Leary 1981: 559.
[155] Ibid. 330.
[156] Park and Epstein 1960: 115.
[157] Arens et al. 2000.

availability, from the amount of rain, characteristics of the soil, depths of the plant roots, rate of evaporation from leaves, temperature, light, [158]altitude[159], salt related stress (affects the stomata)[160], availability of nutrients,[161] the "Canopy effect"[162], differences between plant species such as leaf thickness[163], seasonal changes etc. Moreover, differences in plant's response to the environment[164] and intra-plant differences may also affect the isotopic ratios.[165]

3.3.2. C_4 PHOTOSYNTHESIS

Plants using C_4 photosynthetic pathway are usually found in hot tropical surroundings. From C_4 plants only millet could have been consumed in such a quantity that it can leave an isotopic signature within archaeological context. All other plants in Europe belong to C_3 group.

The process of carbon dioxide entering through stomata is the same like in previously described photosynthesis but here it is converted to HCO_3^- (hydrogen carbonate) as a product of the activity of carbonic anhydrase. It is carboxylated to oxaloacetate and catalysed by phosphoenolpyrucate carboxylase in the mesophyll cells. Then, when in bundle sheath cells, it is converted into malate and aspartate. Carbon dioxide is then produced, carboxylated and a part of it is released into the bundle sheath cells. Following that, it is again recycled by phosphoenolpyrucate carboxylase. This process is irreversible but certain amount of CO_2 leaks and hence there is a discrimination. So, the isotopic fractionation again relates to the diffusion of atmospheric carbon dioxide into the internal air space, the carbon anhydrase and phosphoenolpyrucate carboxylase recycling.[166] C_4 plants have a different pathway due to the necessary resistance to heat, water and light stress. Hence they are not so influenced by environmental factors and have less variations in $\delta^{13}C$ isotopic values. Their carbon fractionation is small, resulting in more enriched $\delta^{13}C$ isotopic composition which are closer to the atmospheric CO_2. They are mainly affected by the action of phosphoenolpyrucate

[158] Yakir and Israeli 1995: 2150.
[159] Hultine and Marshall 2000: 32.
[160] Van Groenigen and Van Kessel 2002: 491.
[161] Bender and Berge 1979: 118.
[162] Merwe and Medina, 1991; Broadmeadow et al. 1992. 437.
[163] Hanba et al. 1999: 635.
[164] Lightfoot 2009: 63.
[165] Waring and Silvester 1994: 1207.
[166] O'Leary 1981: 560.

carboxylase and the bundle sheath leakage at the end of the process.[167] However, variations between types of plants and species do exist and affect the isotopic ratio.[168]

3.3.3. AQUATIC ECOSYSTEM

Worth mentioning are the aquatic plants which are less studied and a significantly more complex in comparison to terrestrial plants. Most of them do use C_3 but some of them use C_4 pathways. They have extremely variable results in isotopic ratio.[169] Their photosynthesis is based on the CO_2 uptake from the atmosphere and in a dissolved state, coming from many sources such as rocks, soil, decaying organic matter, faecal pellets etc. All this sources have very different isotopic values which affects the results.[170] Moreover, the availability and the diffusion of dissolved carbon dioxide is important (since the diffusion in water is much slower than in the atmosphere), as are the speed of the stream, the surface area, light intensity, nutrient availability, pH and physiological factors such as species and type of plants.[171]

Marine plants usually have additional variations such as carbon isotope patterning in the ocean that is correlated to the water depth and the decay of organic matter. Furthermore, every ocean and sea have different $\delta^{13}C$ values.[172] Even though the variability is huge, it is possible to distinguish marine sources from terrestrial foodweb as a trophic level increase.[173]

Freshwater plants are extremely variable and studied even less then marine ones; ranging from -50‰ to -11‰, and affected by seasons, stream direction, formation (river or lakes) etc.[174] Even though it is indeed possible to distinguish freshwater aquatic plants in isotopic signature, it is yet difficult and requires a lot of further research.

3.3.4. Diet to body enrichment – interpretations of the isotopic values

Trophic shift is a difference in consumer isotopic composition relative to their diets.[175] It is defined as an enrichment value between the prey and the predator. Studies showed that the enrichment of $\delta^{13}C$ values between diet and collagen is typically around 0.6 until 6.0 ‰. The

[167] O'Leary 1988: 329.
[168] Lightfoot 2009: 64/ Hattersley 1982: 144/ Tiszen and Boutton 1989: 170.
[169] Smith and Epstein 1971.
[170] Allen and Spence 1981: 279.
[171] Osmond et al. 1981: 120./Popp et al. 1997: 72.
[172] Kroopnick 1985: 61; Lightfoot 2009: 65.
[173] Schoeninger and DeNiro 1984.
[174] Lightfoot 2009: 66/ Keeley and Sanquist 1992/Telmer and Veizer 1999: 70.
[175] Nechlin 2015: 6.

average, however, would be around 1-2 ‰.[176] There are some differences in the enrichment values – for example, large animals tend to have higher enrichment values then smaller ones.[177] It is not yet fully clear why and where there are variations in fractionation. There are several variables: isotopic heterogeneous diet cannot be homogenously digested and absorbed and that can lead to large fractionation between the diet and the body isotopic values, both in terms of digestion, absorption and synthesis of the amino acids.[178] Furthermore, it depends on the diet itself – type of diet (abundant in protein or not) and circumstances (starvation, for example). Therefore it is impossible to have a fixed value representing a constant offset in the $\delta^{13}C$ isotopic composition between the predator and the prey.[179]

The estimated variability of $\delta^{13}C$ considered to be still reflecting homogenous diet is around 0.3‰.[180] However, the differences in tropic levels are not significantly distinguished so this method is used to distinct the contribution of C_3, C_4 and CAM plants in the diet.

3.4. NITROGEN STABLE ISOTOPES

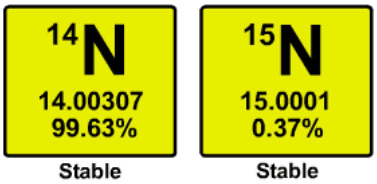

Figure 29: isotopes of nitrogen / http://web.sahra.arizona.edu/programs/isotopes/images/nitrogen.gif

There are two stable isotopes of nitrogen: the more abundant ^{14}N and less present ^{15}N. 99% of nitrogen is contained within the atmospheric molecule N_2.[181] (fig. 29)

Plants take nitrogen from the atmosphere (either via bacteria and soil microorganisms or directly from air) through three stages: fixation, nitrification and denitrification. During the fixation (via nitrogen fixing bacteria), atmospheric nitrogen is converted into ammonia which is incorporated into living tissue. During the nitrification, ammonia is transformed into nitrate by oxidation. Following that denitrification occurs, being a process where nitrate is converted into molecular N_2 by anaerobic and aerobic bacteria and fungi.[182]

176 Bocherens and Drucker 2003: 47.
177 Ambrose 1993: 101.
178 Hare et al. 1991: 283; Lightfoot 2009: 69-70.
179 Hedges 2004: 37; Lightfoot 2009: 70.
180 Lovell et al 1986:52.
181 Ambrose 1993.
182 Sharp 2007.

Generally, isotopic values of the soil are positive and around 2-5‰, being enriched in ^{15}N compared to atmosphere due to the loss of ^{14}N during the decomposition of nitrogen sources.[183] There are variabilities though, mainly due to various conditions such as isotopic ratio of soil,[184] water availability, climate[185], temperature, salinity[186], the amount of animal matter in the soil[187], nutrient availability[188], altitude and topography, type of plant[189] etc.[190]

From plants, the nitrogen is passed into animals via diet. The isotopic composition of nitrogen increase with each trophic level (along the stages of food chain) - from plants, through herbivores and finally to carnivores. The difference between the prey and the predator is between +2.4 and +4.8‰.[191] In marine food chain, the increase is more intensive[192] since the food chains are longer.[193] Thus, nitrogen isotope analysis is very useful in distinguishing the amount of marine food in diet. But, it is important to note that some marine food sources have low values – such as mussels, oysters and some Mediterranean fish.[194]

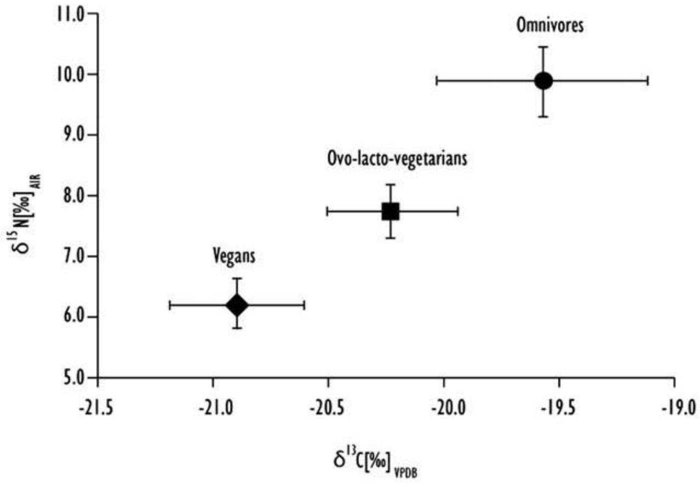

Figure 30: figure showing trophic levels according to nitrogen and carbon isotopes / Reitsema 2013.

The relative terrestrial $\delta^{15}N$ values would be: non-leguminous plants +3‰, herbivores from +4‰ to +7‰ and, finally, carnivores +7‰ to +9‰.[195] In marine environment, the $\delta^{15}N$ are higher – for example, around +15‰ and +20‰ in marine carnivores like seas lions and seals.[196] (fig. 30)

It is not yet fully understood how the trophic level enrichment

[183] Lightfoot 2009: 72.
[184] Shearer et al. 1978.
[185] Heaton 1987: 238.
[186] Ibid. 241.
[187] Bogaard et al. 2007: 338.
[188] McKee et al. 2002: 1068-1069.
[189] Virginia and Delwiche 1982: 319.
[190] Sharp 2006.
[191] Bocheres and Drucker 2003:47; Wada et al 1975:142; Schoeninger and DeNiro 1984; 1978; Minagawa and Wada 1984.
[192] Wada et al 1975: 142.
[193] Ambrose 1990.
[194] Pinnegar and Polunin 2000; Lightfoot 2009: 75.
[195] Van der Merwe 1992: 250.
[196] Schoeninger and De Niro 1984: 627.

occurs but the connection with the fractionation during the amino acids break down is considered partly responsible for it.[197]

Most paleo-dietary studies tend to assume that elevated $\delta^{15}N$ values represent a high protein diet. Some studies show that there is a difference in 1.5‰ to 2‰ between high protein and low protein diet.[198] On the other hand, there is a study showing the opposite – the values were low in a high protein diet.[199] However, most of the studies rely on the premise that high values reflect a high protein intake.

Besides that, nitrogen isotopic composition reflects several other factors that should be discussed:

When breastfed, children tend to have higher trophic level than the mother and elevated nitrogen isotope values. Hence, this strategy can be used in studying infant's nutritional dependence on its mother.[200]

Studies have shown that stable isotope method might reflect physiology and metabolism during pregnancy and lactation[201], nutritional stress[202] and certain diseases such as osteoporosis[203]. It is due to connection of diet and health. The stress might influence fractionation and hence produce different values.

When it comes to age and sex, current research didn't show any correlation. However, there are theories that collagen is affected by the age due to increased reutilisation and recycling of collagen during the lifetime. There could be a physiological change in the way carbon and nitrogen are processed in the body according to the age.[204] However, the archaeological studies done so far, especially the ones on a larger scale, show that there is no significant change in values with age, at least not so much that it has to be taken into account when doing an isotopic study, except of the case of breastfeeding children.[205] Hence age should not significantly affect the way both carbon and nitrogen isotopes are processed.[206]

When it comes to gender, there hasn't been any difference in isotopic values. Except of statistical difference between women having a higher prevalence of dental carries compared to

[197] Minagawa and Wada 1984: 1138.
[198] Sponheimer et al. 2003: 83.
[199] Robbins et al. 2005: 538.
[200] Fogel et al. 1989: 115; Reitsema 2013: 448.
[201] Fuller et al. 2005; Reitsema 2012.
[202] Hobson et al. 1993.
[203] Mainly due to Calcium stable isotopes; see Heuser and Eisenhauer 2010; Morgan et al. 2012.
[204] Schwarcz and Schoeninger 1991: 298.
[205] Craig et al. 2009.
[206] Schwarcz and Schoeninger 1991: 298.

men, reflecting perhaps the different diet[207]or the increased possibility of developing dental carries during pregnancy,[208] there are no other varieties.

There seem to be a difference between children and adults, with children having lower $\delta^{15}N$ values. It is yet unclear if that is due to a different diet or the organism that is still growing.[209] That effect could be connected to the case of pregnancy that show a decrease in $\delta^{15}N$ due to, perhaps, increased nitrogen retention and decrease in amino acid synthesis by the body. Moreover, nitrogen levels are fluctuating: being increased during morning sickness (nutritional stress) and decreased in the periods between them.[210] A study on a female burial from Roman Britain showed very low values that were interpreted as a consequence of pregnancy.[211]

Starvation shows an increase in nitrogen isotopic values.[212] The conclusion is that the protein is being recycled and that the stash of ^{14}N amino acids are being used for energy and as a protein source, resulting in a higher ratio of ^{15}N to ^{14}N.[213]

However, the human body is quite adaptive and very often it doesn't follow the same pattern of response to stress. Hence the connection between diet and pathology is still unclear. It is clear that certain stress factors could influence the health and diet, however the correlation is still impossible to capture.[214] Perhaps improvement of sampling techniques and further research might bring significant results.

Important to note when interpreting results is the environment from where the samples are coming from: in arid environment even $\delta^{15}N$ isotopic values coming from terrestrial diet can be so high that they cannot be distinguished from the marine trophic levels.[215] That would also explain why faunal samples from different historical periods can have completely different values that actually does not show dietary difference but the climatic one.[216] Hence it is important to sample contemporaneous flora and fauna, as a valid *comparandum* in interpretation of the results from human bones.[217]

[207] Larsen 1997.
[208] Reitsema 2013: 451.
[209] Richards et al. 2002.
[210] Fuller et al. 2005: 2894.
[211] Ibid. 2006.
[212] Lightfoot 2009: 76. / A study on human hair of an anorexic person showed increased nitrogen values. During the recovery, the values went lower. See more in Mekota et al. 2006.
[213] Lightfoot 2009: 76.
[214] Reitsema 2013: 451.
[215] Heaton et al. 1986: 823.
[216] Lightfoot 2009: 76.
[217] Stevens and Hedges 2004.

CHAPTER FOUR

4. MATERIALS AND METHODS

This chapter describes samples used in this study, being bones in this case. The instrumentation and the preparation of the samples are described, with the basic introduction to the IRMS technique.

4.1.MATERIALS - SAMPLES

In total, 35 individuals were chosen in this study according to the level of preservation, anthropological assessment, stratigraphical areas, relative chronology and the importance of the burial context. From this data set, 9 of them are men, 6 women and 1 sub-adult. (table 1) The rest are not anthropologically assessed yet.

Sampling process was focused on the parts of bones which exhibited abundance in compact bone which has higher concentration of collagen. There wasn't always possible to follow the same pattern of sampling from long bones, specifically *tibias*. Some of the burials lacked parts of skeleton so the bones had to be sampled from areas such as *mandibula*, *cranium*, *humerus*, *radius* and *ulna*.

To ascertain the variability of the baseline isotopic signature, 9 faunal remains were sampled. All remains are coming from the graveyard around and within the rotunda church and their context belongs to the period of Late Middle Ages (14-16th century), as do most of the graves. The assemblage includes: Four samples belonging to *ovies aries* (mandibula and humerus), two to *bos Taurus* (mandibula and falanga), one to *capra hicus* (astragalus) one *sus scrofa* (astragalus) and one *humerus* belonging to a bird that is classified as *gallus gallus* even though this identification is not entirely sure. (table 2)

Table 2: List of faunal samples[218]

Sample	Species	Description	Context
BRA 02	*Ovies aries*	Mandibula	T10, GR 9, SU 1116
BRA 03	*Sus scrofa*	Astragalus	T10, GR 7
BRA 05	*Bos Taurus*	Mandibula	T7, SU 1283
BRA 07	*Ovies aries*	Bone	T11, GR 11, E7
BRA 08	*Capra hicus*	Astragalus	T10, GR 9, SU 1116
BRA 09	*Bos Taurus*	Falanga	T10, GR 9, SU 1116
BRA 10	*Ovies aries*	Humerus	T10, GR 9, SU 1116

[218] Detailed list of human samples was previously introduced in a table 1, page 26.

BRA 15	*Gallus gallus?*	Humerus	T11, GR 11, E7
BRA 16	*Ovies aries*	Bone	T10, E11, SU 1125

4.2. METHODS

4.2.1. IRMS (Isotopic ratio Mass Spectrometry)

Isotopic ratio from collagen is obtained via Elemental Analyser Isotopic Ratio Mass Spectrometer (EA-IRMS). It identifies ionised molecules and atoms based on the difference between the mass to charge ratio. This technique is widely used in medicine, food industry, forensics and archaeology since it can make precise measurements of isotopic ratios of carbon, hydrogen, oxygen and sulphur.

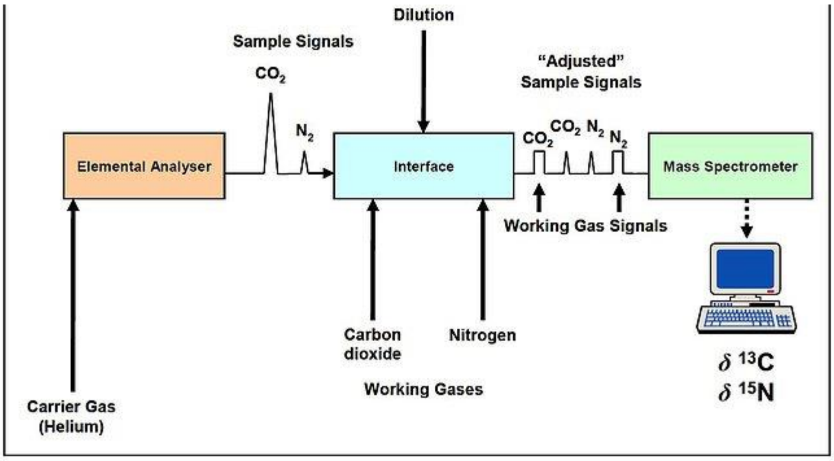

Figure 31: Scheme of main components of EA-IRMS for analysis of carbon and nitrogen isotopic ratios/ https://static.wixstatic.com/media/075a34_825e075b569e474b8a4ee601938ccae3.jpg_srz_653_372_85_22_0.50_1.20_0.00_jpg_srz

EA-IRMS consists of five components: sample inlet, electron ionisation source, magnetic sector analyser, detector (Faraday) and data acquisition system. (fig.31)

The whole interface converts samples into a gaseous state before entering the mass spectrometer. The sample, being collagen in this case, is set within a tin capsule that is dropped into a furnace at 1000ºC. The tin capsule burns exothermically and reaches the temperature of 1800ºC. Collagen turns into gases CO_2, N_2, SO_2 and H_2O and under the constant 1000ºC passes through chromium trioxide (Cr_2O_3) and copper oxide to complete the oxidation process. After that, the sample passes through a silver wool to remove the sulphur.

A copper reduction furnace produces molecules of N_2, removing the remaining oxygen at 600ºC. Water trap containing anhydrous magnesium perchlorate [$Mg(ClO_4)_2$] removes the remaining water and what is left is molecular nitrogen and carbon dioxide that are separated by gas chromatography. This allows the two gases to enter the mass spectrometry separately via helium as carrier gas.

The sample is introduced as a gas within a carrier helium gas. The heated filament emits stream of electrons which bombard the sample, kicking out electrons from outer valence shells and creating positively charged ions. The ions are accelerated and the electronic lenses orient them into a beam which passes through a strong magnetic field. Because of the magnetic field, the ions separate according to the mass to charge ratio within a curved tube. E.g. light ions are deflected more strongly than heavier ones. The ion beams strike the detector (Faraday cups), creating an electric impulse additionally strengthen by the amplifier. The intensity of obtained voltages shows the quantity of ions detected. For the comparison and validity of the each run, standards are analysed together with the sample and their isotopic ratios are mutually compared.

4.2.2. SAMPLE PREPARATION - COLLAGEN EXTRACTION

The protocol for collagen extraction in this research is based on the methods of Longin with some modifications by De Niro and Epstein. [219]

The bones samples, previously mechanically cleaned with a diamond tipped drill (Dremel 225) were grinded to chunks. The weighted bones (between 400-550 mg) were put into plastic centrifuge tubes and soaked in approximately 10 mL of 0.5M hydrochloric acid (HCl) for demineralization process. The samples were vortexed approximately twice a day, being left at room temperature during the day and in the refrigerator overnight. This routine was established daily, with acid change after a week. After two weeks, the bones were noticeable of softer structure, seemingly demineralised.

The samples were rinsed till they reached desired neutral pH with the combination of centrifuge (5.0 RPM x 1000 for 5 min), vortex and milli-Q water. It took approximately 7 repetitions of the process until the pH of samples was neutral. Next step consisted in adding around 10 mL of 0.125M of NaOH (Sodium hydroxide) and leaving the samples on a room temperature for 20 hours. This step is used to remove humic acids and non-collagenous organic residues. Following that, the samples were again rinsed and neutralised as previously, but only five times. Upon achieving the desired neutral pH, all the tubes were filled with 10 mL of 0,01M

[219] Longin 1971, DeNiro and Epstein 1981.

HCl acid and left in a dry oven for 48 hours, under 70ºC, with regular vortexing. Heating samples in a weak acid produces a gelatinised protein. During this process, the collagen is dissolved and humates are precipitated.[220]

Solubilized collagen was filtered with Ezee-Filter™ separators (Elkay Laboratory). All the possible insoluble residues were eliminated in that way and the gelatinised collagen was transferred into labelled collagen vials and covered with parafilm. Following that, the collagen vials were put into liquid nitrogen to freeze and set for lyophilisation (freeze-drying) for 48 hours. Afterwards, all the samples were weighed for collagen yield calculation. The samples were stored into the desiccator with silica gel to keep the sampled dehydrated.

The last step of preparation before entering IRMS was weighting collagen into tin capsules (between 0.65 and 0.75 mg). The tin capsules containing collagen were combusted into CO_2 and N_2 in an elemental analyser (EA) with oxygen (Flash 2000 HT, Thermo Fisher Scientific, Bremen, Germany) with pure helium as carrier gas. The equipment used for obtaining isotopic ratio is Delta V Advantage isotope ratio mass spectrometer (Thermo Fisher Scientific, Bremen, Germany) coupled to the EA via ConFlo IV interface (Thermo Fisher Scientific, Bremen, Germany), in Hercules laboratory Évora, Portugal.

The raw data were normalized by two-point calibrations using international reference materials, such as IAEA-CH-6 (sucrose, −10.449‰) for carbon, IAEA-N-2 (ammonium sulphate, +20.3‰) for nitrogen and IAEA-600 (caffeine, −27.771‰ for carbon and +1.0 ‰ for nitrogen). Measurement errors were less than ±0.1‰ for carbon and ±0.2‰ for nitrogen. Carbon and nitrogen results are expressed in per mil relative to PDB and AIR, respectively. To check and correct instrumental drift, a calibrated in-house standard (*L*-alanine, δ13C

[220] Longin 1970: 241-242.

=−19.17‰; δ15N = +4.36‰) was measured at regular intervals throughout analytical sequences.

Figure 32: key steps in collagen extraction / R. MacRoberts, M. Dreshaj

CHAPTER FIVE

5. RESULTS

This chapter aims to present results from IRMS analysis of human and faunal samples. The results are described, with their averages, standard errors, ranges, outliers and collagen quality. Faunal and human dietary reconstruction is briefly described, together with calculation of the human-faunal offset, before entering the following chapter which discusses the results.

5.1.COLLAGEN QUALITY

All samples satisfied the following criteria of a well preserved collagen: C/N ratio between 2.9 and 3.6[221], collagen yield above 1%, final nitrogen yields above 4.8% and carbon yields above 13%.[222]

Average collagen yield amongst human samples is 9.22 ± 0.65 %, ranging from 3.51% to 19.28%, (table 3) while faunal samples ranged between 2.06% and 10.92%, with the mean value 6.69 ± 0.99 %, (table 4) hence indicating all the samples have enough preserved collagen for extraction.

Nitrogen content for humans varied between 14.3% and 16.6 %, with average 15.39±0.08 %. (table 3) Faunal samples depicted a range between 14.3% and 16.6%, mean value being 15.34 ± 0.24%. (table 4)

Carbon content showed values between 38.4% and 43.5%, with an average of 41.66±0.17% for humans and the range of 38.1% to 43.6% with a mean value 41.18±0.5% for fauna.

Carbon to nitrogen ratio (C/N) ranged between 3.1 and 3.3 for humans and 3.1 and 3.2 for fauna. All samples were in accordance with the expected values for preserved collagen.

Table 3: results from stable isotopic analysis of humans

Sample no.	Collagen yield (%)	% C	% N	C/N	$\delta^{13}C$ ‰ vs PDB	$\delta^{15}N$ ‰ vs. AIR
BRH 01	4.21	39.2	14.7	3.1	-18.2	9.1
BRH 02	11.7	42.1	14.9	3.3	-18.3	11
BRH 03	9.53	42.7	15.3	3.3	-18.8	10.5
BRH 04	3.51	41.5	15.7	3.1	-18.1	9.4

[221] De Niro 1985.
[222] Ambrose 1990; De Niro 1985.

BRH 05	15.56	42.5	15.1	3.3	-17.8	11.3
BRH 06	6.06	38.4	14.2	3.1	-19	9.1
BRH 07	4.46	41.5	15.6	3.1	-18.7	8.4
BRH 08	10.61	41.8	15	3.2	-18.3	11.6
BRH 09	7.77	42.7	15.2	3.3	-18.7	9.6
BRH 10	16.81	41.8	15.9	3.1	-18.8	10.2
BRH 11	13.37	41.4	15.6	3.1	-19	8.6
BRH 12	11.29	42.1	15.1	3.2	-18.2	11
BRH 13	19.28	42.9	16.2	3.1	-18.8	8.6
BRH 14	3.55	42.1	15.8	3.1	-17.1	9
BRH 15	11.85	41.8	14.9	3.3	-18.5	12.1
BRH 16	12.81	42	15.9	3.1	-18.2	8.6
BRH 17	11.41	42.4	16.2	3.1	-18.5	9.2
BRH 18	5.10	40.9	15.5	3.1	-18.8	8.2
BRH 19	6.59	41	15.4	3.1	-18.9	8.9
BRH 20	10.96	42.6	15.2	3.3	-18.2	9.7
BRH 21	7.62	41.7	14.9	3.3	-18.2	10.4
BRH 23	11.55	42.5	16.2	3.1	-18.4	8.2
BRH 24	4.61	41.8	15.8	3.1	-19	9
BRH 25	5.78	40	15.1	3.1	-19	9
BRH 26	10.53	41.3	15.5	3.1	-17.6	9.9
BRH 27	7.67	41.4	14.9	3.2	-18.5	11
BRH 28	4.33	40.7	15.3	3.1	-18.4	8.6
BRH 29	9.46	41.2	14.7	3.3	-18.3	11.7
BRH 30	13.93	41.7	15.7	3.1	-19.3	9.9
BRH 31	7.21	42.5	15.3	3.2	-19.2	13.2
BRH 32	3.72	40.3	15.1	3.1	-17.6	8.9
BRH 33	10.01	41.3	15.7	3.1	-17.3	8.6
BRH 34	10.23	42.1	15.3	3.2	-17	11.9
BRH 35	9.44	43	16.3	3.1	-18	8
BRH 36	10.32	43.5	15.6	3.2	-18.2	9.2
Mean v.	9.22	41.66	15.39	3.16	-17.85	9.76
St. Dev.	3.90	1.03	0.47	0.08	0.55	1.29
St. Error	0.65	0.17	0.08	0.01	0.09	0.21
Range	3.51-19.28	38.4-43.5	14.2-16.3	3.1-3.3	-19.3-(-17)	8-13.2

Table 4: List of stable isotopic results of faunal remains

Sample No.	Collagen yield (%)	%C	%N	C/N	$\delta^{13}C$ ‰ vs PDB	$\delta^{15}N$ ‰ vs. AIR
BRA 02	3.59	40.9	15.1	3.2	-20.1	4
BRA 03	8.66	39.8	14.4	3.2	-20.6	8
BRA 05	2.06	41.1	15.5	3.1	-19.1	4.5
BRA 07	10.14	43.6	16.6	3.1	-20.2	4.1
BRA 08	9.48	42.8	16.3	3.1	-20.7	3.1
BRA 09	5.38	38.1	14.3	3.1	-19.4	5.9
BRA 10	10.92	41.7	15.2	3.2	-20.2	7.5
BRA 15	5.56	41.6	15.7	3.1	-20.1	4
BRA 16	4.44	41.1	15	3.2	-20.4	6.3
Mean v.	6.69	41.18	15.34	3.14	-20.08	5.26
St. Dev.	2.99	1.50	0.73	0.04	0.49	1.62
St. Error	0.99	0.50	0.24	0.01	0.16	0.54
Range	2.06-10.92	38.1-43.6	14.3-16.6	3.1-3.2	-20.7-(-19.1)	3.1-8

5.2. RESULTS FROM FAUNAL SAMPLES

Results of stable isotopic ratio of faunal remains varied between -20.7‰ (*capra hicus*) and -19.1‰ (*bos Taurus*) in $\delta^{13}C$ values and 3.1‰ (*capra hicus*) and 8‰ (*sus scrofa*) in $\delta^{15}N$ isotopic composition. Thus, sampled fauna subsisted on a foodweb based on C_3 plants which isn't surprising since majority of European flora uses C3 photosynthetic pathway. There are no outliers amongst faunal dataset. (fig.35, fig. 36)

5.3. RESULTS FROM HUMAN SAMPLES

Stable isotopic ratio of humans varies between -17‰ and -19.3‰ for $\delta^{13}C$ values and 8‰ and 13.2‰ in $\delta^{15}N$ isotopic composition, depicting diet based on C_3 plants with some incorporation of C_4, most likely millet.

Faunal results were used as a baseline for understanding the diet of humans. The offset between humans and fauna is 2.23 for $\delta^{13}C$ and 4.5 for $\delta^{15}N$. (fig. 33, fig. 35, fig. 36) Usual difference is around 1-2‰ for carbon and 3-5‰ for nitrogen.[223] Thus, ratio for carbon is a bit higher from the expected range (for 0.23‰) while the offset for nitrogen falls into expected parameters.

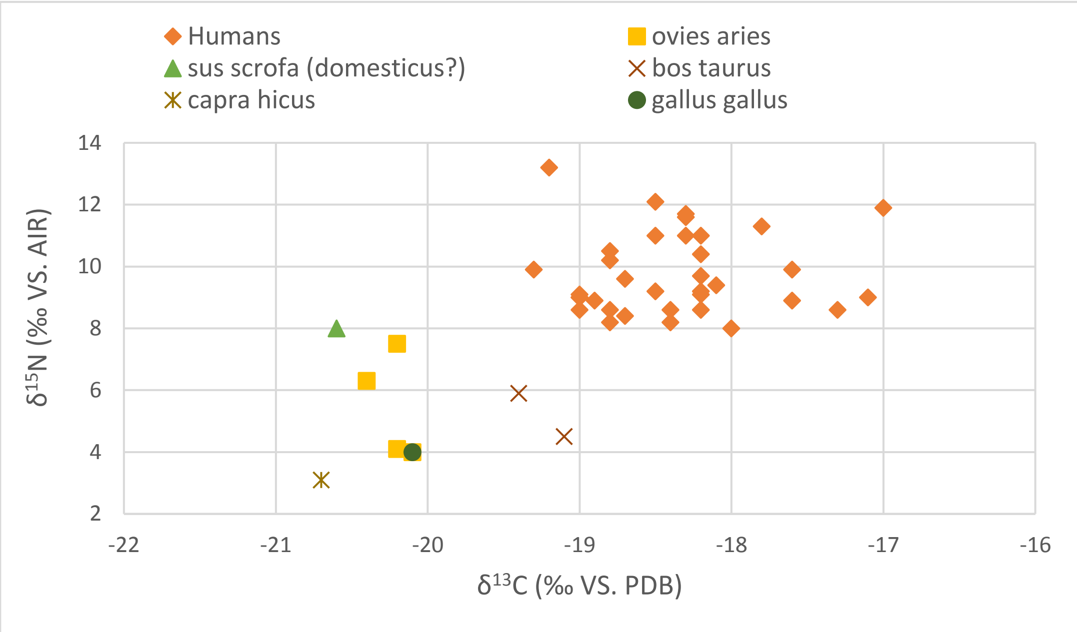

Figure 33: scatter plot with stable isotopic results of human and faunal remains

Outliers were calculated according to the Interquartile range. The values set 1.5 to 3 times the interquartile range from quartile 1 (Upper Quartile) or 3 (Lower Quartile). Extreme outliers are values above 3 times the interquartile range away from the Upper and Lower Quartile. (fig.34)

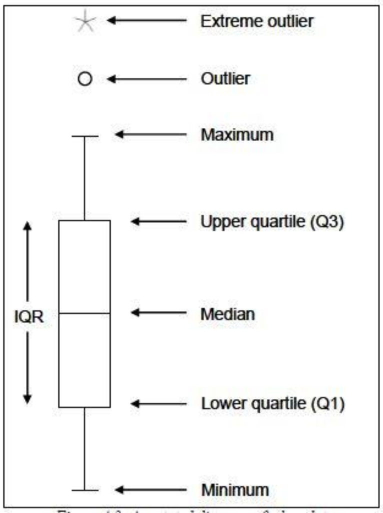

Figure 34: box plot depicting Interquartile ranges/ Lightfoot 2009.

There are five outliers when it comes to $\delta^{15}N$ ratios: BRH 15 (12.1‰), BRH 31 (13.2‰) and BRH 34 (11.9‰) with higher $\delta^{15}N$ levels and BRH 35 (8‰) and BRH 18 (8.2‰) with lower ones. (fig.29, fig.31, fig.32)

The outliers in $\delta^{13}C$ isotopic ratios are BRH 14 (-17.1‰), BRH 33(-17.3‰) and BRH 34 (-17‰) as being extremely enriched while BRH 30 (-19.3‰) and BRH 31 (-19.2‰) have extremely depleted values. (fig.31, fig.32)

223 Lee-Thorp 2008; Van Klinken et al. 2002.

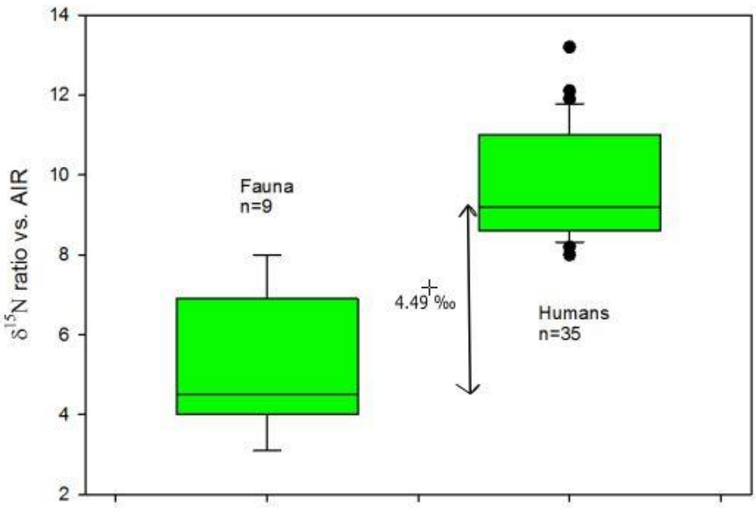

Figure 35: box plot depicting human-faunal offset in δ15N ratios.

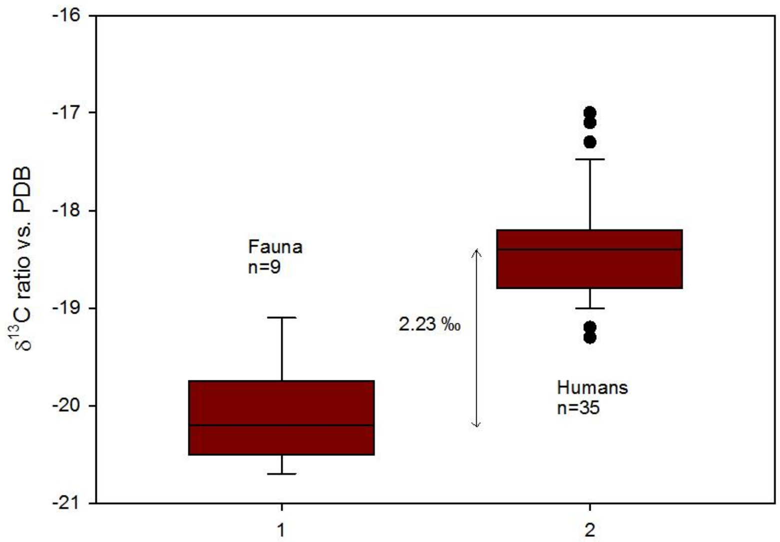

Figure 36: box plot depicting human-faunal offset in δ13C ratios.

CHAPTER SIX

6. DISCUSSION

6.1.INTERPRETATION OF FAUNAL DIET

The results of $\delta^{13}C$ ratio of faunal remains are within a range from -20.7‰ to -19.1‰ with a mean value of -20.08±0.16 ‰ which indicates that these animals were subsisting on C_3 plants, as expected.

There is a high variation in $\delta^{15}N$ ratios, from 3.1‰ till 8‰, some even amongst the same species. The lowest value belong to *capra hicus* (BRA 08) while the highest value comes from *sus scrofa* (BRA 03).[224] The trophic level of BRA 03 is quite high, being the same as of one outlier amongst human samples (BRH 35). Pigs are considered omnivores and their results often vary.[225] However, important to note is the fact that sample BRA 10, *ovies aries*, has $\delta^{15}N$ ratio close to the one of *sus scrofa*, even though sheep are not omnivorous. (Table 4)

Sample BRA 08, being *capra hicus*, has low $\delta^{15}N$ ratio of 3.1‰ and -20.7‰ of $\delta^{13}C$. However, when compared to caprid isotopic range from the surrounding area, it does fall into lower expected range.[226]

Two samples of *bos Taurus* show $\delta^{15}N$ values of 4.5‰ and 5.9‰ with of $\delta^{13}C$ being -19.1‰ and -19.4‰, respectively. This results are in accordance with the isotopic results from Early Medieval fauna in Ravni Kotari, depicting values between 3.4‰ to 6.5‰ in $\delta^{15}N$ ratio, with small difference in carbon isotopic ratio, -19.1‰ and -19.4‰, respectively.[227]

However, the differences between the same species are puzzling: *ovies aries* $\delta^{15}N$ values ranges from 4‰ and 4.1‰ (BRA 02 and BRA 07), 6.3‰ (BRA 16) to 7.5‰ (BRA 10). There are three possible explanations: perhaps sample BRA 10 and BRA 16 fed on broadleaf plants which have higher concentration of nitrogen in comparison to grass. The differences in nitrogen values can be present in the same area due to environmental factors.[228] Second explanation refers to the possibility that BRA 10, with the highest value, is a juvenile since its age could not

224 Lightfoot 2009: 268.
225 Reitsema et al 2013: 3643.
226 Lightfoot 2009: 261.
227 Ibid. 261; Lightfoot et al 2012: 9.
228 Waterman et al. 2015.

be determined. So the high $\delta^{15}N$ value could reflect weaning.[229] Third possibility is that the variations between the same species could be due to possible difference in time periods. All the faunal samples come from the context that is assessed into Late Medieval period, 14-16th century. Samples BRA 02, BRA 08, BRA 09 and BRA 10 come from the same stratigraphic layer (SU 1116, GR 12, T10). (table 2) This should put them into the roughly same time period.[230]

However, there are several factors that have to be taken into account when discussing stratigraphy of burials. Firstly, faunal remains are found in burials inside and around the church, meaning they are not part of the waste from the settlement area and they weren't meant to be in graves. Second, as mentioned in the introductory chapter, the relative dating of stratigraphic layers according to its material has proven to be unreliable since the context was mixed, reflecting periods expanding from Roman period and Late Antiquity until even 17th century. And lastly, according to the anthropological report, the burials showed high percentage of animal gnawing[231] which indicates the bones were exposed and perhaps even moved before finally sealed in a tomb. This is common in Medieval archaeological sites.[232] Which contributes to the possibility of a complete mixture of materials and hence puzzling isotopic results coming from the same context.

Another odd results belongs to *gallus gallus*, which with $\delta^{15}N$ of 4‰ depicts almost twice as lower value than expected.[233] However, the identification of this sample is unclear as only a small part of the bone was preserved. It could have been a wild bird, for example. Hence, this result should be taken with caution.

6.2..INTERPRETATION OF HUMAN DIET

The results on bone collagen analysis with the average $\delta^{13}C$ ratio of -17.85‰ and $\delta^{15}N$ ratio of 9.76‰ suggest that the population of Bribirska Glavica relied on terrestrial food

[229] Katzenberg 2008.
[230] The identification was done by an anthropologist since the archaeo-zoologist wasn't available. The samples should be sent for revision to the expert in near future, to clarify the faunal results.
[231] Animal gnawing occurs amongst both herbivores and carnivores. Animals tend to chew bones to supplement phosphorus and calcium uptake. Caceres et al. 2013.
[232] Crabtree 2000.
[233] Reitsema et al. 2013: 3640.

sources, rather than marine ones. (table 3) The combination of relatively enriched $\delta^{13}C$ values with relatively low $\delta^{15}N$ values suggests that the diet was based on C_3 plants with some C_4 foodweb sources and with little or no marine sources.[234]

Typical faunal-human isotopic offset for humans consuming terrestrial diet is 0-2‰ for carbon and 3-5‰ for nitrogen values.[235] In this study, the offset for nitrogen falls within expected parameters (4.5‰) whilst for carbon it is a bit higher (2.23‰, 0.23‰ higher than expected). This contributes to the previous conclusion - a human-faunal offset in $\delta^{13}C$ above 2‰ suggest the implementation of C4 plants, presumably millet.[236]

According to the archaeobotanic data available, millet was most likely a minor crop in Dalmatia.[237] Its use increased in the Early Medieval period, possibly due to turbulent migrations and arrival of Avars and Slavs who brought the habit of using millet as a significant food source.[238] The benefits of millet is in their natural resistance to poor soil; this plants grows in poor conditions and needs very little amount of water[239] which seems suitable for Dalmatian karstic environment. Furthermore, millet is considered as 'food for the poor'. That could be connected to the anthropological studies showing the decrease in living standards in Early Middle Ages. That was concluded based on observed increase of infectious disease and the amount of trauma (and signs of malnutrition and vitamin deficiency) with higher consumption of carbohydrates and hard fibrous food and significant decrease in the consumption of protein compared to Roman and Late antique period.[240] High frequency of both trauma and pathology is visible on the bones studied in this work, as was discussed in the introductory chapter.

Nitrogen isotopic values range from 8‰ to 13.2‰ depicting a population with a heterogeneous diet, specifically the amount of protein consumed. Moreover, the $\delta^{13}C$ values ranging from -17‰ to -19.3‰ reflects a population which, besides of C_3 plants had additions of C_4 plants, most likely millet, on various levels.

[234] De Niro and Epstein 1978; Schwarz and Schoeninger 1991.
[235] Hedges and Reynard 2007; Bocherens and Drucker 2003.
[236] Lightfoot et al. 2012: 6.
[237] Huntley 1996; Lightfoot et al 2012: 9; Lightfoot et al 2011.
[238] Henning 1987; Barford 2001; Lightfoot et al 2012: 9.
[239] Michalova 2005.
[240] Šlaus 2008; Šlaus et al. 2010.

There are 8 outliers:

1. Individual BRH 31[241], relatively dated to Late Medieval period[242] and exhibiting signs of leprosy, depicts the highest amount of nitrogen, being 13.2‰ and one of the most depleted $\delta^{13}C$ values (-19.2‰), indicating a high protein diet[243] and no addition of millet. The diet of this person could have been considered to reflect a high social status.[244]
2. BRH 15 exhibits high $\delta^{15}N$ ratios of 12.1‰, together with -18.5‰ $\delta^{13}C$ ratio, also indicating a diet abundant in animal protein and depleted from millet.
3. BRH 34 shows high amount of $\delta^{15}N$ value of 11.9‰ but extremely enriched $\delta^{13}C$ values, -17‰. This person consumed millet or low trophic level marine source. This burial is assumed to belong to 8-9th century, being an Early Medieval one.
4. BRH 35, coming from the same burial context as BRH 34, exhibits quite lower $\delta^{15}N$ values, being 8‰ with -18‰ for $\delta^{13}C$. There is no anthropological assessment made but the fact they are coming from the same grave depicts that the burial position does not account for the same diet, at least not in this context.
5. BRH 33, being the only sub-adult (9-10 years) in this set of samples, is an outlier with low nitrogen levels, 8.6‰ and enriched carbon levels, -17.3‰. This may reflect the diet with low protein intake and high millet consumption. It is possible, however, that the physiology of the sub-adult influenced the isotopic signature, since the organism of the sub-adult is still growing and has a different metabolic rate than adults.[245]
6. Individual BRH 30 is an outlier due to his negative $\delta^{13}C$ values, being -19.3‰ which is considered the lowest in this dataset. Nitrogen levels are close to the average range, being 9.9‰. This individual rarely consumed millet (perhaps not at all) and his food was based on C_3 plants. This individual was buried next to the church and had a chalice as a burial good, which is quite rare and is usually found in graves of priests. It is not yet known what the relative date of this individual is nor there is an anthropological assessment made so far.[246]

[241] This individual had only a skull preserved and hence there is no data on gender.
[242] Datation is based on the burial context.
[243] Schoeninger and De Niro 1984; Walker and De Niro 1986; Katzenberg and Weber 1999.
[244] Dyer 1983, Grant 2002:17, Hastorf 2003. (theories on high protein diet reflecting high social status)
[245] Richards et al. 2002.
[246] The burial has been excavated in May 2017 so the data are not published yet.

7. BRH 14, having no anthropological study available yet, is an outlier with quite enriched $\delta^{13}C$ ratios, being -17.1‰. Nitrogen value is close to the average, being 9‰. This individual had a diet heavily relying on C_4 plants, therefore millet. The diet of this person resembles the diet of the sub-adult (BRH 33).
8. BRH 18, being a male aged 30-40 years, has low $\delta^{15}N$ ratio. With 8.2‰ we can assume that the person had one of the lowest consumption of animal protein in this data set. However, -18.8‰ of carbon isotopic ratio indicates there wasn't much of millet in the diet either. This person has several pathologies indicating malnutrition and problems with bones such as *osseous exostosis* (excessive bone growth) on the tibia, lytic lesions on right glenoid fossa, osteoarthritis and mild healed periostitis on the left tibia and fibula. The relative date of the context of this burial falls into Late Middle age, 14-16th century.

6.3.GENDER AND AGE

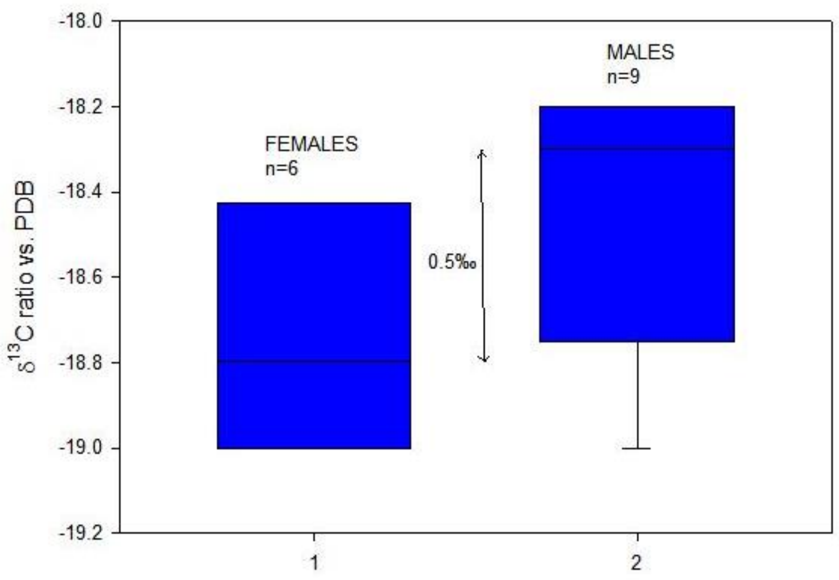

Figure 37:. box plot representing dietary difference between females and males in $\delta^{13}C$ ratio.

An attempt was made to understand the differences correlated with gender and age of each individual analysed in this study. Not all burials have been studied by anthropologist so only 15 of them have assessed gender. There are 9 males and 6 females and their isotopic results have been gathered in box plots and compared to see if there are any differences with the diet connected to their position in the society according to their gender.

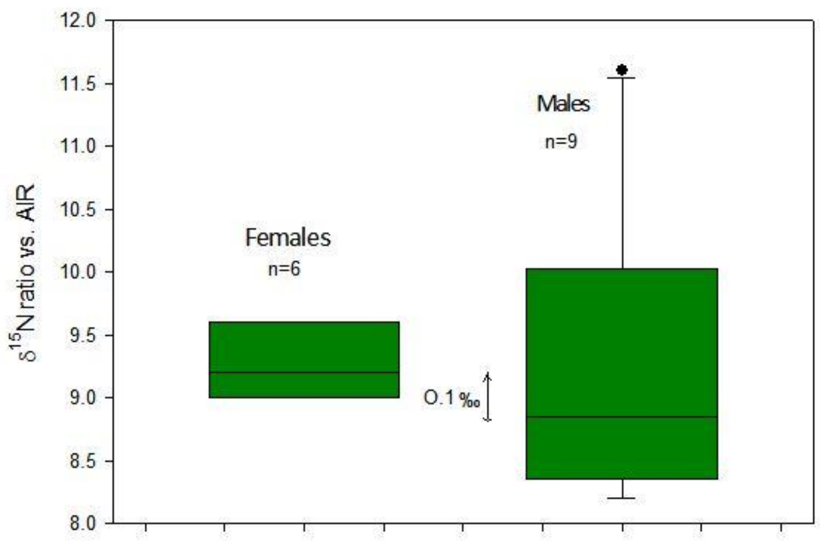

Figure 38: box plot representing dietary difference between females and males in $\delta^{15}N$ ratio.

Despite the fact that the mean value of isotopic ratio of nitrogen from both males and females is not very different with a difference of 0.1‰, male samples depict significantly bigger range, from 8.2 to 11.6‰ whilst females have a tighter range of 8.9-10.4‰ in $\delta^{15}N$ values.[247] (fig. 38) It may suggest that men in Bribirska Glavica had a more heterogeneous diet, perhaps connected to their social status and the role in the family.

When looking at the $\delta^{13}C$ isotopic ratio differences between males and females, it is noticeable that the offset between mean values of men and women is 0.5‰ which is a bit higher than usual 0.3‰ difference that is still considered to be within the homogenous diet.[248] (fig. 37) Carbon isotopic ratio of men seem to be more enriched, depicting that statistically men might have consumed more millet. However, the difference is too small to be considered relevant to the study.

However, it is important to have in mind that the sample size is rather small and not representative and the number of females and males is not equal in this comparison. Moreover, not even half of the burials have identified gender. Hence, perhaps if all the burials analysed in this study were also studied by anthropologists, the correlation would change.

[247] Similar result were obtained in the dissertation study od Anna Moles, 2012. Despite having no significant statistic difference and very different average values, females had less variant $\delta^{15}N$ values than men.
[248] Lovell et al 1986: 52.

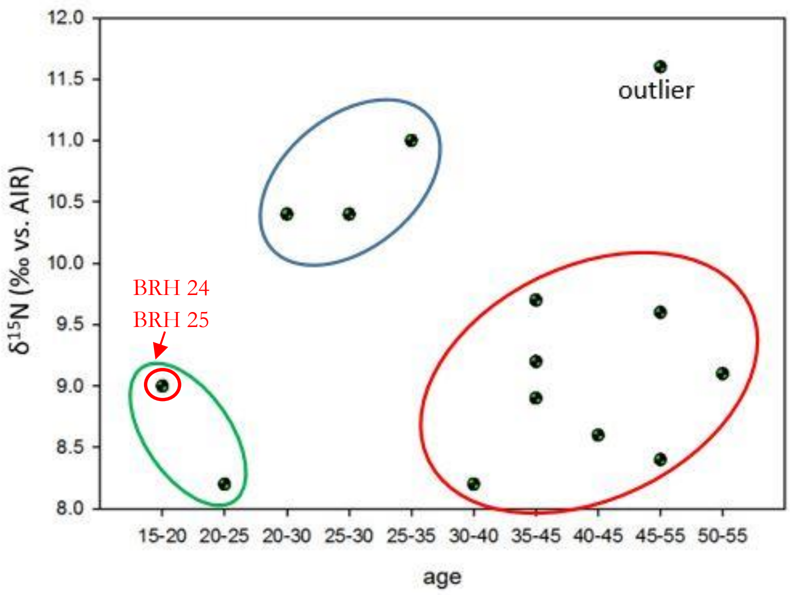

Figure 39: scatter plot representing clusters of $\delta^{15}N$ values according to age group

There seem to be a certain pattern in $\delta^{15}N$ values according to age group, as visualised in fig.39. Individuals between 15-20 and 20-25 years old depict lower $\delta^{15}N$ ratios than individuals from age 25-30 until 25-35 years old. It seems that there is a pattern of increased consumption of animal protein in that age, following by a decrease in $\delta^{15}N$ values at the age of 30-40 years old. The oldest individual in the population is estimated to be around 50-55 years old. BRH 08 is an outlier, having the highest $\delta^{15}N$ valuess and belonging to the oldest age group. Thus, this person was most likely eating a high protein diet.[249]

Samples BRH 24 and BRH 25 have completely equal diet, both in terms of $\delta^{15}N$ and $\delta^{13}C$ ratios, being 9‰ and -19‰, respectively. Interestingly enough, they are both coming from the same burial (GR 15) and they could be of the same age, estimated between 15-20 years old. This could mean that they possibly died in the same time and were buried together.[250]

This data could suggest a certain stratification in the society that was reflected in their dietary habits. People aged 25-35 years old are at the peak of their strength and their life, especially taken into account the average life expectancy and their diet could have been affected by this.

[249] More on this individual will be discussed in the following subchapter on burial context.
[250] Also, there are some resemblances in traumas which indicate they had a same daily routine. For more details see discussion about pathology and trauma.

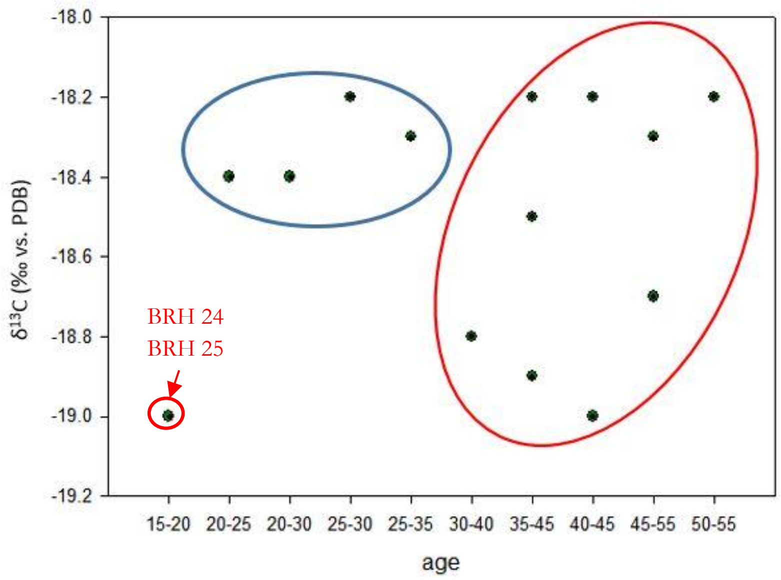

Figure 40: scatter plot depicting differences in carbon isotopic values according to the age group

When observing clusters of $\delta^{13}C$ values according to the age of individuals, it can be concluded that there are again two distinct groups: people aged 20-35 years old tend to depict enriched $\delta^{13}C$ results, rather than having a wider range such as people from the age group of 30-55 years. More enriched carbon isotopic values suggest more millet in the diet. (fig. 40)

However, the sample size is quite small so the validity of this statistical patterns is questionable. These are just attempts to see if there is any pattern in a small sample size but these results should be confirmed or re-established with further studies.

6.4.BURIAL CONTEXT

An attempt was made to understand the connection of diet according to the burial context. Several graves were assumed to belong to families or relatives. In one grave (consisting of a drystone lining) there would be several individuals buried above each other. Their connection can only be assumed without involving more archaeometric techniques. However, trying to look for any possible pattern could give a suggestion of the diet involved into shaping an identity or belonging to a certain group.

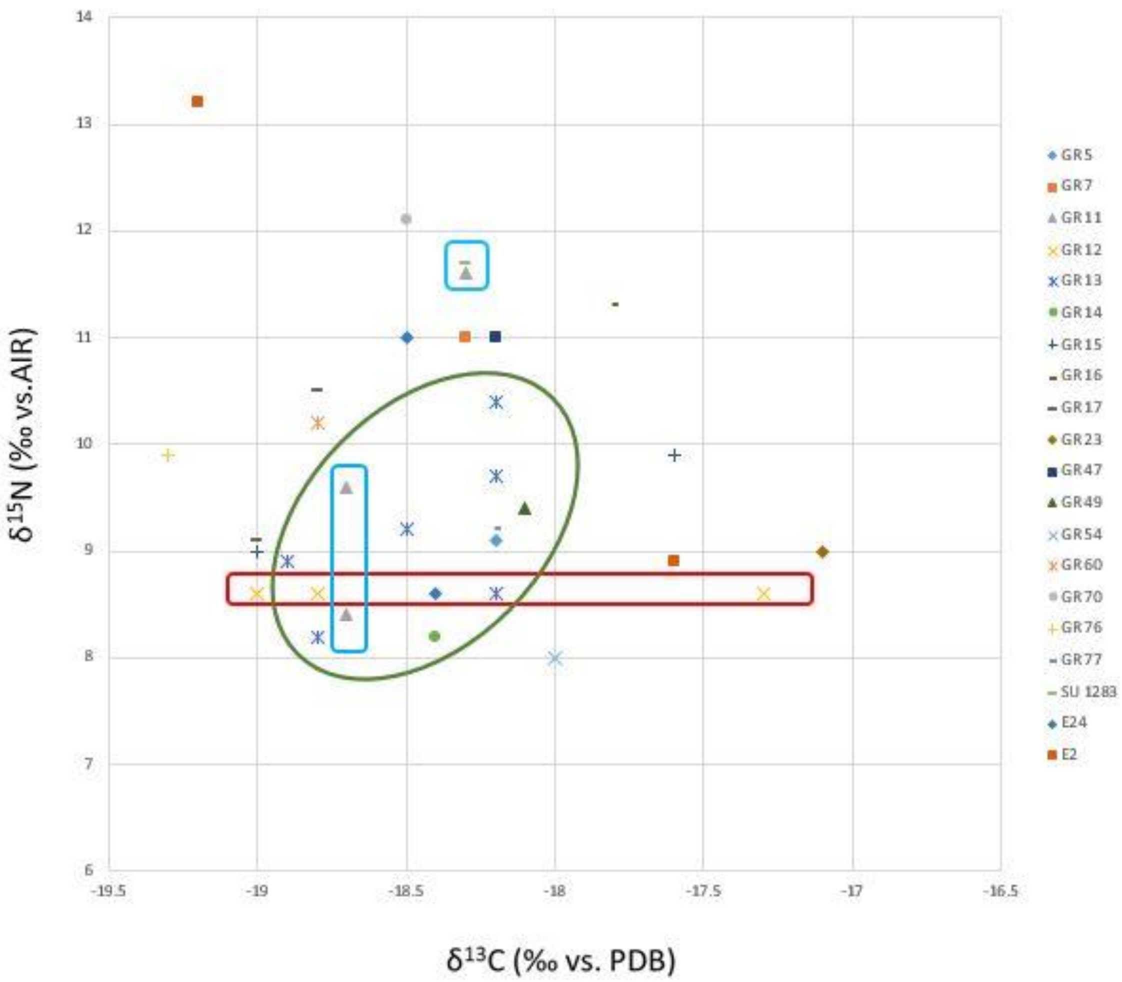

Figure 41: scatter plot depicting relationship of $\delta^{15}N$ and $\delta^{13}C$ with the burial context

Three clusters have been noticed in the distribution of carbon and nitrogen isotopic values for grave 11, 12 and 13, all considered to belong to the same time period, being Late Middle Ages (14-16th century). (fig.41) Grave 15 is also regarded as having a certain patterning since the two individuals analysed in this work depicted exactly the same values in both carbon and nitrogen stable isotopes. Furthermore, they are all set in the same context, inside and aligned to the walls of the naved church which was built on top of the ruins of the rotunda church. The relative date for this building phasing has been proposed to 14-15th century, as a *terminus ad quem* (the latest date possible) based on the findings of Aquileian coins.[251] However, it is important to emphasise that this date is a relative one. For now, these graves have been set in this time period and considered to be contemporaneous to the naved chuch.

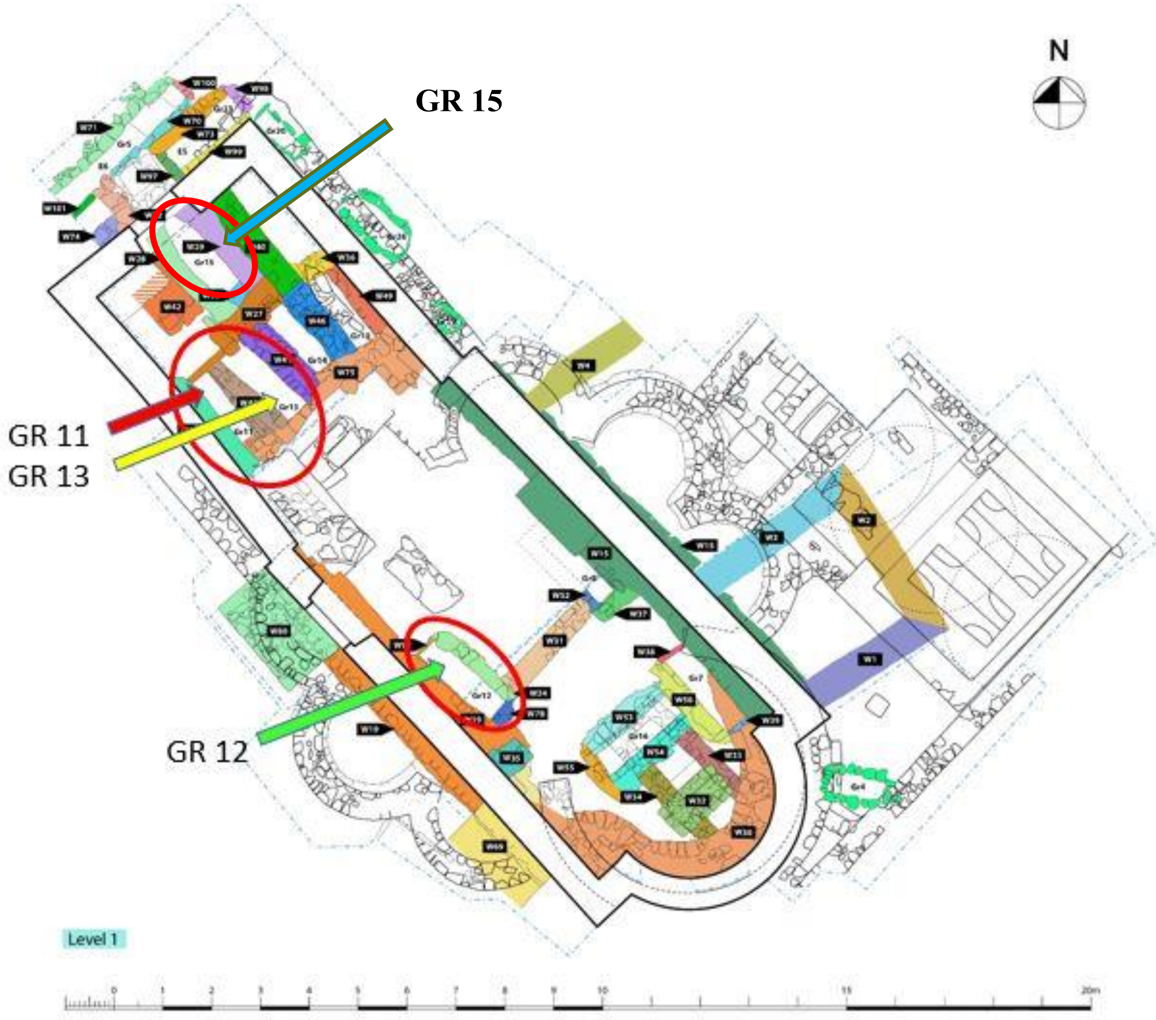

Figure 42: plan of the walls uncovered in level 1. The modern naved church is set on top of the rotunda. Graves 11, 12 and 13 are following the orientation of the walls of the naved church, seemingly contemporaneous. / V. Ghica 2016.

These graves are structured in a drystone square lining and are relatively deep (around 1.5 m) allowing space for more people to be buried in rows. The fact that they are buried inside the church means that they were most likely important. They could have been coming from the higher strata in the society or made a significant contribution to the church or the city itself. Specifically, grave 12 is set near the most sacred area in the church – the sanctuary within the apse, right behind the altar screen. (fig.42)

[251] Ghica et al. 2016: 41.

▲ **GR 11.** First cluster belongs to the grave 11. According to the anthropological report, this grave consisted of 7 buried individuals – 4 adults (3 males and 1 female) and 3 sub-adults. This grave showed a significantly high abundance in trauma and pathology.[252] (see Table 1) Three individuals have been selected to be analysed in this study (2 males and 1 female). They all belong to the same age-group, being 45-55 years old which is the oldest age group in the population of Bribir.[253] The pattern that has been noticed is mostly grouping according to the $\delta^{13}C$ ratios. While BRH 07 and BRH 09 have the same carbon isotopic value -18.7‰, BRH 08 has a slightly more enriched $\delta^{13}C$ value of -18.3‰. The difference is only 0.4‰ which is on the border line to be considered as a fully homogenous diet. Furthermore, when looking at $\delta^{15}N$ values, BRH 07 (male) and BRH 09 (female) are not so far apart with 8.4‰ and 9.6‰ values respectively, while BRH 08 with the value of 11.6‰ in $\delta^{15}N$ indicates an individual on high protein diet. This could reflect social status.

Woman BRH 09 could have slightly elevated nitrogen level compared to a man BRH 07 due to severe pathologies. She has one of the unique case of tuberculosis in this data set.[254]

✕ **GR12.** This grave is particularly interesting due to its privileged position next to the sanctuary of the naved church. It contained a minimum of 16 individuals – 8 adults (5 women and 3 men) and 8 sub-adults. In this study, three of them were analysed, BRH 11 (male, 40-50 years), BRH 13 (female, 20-30 years) and BRH 33 (sub-adult, 9-10 years). They all depicted exactly the same $\delta^{15}N$ results, 8.6‰. This is interesting since they all belong to completely different age groups.

Their $\delta^{13}C$ ratios are of quite different values: -17.3‰ (BRH 33, an outlier), -18.2‰ (BRH 13) and -19‰ (BRH 11). BRH 33, a sub-adult with the most enriched carbon isotopic ratio has clearly been consuming some millet whilst the two adult samples had a significantly lower consumption. The difference between the sub-adult and the men in this context is 1.7‰ which is quite significant.[255] The difference between the woman and the man is 0.8‰ and the woman and the sub-adult 0.9‰ which can imply the difference in the diet, perhaps the amount of millet consumed. The homogeneity in nitrogen and heterogeneity in carbon isotopic levels

[252] For more details, see introductory sub-chapter „Anthropological context", BRH 07, 08, 09.
[253] At least according to so far anthropologically assesed burials.
[254] For more details, see table 1, page 26.
[255] Lovell et al 1986: 52.

implies that the consumption of meat was something that was common and shared amongst all the members, no matter their age.

GR 13. This grave had a minimum of 13 individuals: 10 adults (6 males and 3 females) and 3 sub-adults. There were also severe pathologies and trauma present in this burial context.[256] In total, 6 individuals were selected to be analysed in this study: BRH 16, BRH 17, BRH 18, BRH 19, BRH 20 and BRH 21 (see table 1). The results of carbon and nitrogen isotopic compositions are gathered in a visible cluster containing the biggest number of individuals. (see fig. 37)

Samples BRH 16 (male, 40-50 years), BRH 20 (male, 35-45 years) and BRH 21 (female, 25-30 years) have the same $\delta^{13}C$ ratios, being -18.2‰. However, the $\delta^{15}N$ ratios are quite different, with 8.6‰, 9.7‰ and 10.4‰, respectively. This case is the opposite from the previous burial context (GR 12) where the nitrogen values were the same as opposed to carbon values that varied for grave 13. Type of plants ingested was the same between them whilst the animal protein consumption varied. The highest nitrogen levels in this context can be prescribed to a young woman (BRH 21) which could be due to possible motherhood. Some studies show cases of increased nitrogen levels due to pregnancy and lactation.[257]

Samples BRH 18 (male, 30-40 years) and BRH 19 (female, 35-45 years) show very similar results in $\delta^{13}C$ ratios, of -18.8‰ and -18.9‰, respectively. Their nitrogen isotopic levels are also quite close: 8.2‰ and 8.9‰, respectively, indicating that their diet wasn't high on animal protein. Sample BRH 17 (female, 35-45 years) has a bit higher animal protein consumption, suggested by 9.2‰ nitrogen isotopic ratio and similar carbon isotopic values, -18.5‰.

The range of carbon isotopic ratio in this burial context is between -18.2‰ and -18.9‰ whilst nitrogen isotopic ratio varies between 8.2‰ and 10.4‰.

GR 15. This grave had minimum of 7 individuals present, at least 1 male and 3 females. Two of them have been selected for this study, both being young women between 15 and 20 years old. As mentioned before, both of them have the exact same isotopic values featuring they

[256] Vyroubal, Bedić 2016: 42-43.
[257] Fuller et al. 2005; Reitsema 2012.

were eating the same diet and had the same organism response to it. They were probably belonging to the same family, according to the full similarity of their isotopic signature.[258]

[258] Interestingly enough, both of these individuals have the same trauma. The signs of squatting are present on tibias of both women, simiarly to the individual from the grave 16 that is believed to be a priest.

6.5..PATHOLOGY

One of the correlations that could be observed is based on the connection of diet and health. This attempt tries to draw connection between pathologies that are connected to diet, such as ectocranial porosity caused by malnutrition and vitamin deficiency.[259] (fig.43) Only anthropologically assessed samples were taken into account and there seem to be no pattern between isotopic results and pathologies which developed as a consequence of diet. The sample size is small but it seems that assessing the pathology based on stable isotope results is very unreliable.

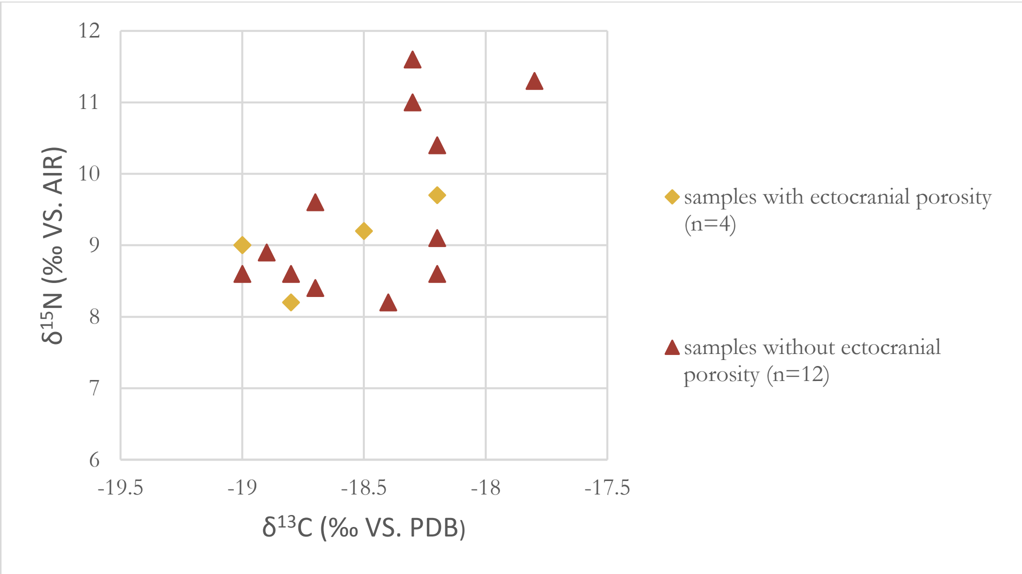

Figure 43: visual representation of samples with and without ectocranial porosity

[259] Hobson et al. 1993; Morgan et al. 2012; Heuser and Eisenhauer 2010.

6.6.COMPARISON TO OTHER ISOTOPIC STUDIES IN RAVNI KOTARI (Roman, Late Antiquity, Early Medieval period)

A significant work in stable isotopic studies has been done in Ravni Kotari.[260] This sub-chapter aims to draw a comparison to the previous studies in the same geographical area, connecting results from Bribirska Glavica to Roman, Late Antique and Early Medieval sites. Furthermore, different time periods will be compared, including the samples in Bribirska Glavica divided by periods. In the first comparison only samples with relative date are taken into account (n=28). (table 5)

Table 5: Mean values of isotopic results from Ravni Kotari, by time periods / Lightfoot 2009; Lightfoot et al. 2012; Novak et al. 2016.

Period	Site	N	Mean $\delta^{13}C$ (‰)	St.dev.	Range $\delta^{13}C$ (‰)	Mean $\delta^{15}N$(‰)	St.dev.	Range
Roman	Zadar-Relja	51	-18.9	0.4	-19.6 to -17.8	10	0.7	9 to 12.9
	Vis-Bandirica	18	-18.9	0.3	-19.4 to -18.5	9.7	0.7	8.5 to 10.5
Late Antique	Podvršje	11	-18.5	0.3	-18.9 to -17.7	10.9	0.9	9.8 to 12.1
	Bribirska Glavica	2	-18.9	0.1	-18.8 to -19	9.8	0.7	9.1 to 10.5
Early Medieval	Velim-Velištak	105	-17.6	0.5	-18.7 to -14.9	9.5	0.4	7.4 to 11
	Glavice-Gluvine	33	-18	0.7	-19.2 to -16.	9.2	0.5	8.3 to 10.4
	Radašinovci-Vinogradine	68	-17.7	0.5	-18.8 to -16.5	9.7	0.5	8.4 to 11.1
	Šibenik-Sveti Lovre	54	-18.4	0.4	-19.2 to -17.2	10	0.4	8.6 to 11.7
	Dubravice	8	-18.5	0.7	-17.6 to -19.7	9.8	0.5	9 to 11.6
	Konjsko Polje	5	-18.5	0.3	-18.2 to -18.8	8.9	0.5	8.6 to 9.4
	Vaćani	8	-18.4	0.5	-17.7 to -19.1	10.2	1	9 to 11.7

260 Lightfoot 2009; Lighfoot et al 2011; Lightfoot et al 2012; Novak et al. 2016.

	Bribirska Glavica	2	-17.55	0.55	-17 to -18.1	10.65	1.25	9.4 to 11.9
Late Medieval	**Bribirska Glavica**	24	-18.3	0.5	-17.1 to -19.2	9.68	1.32	8.2 to 13.2

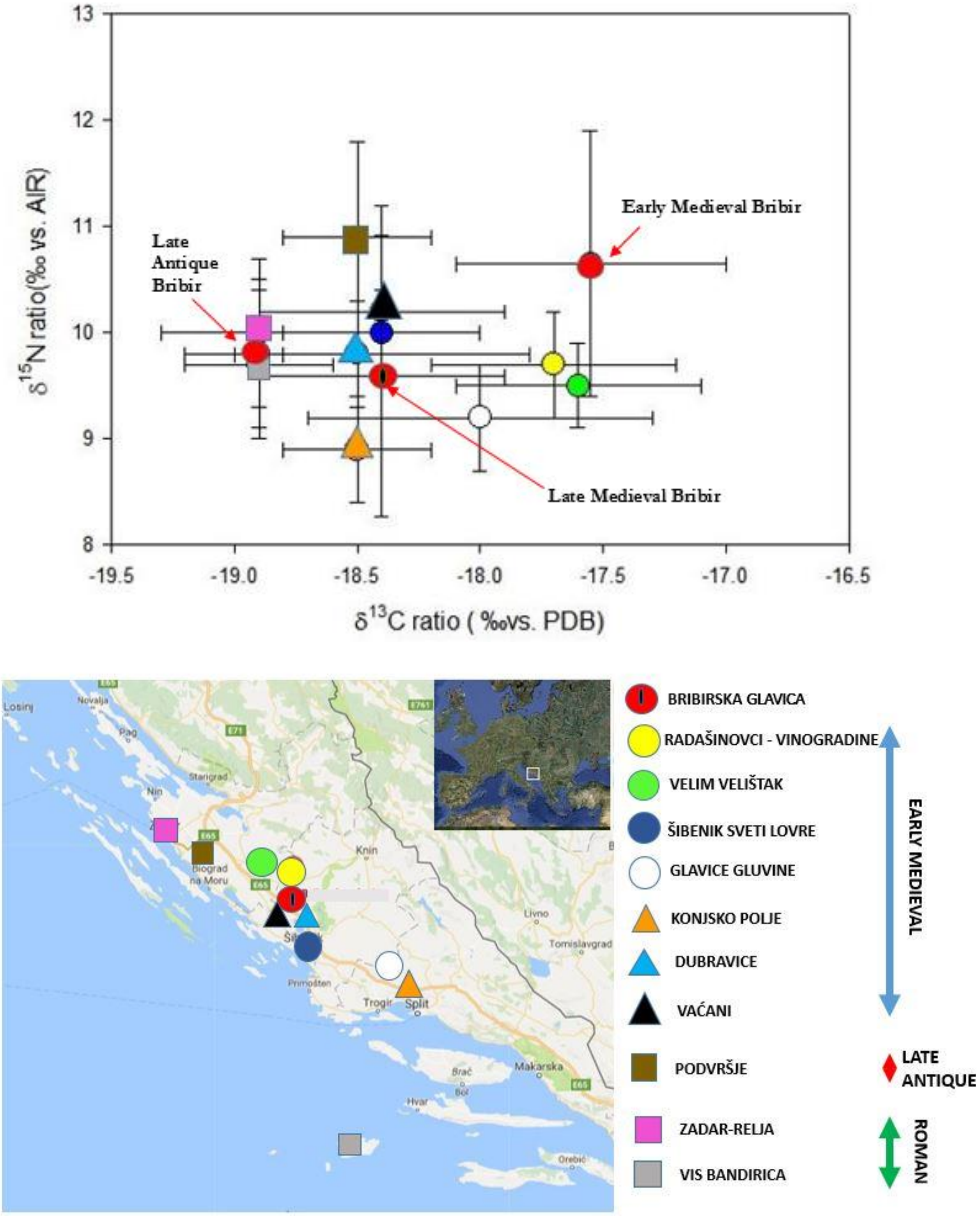

Figure 44: scatter plot (with geographical position marked in the map) depicting different sites according to time periods /Lightfoot et al. 2012; Novak et al. 2016.

Bribir, inter-comparison between time periods. Before bringing up conclusions, it is important to emphasise the discrepancy between the amount of samples between Late Antique (n=2), Early Medieval (n=2) and Late Medieval Bribirska Glavica (n=24)[261].

Late Antique Bribirska Glavica shows more depleted $\delta^{13}C$ ratios, indicating this two individuals ate food based on C_3 and with most likely no millet (at least not enough to be isotopically visible). The level of $\delta^{15}N$ is moderately higher than in Late Medieval population of Bribir (n=24). However, the highest levels of $\delta^{15}N$ belongs to Early Medieval period (n=2) which, together with enriched $\delta^{13}C$ results, indicates diet with more animal protein or possible marine sources. That is not in correspondence with the generalised view on the decrease in standards of living during Early Middle ages but we have to keep in mind that there are only two samples, most likely from a privileged context, as most of these burials are. (fig.44)

Early Medieval Bribir samples (n=2) show a significant enrichment in $\delta^{13}C$ ratio, indicating an increase of millet as an essential part of the diet. This goes well with the historical situation at that time – being characterised by huge raids, migrations and influx of refugees trying to flee from the invaders in the North. At one point, Dalmatia had a sudden increase in population and millet could have been a solution to population pressure.

Comparison to other sites. As seen in figure 44 the results from Bribirska Glavica, when divided by time-periods, seem to fit into different contexts. Late Antique results (n=2) partly overlap with the isotopic results from Roman sites Zadar Relja and Vis Bandirica but not with the Late Antique site Podvršje, as would be expected.

Late Medieval Bribir has very similar $\delta^{13}C$ values with Early Medieval sites Dubravice, Vaćani (both within 5-7 km from Bribirska Glavica), Šibenik-Sveti Lovre, Konjsko Polje and Late Antique site Podvršje. When it comes to $\delta^{15}N$ levels, it corresponds to Radašinovci Vinogradine, Velim Velištak, Late Antique Bribir, Šibenik Sveti Lovre (coastal), Dubravice and Roman sites Zadar Relja (coastal) and Vis Bandirice (island).

Early Medieval Bribir has quite enriched $\delta^{13}C$ values, more similar to Radašinovci-Vinogradine and Velim Velištak. The $\delta^{15}N$ ratio is almost the highest when compared to other sites and time periods in Ravni Kotari, having only Podvršje, a Late Antique site, depicting higher protein consumption (or implementation of fish) in diet.

261 Not all samples were included into this comparison so the burials without any relative date don't buffer the correlations.

Study on Ravni Kotari showed that the geographic position of the site doesn't govern the diet. It seems that even coastal and island sites do not consume fish in Early Medieval period, as was the practice in Roman time and Late Antiquity.[262] Studies in Italy show the same pattern in Early Medieval period.[263]It looks as if there was a sudden abandonment of fishing which was suggested to be a revolt against the Romanised pagan lifestyle and certain stubborn shaping of the new, seemingly vulnerable identity. Furthermore, income of Slavic tribes brought new influences in diet, having emphasis on millet and protein obtained from cattle and caprids with occasional pig in the diet.[264] One of the suggestion for the interpretation is a possible fear of the danger from the open sea, which could have been dominated by pirates and the Venice.[265] The consumption of marine and freshwater sources does not seem to be easily traced isotopically.

The second comparison is made with all the samples from Bribirska Glavica, together with the ones without a relative date. The results are compared to the extensive study of Lightfoot, including both fauna and all the human samples with the fauna and humans from Bribir.[266]

Table 6: table depicting comparison between fauna from Bribirska Glavica and other sites in Ravni Kotari /Lightfoot et al 2012.

Site/Period	Species	Mean $\delta^{13}C$ ratio (‰)	Mean $\delta^{15}N$ ratio (‰)
Bribirska Glavica (Early-Late Medieval)	Caprid/cattle (n=7)[267]	-20.01	5.05
Zadar-Relja, Vis-Bandirica, Podvršje (Roman, Late Antique)	Caprid/cattle (n=32)	-20.5	4.6
Velim-Velištak, Glavice Gluvine, Radašinovci-Vinogradine, Šibenik-Sveti Lovre (Early Medieval)	Caprid/cattle (n=12)	-19.7	5.5

262 Lightfoot 2009; Lightfoot et al. 2012.
263 Craig et al. 2009; Prowse et al. 2004; Rutgers et al. 2009; Salamon et al. 2008.
264 Lightfoot 2009; Lightfoot et al. 2012.
265 Dr André Carneiro suggested this explanation during the defense of this thesis on 20th of October 2017.
266 Ibid.
267 Only samples BRA 02, BRA 05, BRA 07, BRA 08, BRA 09, BRA 10, BRA 16 were included here. Samples of pig and potential rooster/chicken were excluded in this comparison table mainly due to making the comparison more accurate.

As seen in this table, the results from Bribirska Glavica seem to be intermediate between Roman and Late Antique and Early Medieval fauna. (table 6)

Site	**$\delta^{13}C$ enrichment**	**$\delta^{15}N$ enrichment**
Podvršje (Late Antique)	2	6.3
Velim-Velištak (Early Medieval)	2.1	4
Glavice Gluvine (Early Medieval)	1.7	3.8
Radašinovci Vinogradine (Early Medieval)	2	4.3
Šibenik-Sveti Lovre (Early Medieval)	1.3	4.5
Bribirska Glavica (Early-Late Medieval)	2.23	4.5

Table 7: table depicting comparison between human-faunal offsets between sites in Ravni Kotari / Lightfoot et al. 2012

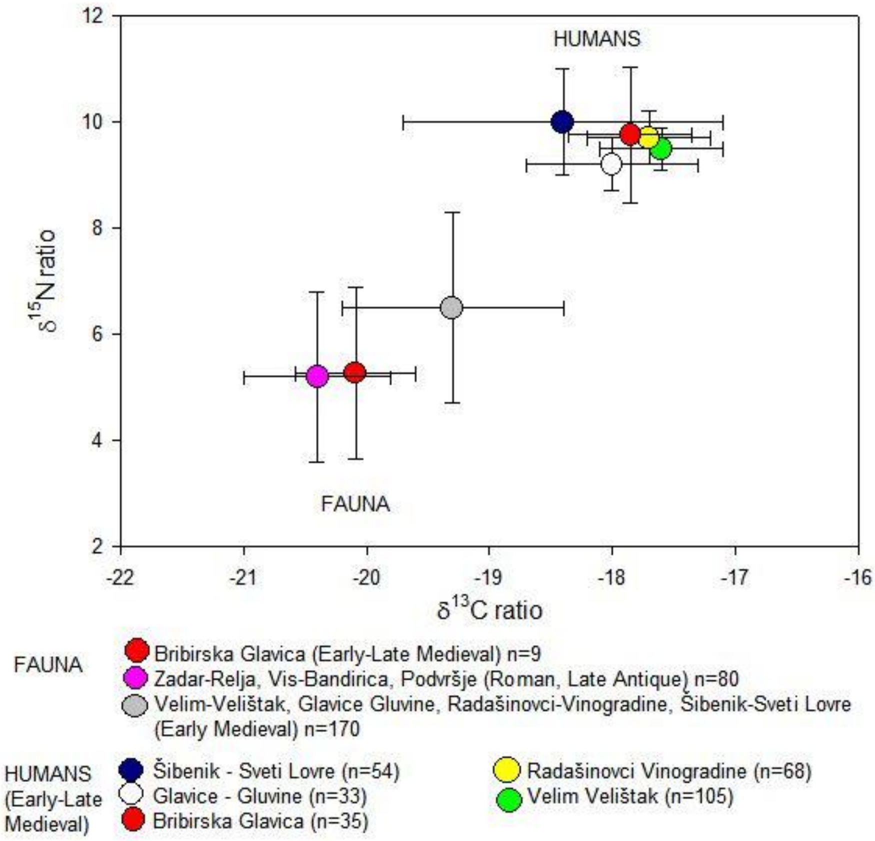

Figure 45: comparison of all the samples (fauna and humans) from Bribir to Lightfoot's study / Lightfoot et al. 2012.

There is a significant difference in fauna from Early Medieval period and Roman whilst Bribir samples, considered to be mostly Late Medieval, show correspondence with Roman ones. (fig.45) One of the possible reasons is environmental factor. Research shows that during Early Medieval period there was a change in climate into a colder one and that might have affected Croatia at the time.[268] Perhaps there was also an anthropogenic influence - change in manuring and the diet which was given to domestic animals. It is possible that the diet has been

[268] McDermott et al. 2005; Castagnoli et al. 2002.

enriched with C_4 plants, presumably millet. Taken into account the baseline, there is a bigger human-faunal offset in Late Antiquity (site Podvršje), indicating that population there was consuming protein from high trophic levels, most likely marine ones, whilst Bribirska Glavica fits into the expected range for terrestrial diet. However, the enrichment in $\delta^{13}C$ is the highest compared to fauna from other sites. (table.7) This could be due to increase consumption of millet by humans which wasn't extended into animal diet.

CHAPTER SEVEN

7. CONCLUSION AND FINAL REMARKS

This study has obtained quantitative data on paleodiet in Bribirska Glavica, Croatia. The main questions “What did people eat?” and “What does their diet reflect?” were addressed to 35 human and 9 faunal samples. Isotopic ratios of carbon and nitrogen were measured and the results were interpreted through several categories:

Dietary discussion. Based on the results on fauna and human samples, the paleodiet of population of Bribirska glavica was interpreted as relying on C_3 with the addition of C_4 plants, most likely millet which is in accordance to the trend of changing diet during Middle ages, together with the decrease of standards of living and turbulent times of raids and migration on Eastern Adriatic coast. The range of $\delta^{13}C$ results deemed to be wide (-17‰ to -19.3‰), most likely due to various levels of implementation of millet in the diet. The average result was -17.85±0.5‰. Range of $\delta^{15}N$ results was also wide (8‰ to 13.2‰) suggesting there were different levels of consumption of proteins and the average value was 9.76‰. (table 3) Human-faunal offset seems to fit into expected ranges for nitrogen, being 4.5‰. Offset for carbon isotopes was 2.23‰, being a bit higher (0.23‰) than expected, possibly due to increased consumption of millet that was not so much extended into animal diet. Faunal samples were discussed with a brief attempt to explain variations in results from *ovies aries* and unexpected results of *gallus gallus*. It has been concluded that the chronology of faunal samples is unknown, the stratigraphy might have been disturbed, the sample size is small and some of the identifications of species were not clear. In total, 8 human outliers have been detected via Interquartile range and each of them has been individually discussed.

Gender and age. The results were grouped into scatter plots and box plots to understand the correlation of diet according to the status that age and gender bring in the society. Box plots depicting gender differences showed that median values in $\delta^{15}N$ are only 0.1‰ apart but men had twice as more variant results while $\delta^{15}N$ values of women are much more grouped, indicating that men had more variations in diet. Median value of $\delta^{13}C$ showed mutual offset of 0.5‰ – women having more depleted results then men, indicating they were consuming less millet. There seem to be clusters according to age groups – in both isotopic results of carbon and nitrogen there is a pattern of 3 groupings. First are people between 15 and 20 years old that have lower protein consumption and more depleted carbon isotopic values, having less millet in the diet (exception is a sub-adult depicting high amount of millet), second group belongs to people between 20-25 and 25-35 years of age that tend to have higher protein diet and more millet whilst the third group consisting of individuals from 30-40 to 50-55 years have more scattered results, depicting wide variations in millet consumption but lower protein intake then the second group. This could suggest that the diet was indeed shaped according to the social status based on gender and age.

Burial context. There have been 4 clusters noticed when comparing results with the burial context. It seems that graves 11, 12, 13 and 15 show certain patterns between individuals buried in the same grave. It is noticed that there are very similar or even equal values in either carbon or nitrogen isotopic results or even in both, as is the case of the grave 15. These graves were deemed to be belonging to important individuals (since they were set inside the church, one of them being even next to the altar screen) and it is assumed that the members of each of these massive graves were somehow related with each other – perhaps as a family. Hence there are some indications that diet shapes the identity within a nucleus or any kind of smaller unit in the society.

Pathology. An attempt to correlate pathologies developed as consequences of diet was made, connecting isotopic results to individuals with diagnosed ectocranial porosity (due to malnutrition and vitamin deficiency and anemia) but no pattern emerged. It has been concluded the relationship of diet and health is unreliable and unclear, at least in this context.

Comparison to other studies and time periods. To understand the results from Bribirska Glavica and the diet responds to the change in lifestyle during time periods and the geographical position, the samples were separated according to relative chronology and compared to another sites. There seem to be an interesting pattern of more depleted $\delta^{13}C$ results in Roman period and Late Antiquity with higher $\delta^{15}N$ values, indicating higher protein consumption and perhaps even some implementation of high trophic level protein, like fish. Two samples (BRH 03, BRH06, GR 17) of Late Antiquity from Bribir seem to match Roman dietary pattern more than the one noticed in Late Antique site in Podvršje.

Early Medieval period shows a significant enrichment in carbon isotopic results, most likely because of introduction of millet in the diet, noticed both on the level of Bribirska Glavica and confirmed in other sites of Ravni Kotari. The average level of nitrogen stable isotopes were lower than in Roman and Early Medieval sites on the level of Ravni Kotari, indicating a certain drop in the intake of animal protein and abandonment of marine and freshwater sources. This is explained by the change in the lifestyle and turbulent times and population pressure which required introduction of millet as a “poor man’s food” that is resistant to poor soil and low abundance of water. However, two samples from Early Medieval period (BRH 04, BRH 34) in Bribirska glavica show higher levels of protein intake (but fit into the noticed pattern of enriched carbon isotopic values), deviating from this general pattern which could be due to small sample size and the fact that people buried in Bribirska glavica are most likely coming from the privileged strata in the society. This combination could imply addition of marine food sources.

Late Medieval period seem to have more depleted $\delta^{13}C$ values compared to two samples from Early Medieval period, showing less relying on millet and relatively average protein intake. However, it resembles results from several Early Medieval sites in close vicinity, such as Vaćani and Dubravice and one coastal site – Šibenik, Sveti Lovre. This could be due to the fact that Bribirska Glavica was a very important opidum and its influence spread in the surrounding settlements, depicting similar diet. Šibenik was a very important city in middle ages and hence their intake of millet could have been less, with more average intake of protein, depicting certain level of prosperity. Late Medieval period in Dalmatia seems to be different, perhaps due to the fact that in that period the cultural and ethnic identity and lifestyle in Dalmatia was more stable, despite the ongoing political turbulences. It was most certainly different compared to the Early Medieval period following the collapse of the Roman Empire and complete abandonment of pagan lifestyle and constant raids, epidemies and settling of so called Croats who were still developing their own ethnic identity.

Faunal samples from Bribirska Glavica, presumed to belong to Late Middle ages, have been compared to other samples from Ravni Kotari, according to the time period, showing that the samples from Early Medieval period do not match the ones from Bribir. Bribir fauna, on the other hand, matches the results from Roman sites. This could be due to the Early medieval climate change into a colder one and perhaps due to increased relying on millet compared to Late Medieval and Roman period and Late Antiquity.

FINAL REMARKS

This thesis provides first known insight into the Late Medieval diet in Croatia and hence has a particular significance. It provides a certain continuum in paleo-dietary studies in Dalmatia, now extending from prehistory to 16th century. However, it is important to have in mind the small sample size and the fact that all the samples come from Bribirska Glavica and most likely from the privileged burial context. To assess the validity of these conclusions, further studies ought to be done, with the emphasis on the isotopic study of settlements.

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