Solange Isabel Ferreira da Silva

Licenciada em Arqueologia

The consumption of seafood by the populations of Islamic Silves (South Portugal)

Dissertação para obtenção do Grau de Mestre em

Paleontologia

Orientador: Pedro Callapez, Professor Auxiliar,
Universidade de Coimbra

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Acknowledgements

So long have I been yearning to reach the conclusion of this step in my life, that now that I stand here, I do not know how to describe this complicated mixture of feelings. I have been working on this Master Thesis for over a year, and while I feel immensely happy and proud of myself and my achievements, I already feel nostalgic for an era that has come to an end.

I could never have gotten this far without the relentless support from my dear parents. For they have always had my back in all my decisions, however questionable they may have been. At the same time, I want to apologize for all the grey hairs I have given them over the past two years.

I also want to thank all my family who supported me. My brother José Paulo that would ask me every day without fail if I had already finished my Thesis. My dear grandparents Fernanda, Joaquim, Maria José. And this work also be a very special dedication to my beloved grandfather Francisco, who has sadly left this world without having seen the graduation of this granddaughter.

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A special thanks to Prof. Doctor Rosa Varela Gomes and the Laboratory of Archaeology of the FSCH-UNL for authorizing access to study in this work one of the most important and largest malacological collections of this period in Portugal, and for the trust placed in me. Also thank you for the invitation to do an internship at the Laboratory of Archaeology of the FSCH-UNL, despite the pandemic that shook 2020 did not allow it.

I also want to thank Lieutenant Colonel José Manuel Pedroso da Silva for offering the photographs of the Arade river estuary used in this work.

A final thanks to my friends who have always supported and encouraged me, and who, in one way or another, have contributed to the success of this thesis.

ABSTRACT

Malacology is the scientific branch of Invertebrate Zoology dealing with the study of the Phylum Mollusca. It includes soft-bodied invertebrates and topics such as taxonomy, systematics, taphonomy, biostratigraphy, evolution, ecology, biogeography, biotic resources, and human interactions. Applied to Palaeontology and Archaeology, Malacology enables palaeoecological, palaeoclimatic, and cultural studies and statistical analyses.

The case study focused on the medieval Silves town (*Xelb* medina; Algarve, southern Portugal), its Islamic population, and the interactions between humans and edible mollusc rich environments. It includes aspects such as: food consumption, economy, estuarine biotope exploitation, and cultural shell usage.

The studied assemblages were collected from a palatial context of the Alcazaba that is estimated to be occupied from the 6th/7th century to the 16th century. The sample studied belongs to different historical periods and consumed by different social levels. The archaeological campaigns were directed by Prof. Rosa Varela Gomes from the Universidade NOVA de Lisboa and archived in the Laboratory of Archaeology of the Faculdade de Ciências Sociais e Humanas (FCSH).

The work focuses on 12,605 skeletal parts, mostly fragmented shells; subjected to systematic, taxonomic, and taphonomic identifications after laboratorial preparations. These were followed by a bulk sample quantitative analysis to obtain statistical data regarding species representativeness, palaeoecological interpretations of surrounding aquatic biotopes, and anthropic interactions, with a shellfish and edible mollusc consumption emphasis. Analysis has revealed 25 bivalve, 16 gastropod, 1 crustacean, and 1 barnacle species from marine and estuarine environments, and 3 terrestrial gastropod species. *Ruditapes decussatus* (venus clam) is predominant in almost all sampled layers, followed by *Ostrea edulis* (oyster) and *Cerastoderma edule* (cockle). Wide mollusc variety was also observed, averaging 12 species per excavated square. Species abundances indicate the exploration of estuarine environments similar to the nearby Arade river. Several valves, intentionally perforated or showing umbonal abrasion facets, were interpreted as fishing net ballasts. A large convex *Pecten maximus* (scallop) valve may result from domestic tool usage.

This work is a first approach to a larger zooarchaeological collection. Further studies will provide crucial data on this important medieval Islamic centre of the Iberian Peninsula.

Keywords: Castle context, Invertebrate Palaeontology, Islamic Period (12th Century), Malacology, Medina suburb (Xelb), Zooarchaeology.

RESUMO

Malacologia é um ramo científico da Zoologia de Invertebrados que se dedica ao estudo do Phylum Molusca. Inclui invertebrados de corpo mole e questões quanto à taxonomia, sistemática, tafonomia, biostratigrafia, ecologia, evolução, biogeografia, recursos bióticos e interações humanas. Aplicado à Paleontologia e Arqueologia, a Malacologia permite realizar estudos e análises estatísticas, paleoecológicas, paleoclimáticas e culturais,

O caso de estudo incidiu sobre a cidade Medieval de Silves (*Xelb* Medina; Algarve, sul de Portugal), a população islâmica que aqui viveu e as interações entre o humano e o ambiente rico em moluscos comestíveis. Refletindo o consumo e a economia alimentares, a exploração do biótopo estuarino e o uso cultural de conchas.

A amostra estudada foi recolhida de um contexto residencial palatino de uma Alcáçova, com uma ocupação estimada desde os séculos VI-VII ao séc. XVI. Esta amostra pertence a diferentes períodos históricos e consumida por distintos estratos sociais. As campanhas arqueológicas foram dirigidas pela Professora Rosa Varela Gomes, da Universidade Nova de Lisboa e armazenadas no Laboratório de Arqueologia da Faculdade de Ciências Sociais e Humanas.

O estudo centra-se em 12,605 partes esqueléticas, principalmente conchas fragmentadas; submetidas a identificação taxonómica e tafonómica após preparações laboratoriais. Seguidos por uma análise quantitativa da amostra de modo a obter dados estatísticos quanto à representatividade das espécies, interpretações paleontológicas dos biótopos aquáticos envolventes e interações antrópicas, com ênfase no consumo de moluscos e crustáceos.

A análise revelou 25 espécies de bivalves, 16 de gastrópodes, uma de crustáceos e uma de cracas, de ambientes marinhos e estuarinos, e três espécies de gastrópodes terrestres. A espécie *Ruditapes decussatus* (amêijoa boa) é predominante em quase todas as camadas analisadas, seguida da *Ostrea edulis* (ostra) e *Cerastoderma edule* (berbigão). Contatou-se uma grande variedade de moluscos, com uma média de 12 espécies por camada. Esta abundância de espécies indica a exploração de ambientes estuarinos de substrato arenoso-vasoso, semelhantes aos do rio Arade. Registou-se também várias valvas deliberadamente perfuradas ou com facetas de abrasão umbonal, interpretadas como pesos de rede de pesca. Uma valva de *Pecten maximus* (vieira) pode resultar do uso doméstico.

Este trabalho é a primeira abordagem a uma grande coleção zooarqueológica disponível deste sítio arqueológico, novos estudos irão fornecer novos dados cruciais quanto a este importante centro Islâmico medieval da Península Ibérica.

Palavras-Chave: Contexto de Castelo; Paleontologia de Invertebrados; Período Islâmico (séc. XII); Malacologia; Arrabalde da Medina (*Xelb*); Zooarqueologia.

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ABBREVIATION LIST

Institutional

FCT-UNL: Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa.

FSCH-UNL: Faculdade de Ciências Sociais e Humanas da Universidade Nova de Lisboa.

Nomenclatural

COMV – Complete valve.

FRAV – Fragmented valve.

FCH – Fragment with complete hinge.

AHF/PHF – Anterior/posterior hinge fragment.

FTS – Fragments (absence of hinge).

COMI – Complete individual.

FRAI – Fragmented individual.

APIF – Apical fragment.

STOF – Stoma fragment.

UMBF – Umbilical fragment.

FCOL – Columella fragment.

FTS – Fragments (absence of apex or stoma).

NRE - Non-Repetitive Elements.

MNI – Minimum Number of Individuals.

NISP – Number Identified Specimens Present.

PP – Pinnacle Point

UP – Upper Palaeolithic

MJ – Middle Jurassic

UT – Upper Triassic

Chapter 1 INTRODUCTION

1.1 MOTIVATION AND CONTEXT

Silves, a city located in the Algarve region, in southern Portugal, remained under Islamic occupation for most of the Medieval Period – more precisely between 713 to 1247. During this period, *Xelb,* as it was called, was an important city and the last capital of the *Gharb al-Andalus*. The long period of occupation has resulted in remarkable evidence of their presence.

This Islamic context was subjected of several archaeological campaigns, lasting for more than two decades. It has led to the discovery of a vast record of ruins and diverse findings, located not only on the most emblematic places on the historical centre of Silves, but also in its peripheral zones. The large and rich collections of archaeological materials sampled from the site in Silves are a perfect scenery for a wide range of possible research. These have thus been the motivation involvement and contribution in expanding the state-of-the-art to their when opportunity arose to study their invertebrate assemblages.

Concerning this context of said research, the present dissertation deals with the study of a zooarchaeological bulk-sample, with invertebrate remains, all collected during the above-mentioned excavation campaigns, under direction of Prof. Rosa Varela Gomes from the Faculty of Social Sciences of the Nova University of Lisbon (FCSH-UNL). It consists of two containers, of about 23 kg each, comprising approximately 4089 identified specimens (*i.e.*, MNI - Minimum Number of Individuals), composed by skeletal remains of aquatic and terrestrial molluscs, crustaceans and other invertebrates, representative of anthropic deposits with garbage concentrations related to food consumption and shellfish, and associated fishing activities.

This bulk-sample represents the first part of a large collection of zooarchaeological materials, carefully sampled during fieldwork and stored at the Laboratory of Archaeology of the FSCH-UNL, in the campus at Avenue of Berna, Lisbon. All the still unstudied materials – except for the present bulk-sample – constitute one of the largest collections of its type for the Islamic contexts of the Iberian Peninsula. This fact clearly emphasises its importance for a better knowledge regarding this key chronological period from the history of mainland Portugal. The materials were made available for study by professors Rosa Varela Gomes and Mário Varela

Gomes, which are in charge of the laboratory and have dedicated for several years to the study of the Prehistory to Medieval Epoch of South Portugal. For both, I would like to express my best acknowledgements and the wish that this MSc monograph will be followed by more, deep, and always interesting research on the invertebrate remains of Silves.

The skeletal remains presently studied and taxonomically classified in this work, were collected from the archaeological interventions in the Silves Castle, this sample has two distinct origins, a small part comes from the northeastern sector of Alcazaba, corresponding to silo 4 (squares 537/538) mostly Islamic. The rest comes from the west sector of Silves Castle started between 2003 and 2007, and motivated by the project of musealization of this castle, within the scope of the Silves Polis Program, by the Municipality of Silves (R. V. Gomes, 2012). In this project it was possible to recover and restore the two Islamic palaces, as well as excavation of part of the west sector of the Castle, where the Alcaidaria was recognized (*op. cit.*), whence the studied malacological sample was found.

Thus, the focus of this research into the study of shells and other invertebrate remains in their archaeological context, seeks provide a large amount of insights, regarding the economic trends at the time, differences in society, connections between towns and between town and outskirts, and trade and living environment, among others.

In conclusion, the analysis of this collection enables further the discussion and contextualization of the anthropic and ecological surroundings of the site during Medieval times. Additionally, they allow a better reconstruction of the local environment, alongside with aspects of the food consumption, and the recreation of habits of this human community, by drawing comparisons between it and other with other Islamic communities of the same period in the Iberian Peninsula.

1.2 ZOOARCHAEOLOGICAL STUDIES AND THEIR IMPORTANCE

As a main part of Bioarchaeology, which also includes plant remains, and with micropalaeontology among its goals, Zooarchaeology is a branch of modern Archaeology that examines animal remains from the archaeological sites. It has long been used by experts seeking to understand the human-animal-environment interactions, through the application of anthropological, biological, and ecological concepts.

According to Reitz and Wing (2008), zooarchaeology has two interconnected goals: to understand the biology and ecology of animals, and to understand the structure and function of human behaviour through time and space. These are mainly studied by biological and physical sciences, through anthropology and archaeology sources. This present research is focused in both biological and anthropological approaches. It is an anthropological analysis of shell remains with a biological foundation that seeks to consider the human context of the materials, aiming to present a complete picture of the archaeological context in question, concerning shellfish consumption.

The study of animal remains from archaeological sites was first considered as an area of scientific study in the 1800s, as a combination of zoological, palaeontological, and anthropological components (Reitz, 1993). Despite being practised for a long time, it was only formalized in the middle of the 20th century as an examination of antique animal remains that sought to decipher ancient environmental conditions, (Faith & Lyman, 2019). The term "zoologico-archaeologist" was used by Lubbock (1865, p. 169) to mention the two Danish and Swedish researchers Steenstrup and Riitimeyer, who studied animal remains from archaeological sites and their relationship with humans, one of the first clear references to this field.

Studies of fauna collection in Portugal first appear with a few authors producing data. One of these pioneers is Nery Delgado (1865), who collected shells of the yellowish snail *Cepaea nemoralis* in the Neolithic burial levels of Cesareda caves, interpreting them as possible food remains (Callapez et al., 2016). Studies of fauna from archaeological contexts dating to the Medieval period in Portugal are not very abundant as well. There is, however, a remarkable growing interest in this area, with the field slowly changing. An interesting set of recent publications has emerged, related to archaeofaunistic data from archaeological sites all over the Portuguese territory, with a socio-economic focus to the cultural zooarchaeological research (Costa & Braz, 2007). Examples include studies in Silves (Cardoso & Gomes, 1996; Gonçalves, 2006; Gonçalves et al., 2007; Telles Antunes, 1991), Almodóvar (Cardoso, 1993, 1994), Mértola (Antunes, 1996; Carrasquilla, 1993; Morales Muñiz, 1993; Rosello Izquierdo, 1993), Santarém (Davis, 2006; Ramalho et al., 2001), among others.

During the early stages of zooarchaeological, researchers were more focused in the subsistence economies, rather than in the political economy of settlements and cultures (O'Connor & O'Connor, 2003). Animal remains such as bones, teeth, and shells have been recognized as evidence for chronology, ancient environment, and human activities (Gifford-Gonzalez, 2018). Currently, the relationship between animal remains and cultural studies is deemed more relevant. Common research themes in the field include: subsistence and palaeoenvironmental reconstruction, zoographical distributions and ranges, morphological and taxonomical characteristics, technology, anthropogenic impacts on biodiversity, historical and cultural ecology, cultural and social uses and significance of animals, human population and human manipulation of animals, and the contribution of the zooarchaeological perspective, in contemporary biological and ecological conservation (Giovas & LeFebvre, 2017; O'Connor & O'Connor, 2003; Reitz, 1993; e.g. Reitz & Wing, 2008).

Applying zooarchaeology to the study of shells, a research domain also called archaeomalacology, the scenario changes substantially, for although shell remains of molluscs and other coeval invertebrates are generally the most common in archaeological sites, for a long time, their study was not as emphasised as that of vertebrates. Nevertheless, the trend has been inverted in the last two decades, through a growing number of works specialized in the study of invertebrate remains from archaeological sites of different chronologies. These include the oldest Palaeolithic ones (e.g. Zilhão et al., 2020). A new generation of archaeologists with an expertise in this emergent research field is presently forming in many countries, including Portugal, thus revealing the extreme importance of multidisciplinary approaches with the context of Zooarchaeology.

The term Malacology, derived from the Greek works *malakos* “soft”, and *logos* “discourse”, is the science of soft-bodied animals *i.e.,* molluscs. The designation Conchology, that comes from the Greek word *konche* “shell”, refers more specifically to the study of mollusc shells (Martin, 1995). The first malacological organization, the Conchological Society of Great Britain and Ireland, founded in 1876, was followed by the Malacological Society of London, founded in 1893. Both societies have long been concerned with the research and collecting of molluscs and their shells and have been followed in their footsteps by dozens of similar organizations worldwide, including the short-lived Portuguese one, active from the seventies to nineties. Since the second half of the 19th century, there was always a small Portuguese community of collectors and researchers. These included some biologists and palaeontologists among them, who collaborated times to times with the archaeologists, contributing to the advancement of this research area in Portugal.

1.3 THE PORTUGUESE MALACOLOGY

The field of malacological study in Portugal starts in the 1800s with two, almost simultaneously works published by foreign researchers. In 1845, the first monograph dedicated to Portuguese malacology was published by the French naturalist Arthur Morelet (1809-1894)

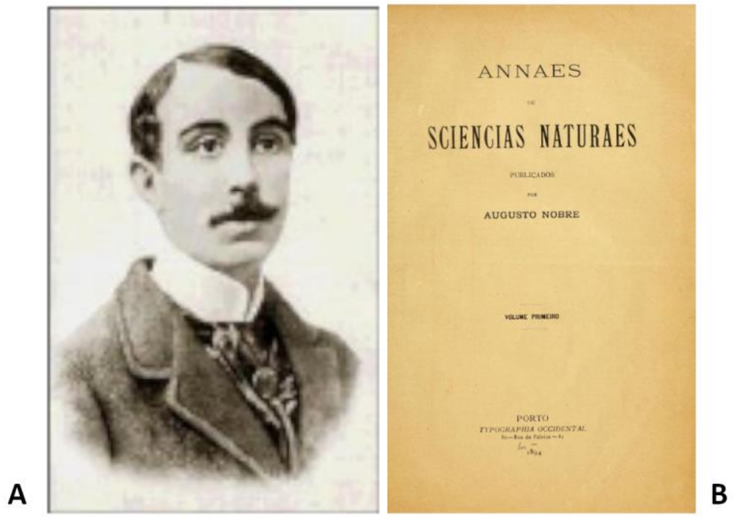
Description des Mollusques Terrestres et Fluviatiles du Portugal (Morelet, 1845). In the same period, the Scottish scholar Robert MacAndrew (1802-1873) explored the Portuguese coast, outlining the geographic distribution of the various species in the areas, and publishing in 1850 the first systematic work on marine molluscs: *Notes on the distribution and range in depth of Mollusca and other marine animals observed on the Coasts of Spain, Portugal, Barbary, Malta and Southern Italy in 1849* (MacAndrew, 1850).

Madeira and Azores also were the focus of attention of foreign naturalists: in 1831 the British clergyman and naturalist Richard Thomas Lowe (1802-1874) published the first monograph dedicated to terrestrial molluscs in the Madeira archipelago (Lowe, 1831), followed by a book of the German malacologist Johan Christoff Albers (1795-1857; Albers, 1854). By the turn of the century, many other works in the area has been published. Also, during this period, the French naturalists Henri Drouët (1829-1900) and Arthur Morelet visited the Azores and subsequently published their works on the molluscs of the archipelago (Drouët, 1858; Morelet, 1860).

This emerging interest in Portuguese malacology studies quickly influenced national researchers. In this same century, the first generation of Portuguese malacologists arose, with some emblematic names, whose work endures through time. Some of this names include, for instance, the zoologist Eduardo Augusto Allen (1824-1899), author of *a Systematic Catalogue of the collection of molluscs and their shells, belonging to the Municipal Museum of Porto 1856/58* (Allen, 1856-58); Jacinto da Silva Mengo (1808-1866), a renowned amateur malacologist of his time; Augusto Luso da Silva (1827-1902), a professor who, between 1869 and 1873, published a set of notes concerning terrestrial and river molluscs in the "Jornal de Sciencias Mathematicas, Physicas e Naturaes"; Arruda Furtado (1854-1887), an insular naturalist dedicated to anthropology and malacology, and Darwin sympathizer, who exchanged correspondences about the Theory of Evolution and published several research works on molluscs, mainly those from Azores; also the king D. Pedro V (1837-1861) who demonstrated quite an interest in the study of nature, and his brother D. Luís (1838-1889 Felismino et al., 2016).

From 1848 forward, the malacological collection gathered by them at the Museu Real das Necessidades (near 4000 specimens corresponding to more than 1400 species, in 1861), became one of the finest and most scientifically relevant in Europe, receiving the visit of countless foreign naturalists. Among them, the famous Charles Bonaparte (1803-1857) and the aforementioned Pierre Morelet and Henri Drouët to whom D. Pedro V sponsors an expedition to the Azores, resulting in 1858, in the publication of the catalogue *Mollusques Marins des Iles Açores* (Vicente, 2003).

Perhaps the most important researcher, worthy of special mention, is Augusto Nobre (1865-1946; Fig. 1), professor in the University of Porto. A pioneer of modern Marine Biology in Portugal, he dedicated most of his scientific life to the knowledge of recent marine fauna in Portugal, both invertebrate and vertebrate faunas, with some excursions into the area of freshwater fish and land snails. With a particularly focus on the study of marine, freshwater, and terrestrial molluscs, he published numerous malacological monographs that are still mandatory to those dedicated to the study of Portuguese marine fauna (Machado, 1946), including the present dissertation. Nobre published his first work in 1882, intitled *Ensaio sobre os Moluscos testáceos marinhos observados entre Espinho e Póvoa*.



ANNAES
DE
SCIENCIAS NATURAES
PUBLICADOS
POR
AUGUSTO NOBRE

VOLUME PRIMEIRO

PORTO
TYPOGRAPHIA OCCIDENTAL
1894

Figure 1: Photograph of Augusto Nobre (A), (Universidade do Porto, 1996-2020), and the cover of the magazine «Annaes de Sciencias Naturaes» (1894-1907) founded by Nobre (B).

1.4 OBJECTIVES

The study of a large faunal bulk sample, yielded from Islamic contexts of the medieval castle of Silves, allows us the realization of a wide range of bioarchaeological interpretations based on quantitative analysis of invertebrate assemblages. This allows for the work to be able to answer questions that go further beyond the mere topic of feeding habits. Such is the case, for instance, of intentional marks found in several mollusc shells, an indication of the reuse of these shells for fishing activity. It seems pertinent to admit that the research of faunal material, in archaeological contexts, can generate significant contributions to the understanding of the *modus vivendi* medieval communities settled in this important coastal region of the *Gharb Al-Andalus*.

The general objective of this study can be summarized and divided in two parts. One, focused on biological interpretations, the analysing of taxonomy, diversity, relative abundance of studied assemblage, ecology, taphonomic processes and environmental aspects. The other, focused on archaeological interpretation, namely the human-animal interrelationships, including the anthropic footprint on the surrounding ecosystem, and social-cultural implications related to shellfish consumption, and traditional activities and procedures required to do so.

With these in mind, it is intended to equate the social nature of the relationship between humans and invertebrates (mostly aquatic molluscs) with the contemporaneous environment. To this end, the following specific objectives were assumed:

a) To review the state of the art of the zooarchaeological studies based on invertebrate assemblages from the Islamic context in Portugal;
b) To perform a morphological and taxonomical identification of the invertebrate assemblage;
c) To make an identification and quantification of the present species;
d) To make a taphonomical interpretation of the studied specimens, regarding their pre- and post-burial history;
e) To accomplish the spatial quantification of the represented species, by square and level;
f) Interpret the spatial distribution of the mollusc remains in relation with their contexts of provenance (mainly the estuary and ocean);
g) To evaluate the overall aspects of present-day biotopes from the Arade river and nearby Atlantic seashore;
h) To develop a palaeoecological interpretation of the studied assemblage based on the known ecology of each species and to determine their provenance areas;
i) To do social and cultural interpretations of the remains, through their study in animal economy at the site, such as shellfish provision and consumption strategies, tools usage and other casual related objects;
j) To perform a comparative analysis between the Silves case study and other documented sites of southern Portugal and the Iberian Peninsula at large, during the Islamic period, showing similar chronological and cultural realities.

1.5 STRUCTURE OF DISSERTATION

This work is divided into seven chapters. Chapter 1 provides a theoretical background to the research performed. In Chapter 2 is presented the framework of Silves and state of art. Chapter 3 expands the introduction of source material and description of methods. Chapter 4 is dedicated to the discussion of the molluscs themselves, mentioning their evolutionary history, and taxonomy. Chapter 5 alludes to the results obtained from the analysis of the remains. In Chapter 6, discusses the results and makes some palaeoecological and anthropological interpretations of these. And finally, Chapter 7 the conclusions.

Chapter 2 SILVES: FRAMEWORK AND STATE OF ART

2.1 GEOLOGICAL AND PALAEOENVIRONMENTAL CONTEXT

The physical characterization of a territory has an important role in archaeological studies because past populations have tended to settle in spaces with favourable conditions to their prosperity. This relationship means an abundance of natural resources, good seasonal climatic conditions - including humidity, precipitation, and sun exposure, access to drinking water, fertile soils for farming and cattle breeding, and high faunal effectives available for hunting, fishing, and shellfish practices. All of these were key criteria for selecting a certain territory to establish themselves.

The study of faunal and floral remains found in an archaeological context help us to recreate the environmental scenario in which these populations had lived, which species existed at the time, their abundance, the defining dietary preferences for certain animals and plants instead of others, among a variety of other factors. To this end, the study of both topographic (1/25,000) and geological maps (1/50,000), has played a key role, since these detail aspects of the relief, hydrography, and lithology of the territory in which the present work is focused on. This helps to process of apprehending the landscape and thus better understand the relationships between human and the environment throughout history.

2.1.1 Location

The settlement of human communities and their further development through the Roman and Islamic periods gave rise to the historical city of Silves (Fig. 2) in a region rich in natural resources enough to provide abundance and wellness. During part of Middle Ages, the territory under cultural, administrative, and economic influence of Silves domain was quite large, covering the entirely western Algarve. In this period, the city established reciprocal relations with other cities of the *Gharb al-Andaluz* and asserted itself as the centre of power in this region (Gomes, 2002b).

The Algarve is a very diversified territory, containing a wide variation in terms of relief, soil composition, climate, fauna, flora, hydrography, river navigability, etc. (Gomes, 2002b). The most common disparities in the Algarve are between coastal zone (Faixa Litoral), the Barrocal, and the mountainous areas (Serra Algarvia), with all their inherent characteristics. This diversity translates into a richness of natural resources that provides abundance and draws diverse populations, with distinct interests and forms of exploring their surrounding environments.

Silves, known as the “Baghdad of the Occident” during the Islamic period, especially during the Taifa period (Nunes, 2017) is settled 10 km from the seashore, on a plateau rising over the margins of river Arade, once an important navigable river with direct sea access. The river has had a crucial role in accessing the city in ancient times, being also important for commerce, the supply of the city, and also as an easy access to the Atlantic Ocean and Mediterranean Sea, rich in fish, seafood, and other goods. The territory in Silves, with an area of approximately 2 200 km², would have its eastern limit between the present municipalities of Albufeira and Loulé. To the north, this limit would extend to Castro da Cola, then wrap around the Monchique mountain range, which would still integrate its territory. Its southern and western limits are imposed by the sea (Gonçalves, 2008). In figures 2 and 3 we can see its location, both geographically and topographically.

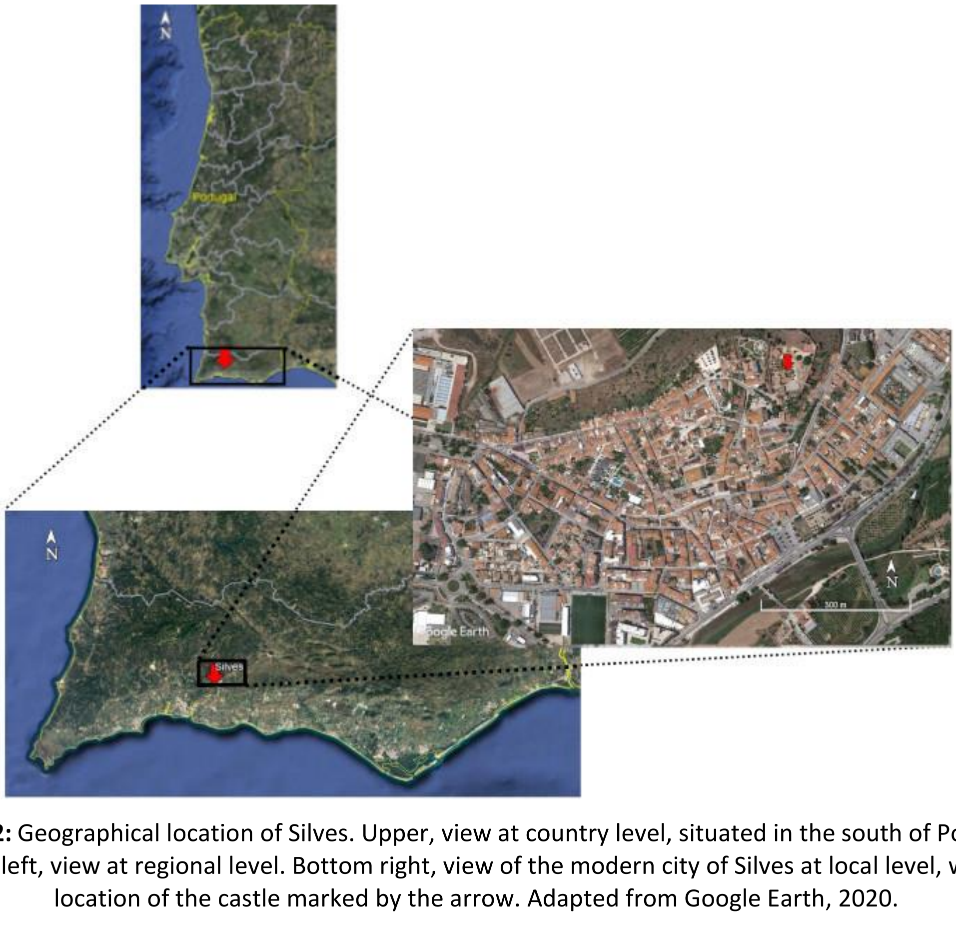


Figure 2: Geographical location of Silves. Upper, view at country level, situated in the south of Portugal. Bottom left, view at regional level. Bottom right, view of the modern city of Silves at local level, with the location of the castle marked by the arrow. Adapted from Google Earth, 2020.

The focus of this work corresponds to the Silves castle of the medieval city. It is situated at the base of the hill where the city is located, about 50 m from the Arade river that flows to the south (*op. cit.*).

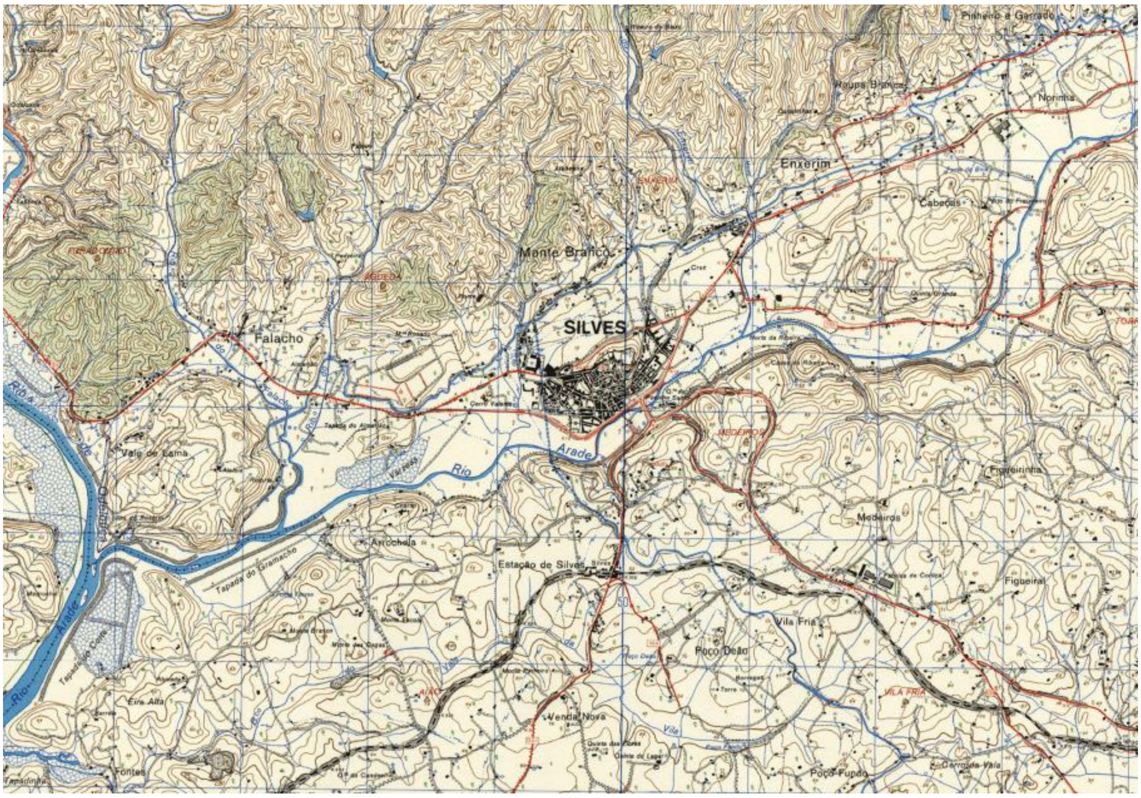


Figure 3: Topography of the surrounding area of Silves. Excerpt of the topographic map of Silves (1/25,000), sheet No. 595 (I.G.E., 2005).

2.1.2 Geological framework

The Algarve region is subdivided into two major morphostructural zones of the southwest Iberian range: the south Portuguese Zone of the Hesperian Massif and the Meso-Cenozoic southern Portuguese Border (e.g. Almeida, 1985; Pereira, 1990). The second of these is bordered by a wide coastal area with well-developed estuarine and lagoonal systems. Both zones are characterized by distinct geological units, which successively outcrop from north to the south, as follow:

a) As the oldest stratigraphic succession, the Carboniferous formations of the mountainous ranges of northern Algarve stands out as part of the southern area of the south Portuguese Zone. Integrated in the Hesperian Massif, they record the regional basement of the Iberian Peninsula, formed by a thick succession of shale and greywacke beds deformed by the

Variscan orogeny (Teixeira & Gonçalves, 1980). These metasedimentary rocks are overlain by Upper Triassic (UT) conglomerates and red sandstones interbedded with luties, mudstones and fine-grained volcano-sedimentary levels belonging to the Silves group ("Grés de Silves"), which contact in a almost continuous way with the Carboniferous formations through a Triassic depression (Feio, 1951; G. Manuppella, 1992; Terrinha et al., 2013). These units are cut by a network of ophite, basalt, and dolerite dykes and flows, together with the larger instrusion of the terminal Cretaceous phenelitic syenites of the Monchique subvolcanic Massif, rising from the carbonic surfaces (Feio, 1951; G. Manuppella, 1992; Terrinha et al., 2013). The Silves Group basal formations of the Mesozoic overlap in an angular unconformity over the deformed Carboniferous succession. Such a phenomenon is practically visible from the northwest of Telheiro beach to the north of Cabo S. Vicente (Rocha et al., 1979). This main continental unit is related to the breakup of Pangea and also serves as a record of the basal infill of the Meso-Cenozoic Margin of Algarve. This corresponds to a sedimentary basin, with sediments deposited from the UT to the Quaternary, with some intercalated sedimentation gaps (Dias, 2001).

b) The overlying Mesozoic succession, which continues with a rather complex stratigraphy of Jurassic and Lower Cretaceous formations, mostly carbonated and from marine environments. These form an extensive strip of carbonated Mesozoic outcrops in the Barrocal (G. Manuppella, 1992; Pinto Gomes & Paiva Ferreira, 2005). The fossiliferous units siliciclastic beds, form large promontories and a rocky coast in Western Algarve and Albufeira, with excellent exposures.

c) The marine Miocene, represented in both Western and Eastern Algarve, from Lagos to Olhos de Água, and around Cabanas and Cancela (Manuppella et al., 1984; Rocha et al., 1989; Rocha et al., 1983), giving a typical yellowish appearance to the rocky cliffs. Good examples of the exist in Praia da Rocha and Ferragudo, close to the Arade estuary and midway to Silves.

d) The Pliocene and Quaternary continental siliciclastic units, and the recent sedimentary cover of the coastal area (Faixa Litoral; Kopp et al., 1989; Terrinha et al., 2013), better represented in the large lagoonal system of Ria Formosa and the estuarine domains of the Alvor, Arade, Quarteira and Guadiana rivers.

2.1.2.1 Meso-Cenozoic tectonosedimentary evolution

The geological history of the Algarve, from the beginning of the fragmentation of the Pangea supercontinent, about 200 Ma ago, to the closing of the Tethys Ocean and the gradual opening of the proto-Atlantic Ocean onwards, is very rich and complex when considering the diversity of units known and their tectono-sedimentary evolution. As with the Lusitanian Basin in the Western Portuguese Margin, the crustal depression of the Algarve Basin developed at the same time, through a rifting event associated with the opening of the North and Central Atlantic Ocean, succeeding the breakup of Pangea in the UT with the deposition of a thick continental series of red beds, called "Grés de Silves".

As stated above, the base of the Algarve Margin infill is made of conglomerates, sandstones and fine-grained pelitic beds, generally reddish or yellowish in colour, with intercalations of mudstones and dolomites of continental origin (Almeida, 1985). This period of rather uniform sedimentation lasted from the Triassic (probably Lower Triassic) until the Sinemurian. Situated in the southwest corner of the Eurasian continental plate it was therefore bordering the continental margin of two oceans: the Atlantic and the Neo-Tethys. The evidence for the Tethyan influence is largely inferred from the dominance of sub-Mediterranean Late Pliensbachian to Tithonian ammonite faunas, since it disappeared through subduction and collision of zone of the alpine orogeny (Manuppella et al., 1988; R. Rocha, 1976; Rocha et al., 1979; Terrinha et al., 2013).

According to Palain (1976), the sediments resulting from the erosion of the Hercynian Chain (during the Permian) would have been transported to coastal areas and subsequently be subject to sedimentation in alluvial fans. Furthermore, Moura et al. (2006) add that the Silves Group has resulted from the dismantling of the Hercynian Chain and posterior deposition in sedimentary basins, possibly associated with the action of ephemeral river regimes.

The coarse siliciclastic alluvial fan deposits are followed by a thick series of evaporitic marls and dolomites with gypsum and halite deposits associated to diapiric structures, constituting the "Evaporitic Carbonated and Pelitic Complex" (Azerêdo et al., 2003; Manuppella, 1988). Finally, lying on the top of the Silves Group is the approximately 160 m thick "Volcano-Sedimentary Complex", whose origin is related to fissure vents caused by a phase of distension that coincided with the first rifting phase, formed by interbedded tholeiitic lava flows, tuffs and volcanic breaches (Azerêdo et al., 2003; Manuppella, 1988). This series ends at the base of the Lower Jurassic (Hettangian) and constitutes a practically impermeable substrate, with hydraulic characteristics similar to schist and greywacke (Almeida et al., 2000). The thickness of this set that constitutes the Grés de Silves Group differs between 80-120 m to 600-800 m, with a maximum expression between Silves and Querença (Costa et al., 1985).

During the Early to Middle Jurassic (MJ) transition, the trend of marine transgressions continued, leading to an increase in the water column depth along the submerged continental margin (albeit gradually). This is evidenced by presence of pelagic and nektonic fossils such as ammonites and belemnites, in the limestone, marly limestones and marly beds that record locally the MJ stages (Costa et al., 1985). However, a major stratigraphic gap is observed between the Middle Toarcian and Middle Aalenian (G. Manuppella, 1992).

During the MJ, between the Aalenian and the Bajocian, due to tilting movements of the blocks along the continental margin flexures, a new transgressive movement occurred, which ended at the Callovian, turning into period of marl-limestone sedimentation associated with an interval of relative sea level stability (Cruz, 1981). At the end of Callovian and beginning of the Oxfordian, a generalized regressive movement occurred. This culminated in the late Callovian-early Oxfordian a sedimentary gap (Almeida, 1985; Andrade, 1989; Costa et al., 1985; Manuppella, 1988). In Iberia, this Callovian-Oxfordian unconformity is often described as the «Callovian Crisis», since it is well developed in all Iberian Mesozoic basins, including the Algarve Basin, and corresponds to a major erosion event caused by the uplift of the continental margins (Terrinha et al., 2002).

At the Late Jurassic to Early Cretaceous, a new distensive phase related to the Atlantic Ocean opening took place, as evidenced by the existence of several faults resulting from vertical movements. In this period, the coastline gradually regressed (perhaps occupying a similar position to nowadays), as for the pelagic fauna, characteristic of the open sea, succeeded by the coral reefs, typical of shallower waters (Manuppella et al., 1988). The sea retreat was followed by the formation of brackish environments that allowed for the development of a vast lagoon system occupying a large area of the Algarve region. As in every marine regression setting, these lagoon areas would have received a siliciclastic unput of gravel, sand, and clay, transported by the river systems that flowed into them (Manuppella et al., 1988).

The Lower Cretaceous is well represented in the region between Lagos and Portimão, particularly on the cliffs between the Zavial and Porto de Mós beaches, where Miocene units cut the uppermost Cretaceous levels. In the western Algarve, between Portimão and Albufeira, the Cretaceous succession is poorly exposed, with the most representative section located near

Porches. In the eastern Algarve, the Cretaceous units are exposed in Albufeira and Tavira, in small outcrops (Terrinha et al., 2013).

In the Upper Cretaceous, two groups of alkaline magmatism can be found, associated with the compressive regime that followed Aptian: the Monchique alkaline complex and the volcanic rocks from the littoral Algarve. The first presents a concentric structure, with a homogeneous nepheline syenite nucleus, bearing the fact that the Monchique mountain range was formed through differential erosion. The volcanic rocks of littoral Algarve appear associated with dykes, sills, volcanic pipes, and extrusive volcanic breccias dispersed throughout the basin, corresponding mostly to the basanite and lamprophyre petrographic types (*op. cit.*).

According to Manuppella (1988), after the intrusion of the subvolcanic massif of Monchique, began a long period of erosion which comprised part of the Paleogene. This is justified through the absence of records of significant geological events throughout the Algarve region, which do not allow a precise dating between the Upper Cretaceous and the marine transgression (Almeida, 1985).

The Algarve Basin has a complex Cenozoic tectonic evolution with respect to its geometry and phenomenology involved. During the Paleogene, sedimentation was only preserved in the offshore area, suffering a compressive tectonic environment – *i.e.,* the same compressional episode that shortened and inverted the Mesozoic basin - (Lopes et al., 2006; Pais et al., 2012). The Neogene units characterized thus far belong mostly of the Miocene and are mostly marine, constituting a large part of the coastal cliffs. These marine formations were deposited mainly in a temperate carbonate platform environment until the end of the Middle Miocene and were irregularly covered by more recent detrital deposits (Cruz, 1981; G. Manuppella, 1992; Pais et al., 2012). During the Upper Miocene, possibly due to tectonic instability in the Quarteira Fault, sedimentation started to take place at the east of this accident. The units of the Upper Tortonian and Lower Messinian mainly correspond to the western infilling sector of the Guadalquivir Basin (Pais et al., 2012).

From the Pliocene onwards, important tectonic movements occurred, and a regressive trend, with rhythmic oscillations due to glaciations has remained until the present age, which has been responsible for the erosion and karstification of the relief. The continental influx of siliciclastic sedimentation has continued in the Pleistocene and Holocene with ancient alluvial deposits represented, for example, by “Faro-Quarteira Sands”, well exposed in the Falésia beach

(Vilamoura), through both a succession of red sands, river terraces, alluviums, beach sands and estuarine and lagoonal sediments (Antunes et al., 1981).

2.1.2.2 Geology of the Silves area

From a geological point of view, the Silves area is located near the contact between the Barrocal and the Serra. As we can observe in the figure 4, it presents a bedrock of dolomite, dolomitic limestone beds, and limestone intercalations from the Sinemurian, together with evaporites of the Hettangian marl-limestone complex and Triassic reddish sandstones of the Silves group. To the north, these sedimentary units are replaced by turbidite beds of schist and greywacke, which record the Upper Carboniferous Brejeira Formation (G. Manuppella, 1992). This Upper Palaeozoic and Lower Mesozoic substrate is largely covered by the variety of Quaternary deposits, with emphasis to those related to the Arade river alluvial and estuarine systems (Rocha et al., 1983).

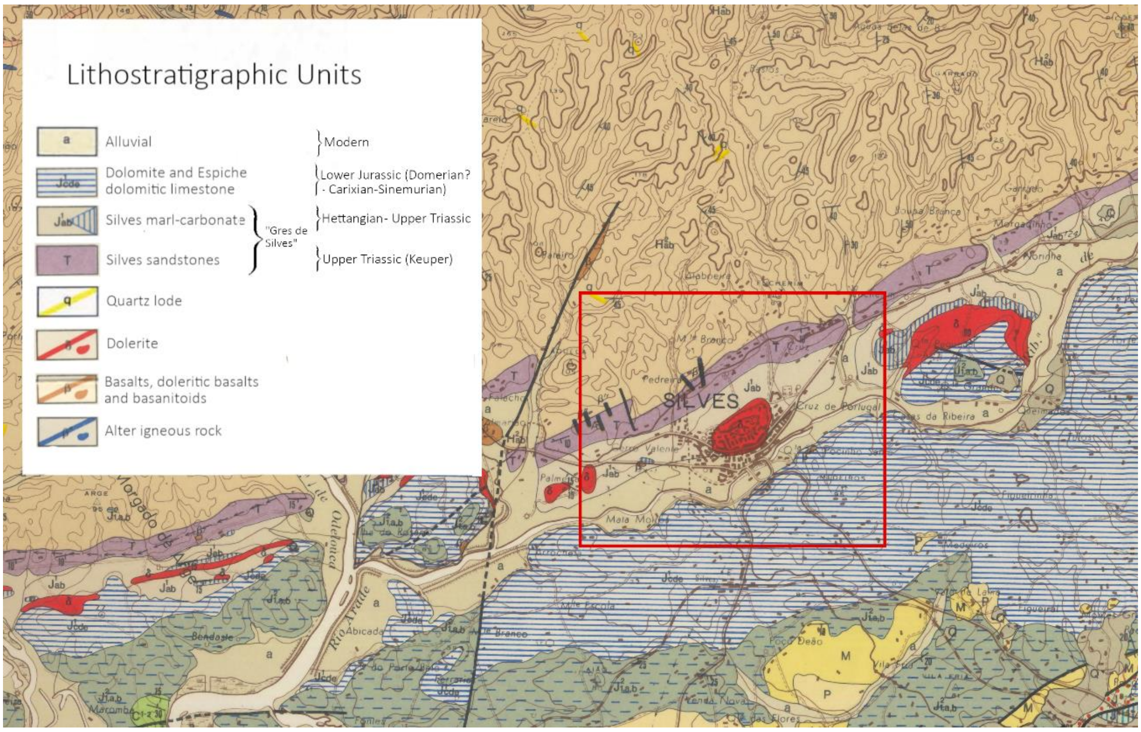


Figure 4: Location of the city of Silves in the Geological Map of the Western Algarve, scale 1/50,000. Adapted from Rocha, 1976.

The UT iron-rich reddish sandstones, commonly designated as "Grés de Silves", are historically well-known to be a kind of locally abundant and easy-to-handle raw-material. It has been used as feedstock for all the monuments of the city and archaeological structures found in the surrounding area (Gonçalves, 2008).

2.1.3 Geomorphology

The geological, morphological, and climatic particularities, as well as the vegetation cover typical of the Algarve have determined the evolution of the main geomorphological groups recognized in the region. By these criteria, we can consider the Algarve province to be historically divided into three distinct sub-regions in a north-south direction: the Serra Algarvia, the Barrocal Algarvio and the Litoral Algarvio (Bonnet, 1850; Fig. 5).

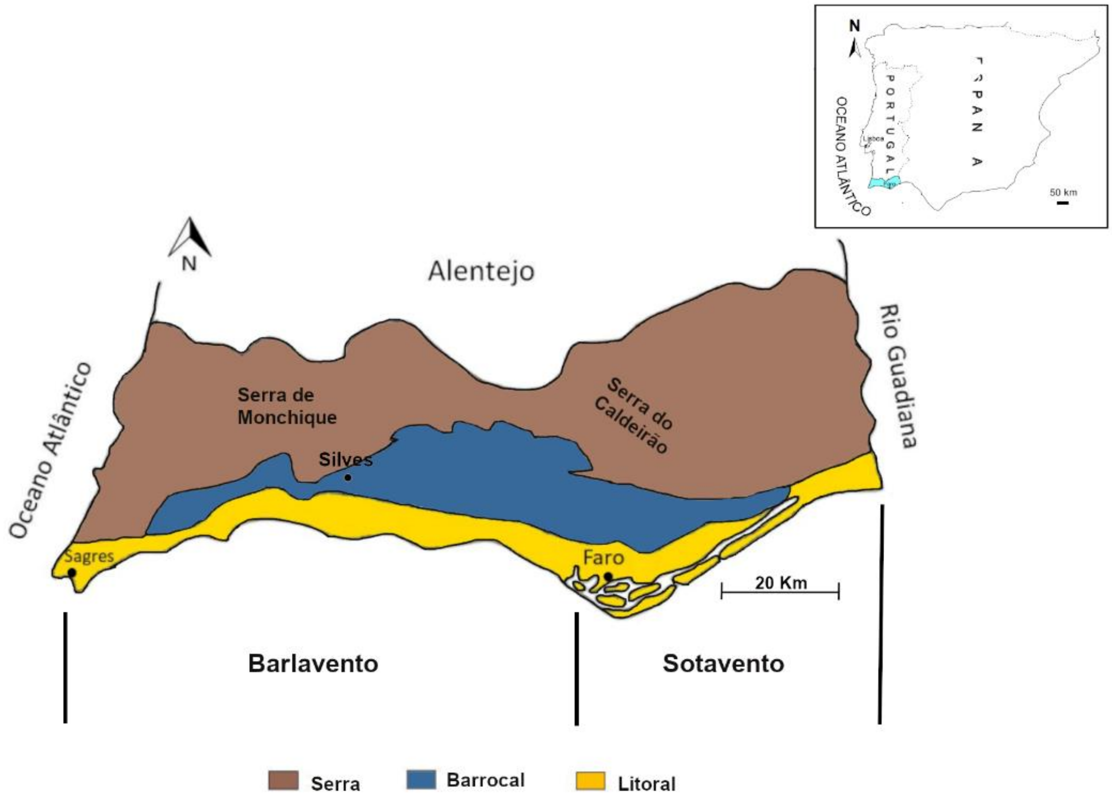


Figure 5: General location of the Geomorphologic Units of the Algarve. Adapted from Oliveira et al. (2009).

In the north, the traditionally called **Serra Algarvia** develops on terranes of the Hesperian Massif (Medeiros, 1990), where it forms a mountainous barrier that, in some regards, mark the southern end of the Lower Alentejo plains. The Serra comprises two mountainous systems – Monchique Range in the west and Caldeirão Range in the east – separated by the Hercynian, north-west to southeast oriented depression of S. Marcos-Quarteira. With the except of the syenitic soils of the Serra de Monchique massif, this area is characterized by the predominance of incipient soils, Upper Palaeozoic schists and greywacke outcrops.

To the west, the Monchique Massif, formed in the Mesozoic, consists of a pluton with alkaline igneous rocks that intruded during the Late Cretaceous onto earlier ones from the Upper Palaeozoic. It reaches 902 meters at Fóia peak, making it the highest elevation of the Algarve. The mountains contact in the south with a thin strip of sandstone, ophites, basalt, and dolerite rocks from the Triassic where the transition to the Barrocal takes place (Feio, 1951; Oliveira et al., 2009; G. Manuppella, 1992; Gago, 2007; Gouveia, 1938; Lopes et al., 2015; R. Rocha, 1976; Terrinha et al., 2013; Terrinha, 1998).

The **Barrocal** is a transition zone between the Faixa Litoral and the Serra Algarvia. Together with the coastal area, they develop on terranes of Algarve Bain. It is also known as the limestone Algarve. It has a moderate relief, dominated by the marly-alkaline soils, red and yellow Mediterranean soils typically associated with limestone outcroppings, and clay-rich marly vertical soils. The extensive strip of Jurassic and Cretaceous, mostly carbonated, has allowed for the development of slight elevations, whose axes are aligned from east to west, extend from Cape Saint Vincent in the west to the Guadiana river on the Portuguese-Spanish border.

This translates into a large monoclinal, with half slope land towards the south and less pronounced reliefs, and a wide, open valleys with more water lines and more favourable to agriculture. The Barrocal is traditionally the main supplier of agricultural products in Algarve (Feio, 1951; G. Manuppella, 1992; Gago, 2007; Gouveia, 1938; Lopes et al., 2015; Oliveira et al., 2009; R. Rocha, 1976; Terrinha et al., 2013; Terrinha, 1998).

Contrastingly, the **Faixa Litoral** is the area of preferential human occupation. In a vast, flat, and narrow region of fluvial and lagoonal sedimentation with red and grey litholic soils and red and yellow Mediterranean soils. These correspond to the most recent formations that cover the Algarve Coast and extend throughout the shoreline. It consists of sedimentary rocks from the Mesozoic and Cenozoic (Feio, 1951; G. Manuppella, 1992; Gago, 2007; Gouveia, 1938; Lopes et al., 2015; Oliveira et al., 2009; R. Rocha, 1976; Terrinha et al., 2013; Terrinha, 1998), and include an important contribution of Holocene sediments.

The great lithological and relief contrasts between the Serra, Barrocal and Faixa Litoral regions give rise to a strong contrast, not only in the landscape, but also in the identity of the local population (Guerreiro, 2015). Regarding these disparities, it is relevant to point out the local geomorphology of the Silves area, which comprises two major landscape units, roughly delimited by the NE-SW (Silves-Messines) axis and corresponding to the peripheral depression that divides the Hesperian massif to the North, the Serra, and the Meso-Cenozoic Margin Border of the Algarve Margin, at the South, the Barrocal.

To the north, the relief of the Serra Algarvia is oriented in an east-west direction, marked by peaks whose elevations can exceed 400 m (Fig. 6) and contain a profusion of steep slopes and V-shaped enclosed valleys conditioned by faults. This quite rugged relief protects the comparatively small hill in which Silves stands in the Barrocal, just 56 m high. The plain further to the south are generally exiguous, confined to interfluves and plain valley bottoms that seasonally give rise to important floodplains.

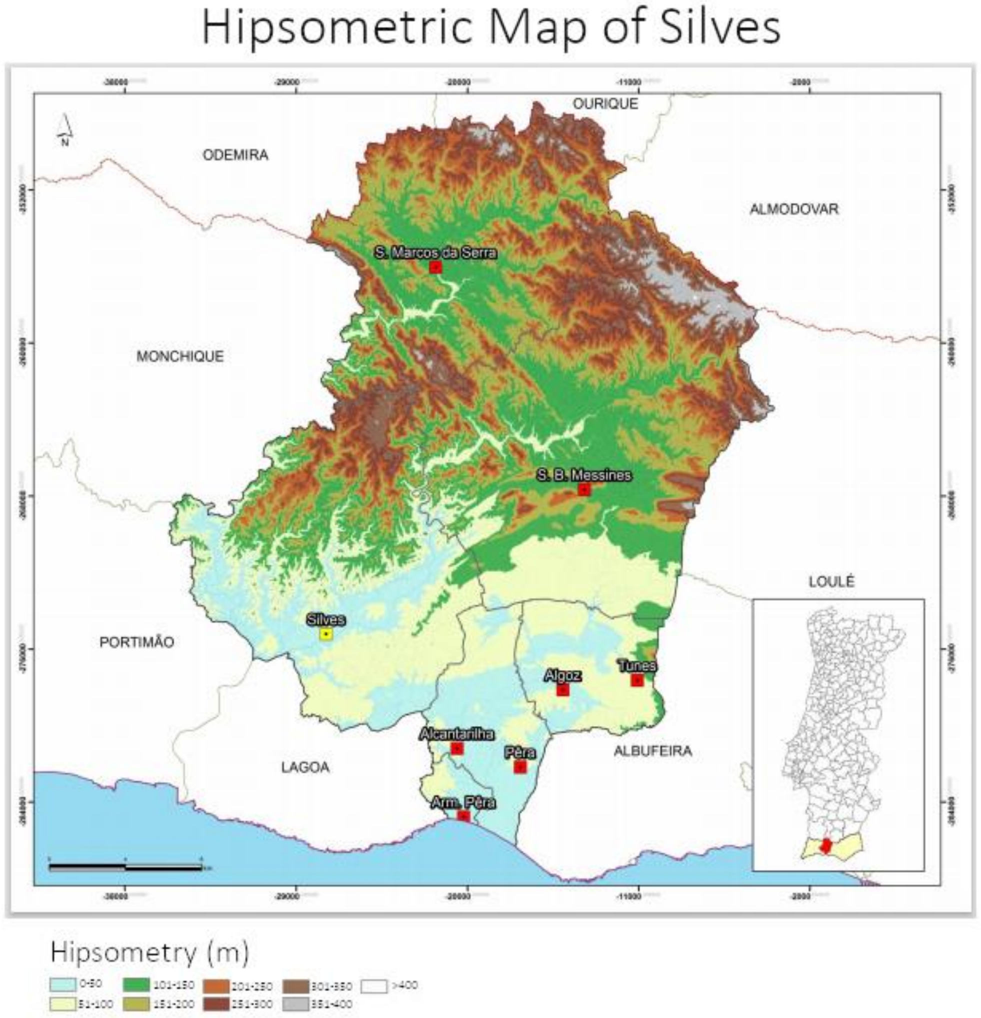


Figure 6: Hypsometric map of the municipality of Silves. Adapted from Comissão Municipal de Defesa da Floresta Contra Incêndios (2018).

The city of Silves and its neighbourhoods are located in the transition zone of the Barrocal. This means that their rocky substrate is sedimentary, and Triassic and Jurassic in age. This substrate belongs to the large morphostructural unit of the Algarve Mesocenozoic Border. Here, the relief is comparatively less accentuated than in the nearest Hesperian Massif, and is marked by staggered levels running from north to south, structural forms (coastal reliefs, anticline, and syncline, among others) and erosion (karst morphology).

It is the area where the alluvial plain valley of the Arade river is incised, with its progressively enlarged plain surrounded by a relief of hill type. The elevations in this area do not generally surpass 100 m, with only occasional exceptions where the exceed 200 m. The relief shows a tendency towards successively lower elevations as we approach the coast (Fig. 6).

Focusing on the purposes of this work, the archaeological site studied is situated in the transition zone between the Triassic-Jurassic "Volcano-Sedimentary Complex", the Holocene alluvial plain, and saltmarsh zone of the lower course of the Arade river (Gonçalves, 2008).

2.1.4 Hydrographic system

As previously mentioned, accessible water resources are needed in daily life and for the very survival of any population. It is one of the decisive factors for settlement in a certain territory. In the territory corresponding to Medieval Silves, population settlements have benefited from hydrographic networks composed of several seasonal streams and their respective tributaries. These have proved to be essential to subsistence of said populations, allowing for fertile valleys where agriculture could be practiced. Furthermore, the navigability of Arade river, turned it into an important route of communication and trade between the coast and the Algarve hinterland. The most imposing water resources in Algarve is the Querença-Silves aquifer. This system extends from Querença (Loulé) to Estombar (Lagoa) and occupies an area of roughly 317 km² (Almeida et al., 2000).

The dense hydrographic network developed within the Silves area takes the form of very enclosed ravines. It should be noted however that many of the watercourses in this region dry up during the hottest months, filling back again during the winter rains. The dendritic type of drainage pattern reflects the lithological monotony of the outcrop formation and its low permeability. The most efficient fluvial axes in the runoff of water are the Falacho and Almarjão streams at the northwest, respectively an affluent and sub-affluent of the Arade river. Also, the Enxerim stream to the north and the Baralha stream to the northeast contribute to the flow of this main river (Gonçalves, 2008). The occurrence of the Portimão-Monchique fault, oriented in a north-south direction, near the confluence of the Arade river with the Odelouca stream, prevents groundwater from proceeding to the west, having necessarily to emerge in the depressed areas that intersect the saturated level. The result is the prevalence of several springs in the Arade river valley (Gago, 2007). This prevents the formation of other aquifers since the amount of infiltrated water is insignificant.

The Arade river, which passes by Silves and flows into the Atlantic Ocean in Portimão, was since Antiquity and until the 16th century, one of the main access ways to the city, where flat-bottomed barges passed carrying cork and dried fruits to the coast (Gomes, 2002b).

2.1.5 Vegetation cover

The natural vegetation cover is the result of the combination of a series of factors such as the geological substrate and the pedological material, as well as climate and human action. Not only the fauna, but also the flora of Algarve has autochthonous species side to side with allochthonous ones, brought by successive waves of colonizers. Firstly, the Phoenicians of Tyre, which are possibly responsible for importing the almond tree (and possibly others), and for the development of the olive cultivation in the area (Gomes et al., 2005; Gomes, 2002b). Also, through importation from other places where they established connections.

In a later period, the Greeks also introduced a large number of agricultural species that constitute staples of the traditional food diet in the Algarve, including among others, the fava beans (*Vicia faba*), peas (*Pisum sativum*), lentils (*Lens esculenta*), lupins (*Lupinus albus*), and grass pea (*Lathyrus sativum*). Additionally, they also brought fig (*Ficus carica*) and almond trees (*Amydalus communis*), highly esteemed in Ancient Greece (Gomes et al., 2005).

The schist mountain range of northern Algarve ("*Serra*"), according to Gomes (2002b), possesses a greater variety of species that constitute a shrubland environment. It is mainly dominated by the gum rockrose (*Cistus ladaniferus*), formerly used as a medicinal flower as well as in perfumery, heather (*Erica arbórea*) and Portuguese heath (*E. lusitanica*), broom (*Genista polyanthus*), gorse (*Pterospartum tridentatum*), myrtle (*Myrtus communis*) and strawberry tree ("medronheiro" *Arbutus unedo*). The fruit of the later one has long been used for the manufacture of "*Aguardente*", the highly alcoholic distilled beverage originating in the Iberian Peninsula, which is still currently held in Algarve.

Various aromatic species can be found in the region, such as the lavender (*Lavandula* stoechas*)*, thyme (*Thymus vulgaris*), rosemary (*Rosmarinus* sp.), juniper (*Juniperus oxycedrus*), and laurel (*Nerium oleander*), all of which are abundantly used in Muslim cuisine. Additionally, can also find saffron (*Crocus sativus*) that besides the culinary use, has also traditionally found applications in both medicine and dyeing, providing for a yellow-coloured pigment (Gomes, 2002b). As for large trees present in both the Serra and the "Barrocal", the oak (*Quercus ilex*) and the Lusitanian oak (*Q. lusitanica*) stand out as an important resource for the naval industry, while the chestnut (*Castanea sativa*), the holm oak (*Quercus rotundifolia*) and the cork oak (*Q. suber*) also proliferate in the windward mountains (Gomes, 2002b).

The abundance of fruit trees found in the Barrocal can mainly be explained due to Muslim influence, who developed agro-pastoralist communities. Such communities also improved irrigation and introduced several species of fruit bearing trees such as the orange (*Citrus* var. *amara*) and the lemon trees (*C. medica* var. *limon*). They also contributed to the spread of the carob tree (*Ceratonia siliqua*), while also cultivated various other species in the coastal areas. These include, among others, the European plum (*Prunus domestica*), the ansu apricot (*P. armeniaca*), and the fig trees (*Ficus* spp.), peach tree (*P. persica*), and the apple trees (*Malus domestica*). All these species still being a feature of the present-day Barrocal landscape (Gomes et al., 2005).

The vegetation that covers the Silves area is part of the what is known Calco-Mediterranean Zone (Albuquerque, 1954). This zone is essentially composed by several different species, such as the Mediterranean fan palm (*Chamaerops humilis*), the carob (*Ceratonia siliqua*), introduced through Muslim influence, the wild olive tree (*Olea europaea* var. *sylvestris*), the almond tree (*Pronus dulcis*), the southern daisy (*Bellis sylvestris* var. *pappulosa)* the quince (Cydonia oblonga) and the Portuguese oak (*Quercus faginea*), very typical of the marly limestones of Barrocal.

Also present in lesser abundance are the maritime pine (*Pinus pinaster* subsp. *atlantica*), the stone pine (*Pinus pinea*) and the cork oak (*Quercus suber*). Furthermore, the common alder (*Alnus glutinosa*), the willows (*Salix* spp.), the alder buckthorn (*Frangula alnus*) and the tamarisk or salt cedar (*Tamarix* spp.) are species known to be present near waterlines, such as the Odelouca stream (Gomes et al., 2005).

Additionally, a worth mentioning in the landscape surrounding the city is the production of cereal crops, such as wheat, and barley (Gomes, 2002b, 2011a).

2.2 HISTORICAL BACKGROUND AND ARCHAEOLOGICAL EVIDENCE

The region of Silves has a long record of human presence, dating far back into the Neolithic Period, as evidenced by artefacts found in the urban perimeter of the current city (Veiga, 1887). This occupation can be justified by the abundance of natural resources in the territory, including the diversity of its fauna and flora, by the abundance of courses of water and rocky substrates, that allow for a gentle climate of Mediterranean type, by the proximity of the

Arade estuary and the Atlantic seashore, that provide a considerable diversity of biotopes, as well as by the navigability of the surrounding rivers in past times. There are countless archaeological finds in the region, belonging to different periods and contexts, from rock art, ornaments, stelae, and small objects to large monuments such as menhirs, walls, bridges, and castles, among others (Cardoso, 2002, M. V. Gomes, 2002; Gomes & Cabrita, 2006/2007; R. V. Gomes, 1988, 1989, 1991, 1993, 1995, 2002a, 2002b, 2006, 2011a; Gonçalves, 2007; Maia, 1980).

The archaeological excavations at Islamic levels in the south of Portugal, were enahnced in 1958, through the work of Abel Viana in the Castro de Nossa Senhora da Cola, in Ourique. In the following years, this researcher continued his investigations within the same subject of study, with other authors following his footsteps. From the 1970s onwards, several sites of Islamic occupation in the area began to be studied (Gomes, 1988). In addition to Abel Viana, a mention must be given to the works of Estácio da Veiga, A. dos Santos Rocha and J. Leite Vasconcelos, who studies medieval materials or excavated sites with bearing evidence of Muslim presence (Gomes, 2002a).

Archaeological investigations in the city of Silves started being carried out during the early 1980s by Rosa Varela Gomes and Mário Varela Gomes, with an excavation of an Almohad cistern-well (12th century), near a wall that surrounded the *Medina*. This archaeological intervention exposed, among other finding, the remains of three walls belonging to previous defensive devices, a housing structure, human osteological remains, fauna, objects made of metal, glass and bone objects, and enormous quantity and variety of ceramic fragments (Gomes, 1988). The archaeological excavations conducted here revealed that the urban centre of Silves has been an important point of passage or even a settlement of prehistoric, Roman, late Roman, Visigoth and Byzantine communities. This is attested by the presence of a diverse set of findings, including, but not restricted, to artefacts, ceramic fragments, and coins (Gomes, 2003, 2011b; R. V. Gomes & M. V. Gomes, 1989).

The investigation into the Islamic heritage of Silves is an ongoing, decades-long process that has yielded countless findings, such as defensive structures, houses, cisterns and other water supply systems, outskirts of the old city, and silos (*matmûras*). Regarding the artefacts found, these include countless pieces and fragments of ceramic belonging to different styles and periods, coins, steles, lamps (*lucernas* in Portuguese), apotropaic and other decorative plaques, and even a rare representation of zoomorphic motifs, among many other (Gomes, 1988, 1991a, 1991b, 2003, 2011; Gomes & Gomes 1989a, 1996, 2006; Gomes & Gomes 1989b, 1997; Gonçalves, 2008; Gonçalves & Santos, 2005).

One of the pre-Islamic settlements located near Silves is Cerro da Rocha Branca, also known as Guerrilha, near the Arade river. This settlement shows signs of being inhabited at least since the end of the Bronze Age. Having likely been at first a settlement similar to other Phoenician-Punic trading posts (factory) present in the west of the Iberia Peninsula, it was protected by cyclopean-style walls and towers. This place provided a rich collection of artefacts from Iron Age, Roman, late Roman, and Islamic periods (Gomes, 2002b, 2013; R. V. Gomes & M. V. Gomes, 1989).

According to Gomes (2013), the Cerro da Rocha Branca may have been the primitive urban centre that gave rise to the city of Silves, which was subsequently transferred to its current location. This process may have occurred during in the Late Roman times. This author also mentions the description made by Estácio da Veiga of coins found near this hill of a pseudo-autonomous workshop with the inscription “CILPES” (Fig.7).

Figure 7*:* Cilpes coin *in* Reis (1934).

The Medina *Xelb,* like many others of the Muslim *Gharb,* was built in a key strategic location. Raised on a small hill, in a very fertile area bound by the Arade river, the city area was protected from the north side by a mountainous range (Serra de Monchique and Serra do Caldeirão). The Arade itself provided one of the main ways of communication, complemented by terrestrial itinerary routes towards S. Bartolomeu de Messines and Monchique. These connected the town with the Baixo-Alentejo region to the north and with other coastal cities, such as Lagos to the east, and Lagoa, Algoz and Acantarilha to the west. Furthermore, the Arade river itself would also have been a key element towards the creation of alluvial deposits favourable to agriculture (Gomes, 1988).

During the Islamic conquest of Portugal, many of the pre-existing urban centres, with previous prehistoric and Roman origins became major Islamic agglomerations. In other words, due to the defensiveness, richness in feedstock and favourable location, some cities - mostly those near the coast, for mid to long-distance maritime commerce - were somewhat “reused” for the settlement of Islamic communities (Gomes, 2013). On the other hand, other urban centres lost their prominence, as it was the case with cities such as Évora, Faro, Tavira and Mértola, which kept their late-Roman fortified perimeters, although their population possibly decreased (*op. cit.*).

In the year 713, under command of Abd-a-Aziz, the Muslim conquered the city of Silves, known during the period as *Xilb, Xelb, Shelb* or *Cilpes*, and initiated a period of Islamic domain that lasted around five centuries.

Surrounded by its outskirts, the medieval city of Silves was strongly protected by a robust defensive system. It included the Alcazaba, placed in a dominant position on the highest elevation of the land. The aforementioned elevations also included the castle, walls, several towers, cisterns, and gates with arrowslits. These connected with the Alcazaba through a door, protected with towers, with the Almedina or Medina quarter inside it. This quarter was surrounded by a wall with several towers, gates, barbicans, moats, and ditches. Furthermore, the outskirts of the city were also protected by walls, towers, moats, among other fortification structures (Fig. 8).

These were mostly built with the feedstock from the region: blocks of red sandstone, known as “Grés de Silves”, which are mentioned in several geographical sources of the time. These sources also highlight the important defensive elements of the city (M. V. Gomes & R. V. Gomes, 1989; R. V. Gomes & M. V. Gomes, 1989; Gonçalves, 2013; Gonçalves & Santos, 2005).

The economy of the Islamic city *Xelb* had a particular focus on the trade of timber, as the city was an important centre of boat construction. The fertility of the land and beauty of this city, the abundance of animals and lands for pasture, favourable conditions for agriculture, hunting and fishing, the availability of other feedstock, and its location near the Atlantic Ocean all compounded to provide great wealth to the city. These and other political-cultural factors established perfect conditions to create, further in the Islamic period, a Capital city that played a fundamental role in the history of the *Gharb al-Andalus* (Davis et al., 2008; El Hour, 1998).

Silves did not receive much attention from Islamic texts of the epoch, until 10th century when the city becomes district capital, to be administrated by crown prince, Al-Mutamid, who remained there for several years. Silves came to be considered in the literature sources of the period as one of the main urbes of the region, and the cultural and political centre of *Gharb al-Andalus.* One of the most important cities of Algarve, Silves sheltered some important figures and families from the Taifa, as well as intellectuals, poets, and philosophers (El Hour, 1998; Fernandes et al., 2006; Nunes, 2017; Rei, 2012).

Due to the more prolonged Islamic presence in the southern Portugal - Alentejo and Algarve – during the Medieval period, these have been the main regions were structures and relics from this chronological interval were identified. This has occurred in locations such as Silves, Aljezur, Faro, Mértola, Beja, and Évora (Gomes, 2013). Such cities thus carry a huge historical legacy, encompassing not only the archaeological discoveries and monuments themselves, but also the oral traditions, agriculture, vocabulary, and certain living ways that have prevailed over the centuries (Cuvier et al., 1834).

The word *al-rabad*, in plural *arbãd*, from which came from the Portuguese word "arrabalde", roughly translates as a suburb or outskirt located right outside the main urban core, the Medina (Torres Balbás, 1953). These did not constitute peri-urbanized spaces, but were instead completely urban cores, with all the functions of the Medina, even though they were physically separated from it.

These suburbs were integrated into the social complex through a series of defensive structures such as walls, outer walls and moats, a road network, commercial structures, etc. The outskirts emerged as the result of a period of rapid population growth, deprived of enough space inside the city walls to accommodate the entire population; thereby, secondary urban cores outside the city gates were created (Epalza, 1988; Fig. 8).

Archaeological interventions carried out at Silves castle began in 1984 and lasted for more than two decades. This defensive device started to be built in the 10th century, and over the centuries it underwent several constructions and reformulations, especially after the Christian reconquest of the city, including the constructions of the Alcaidaria located in the west sector (figs. 9, 10 and 11), well documented through numismatics findings (R. V. Gomes, 2016).

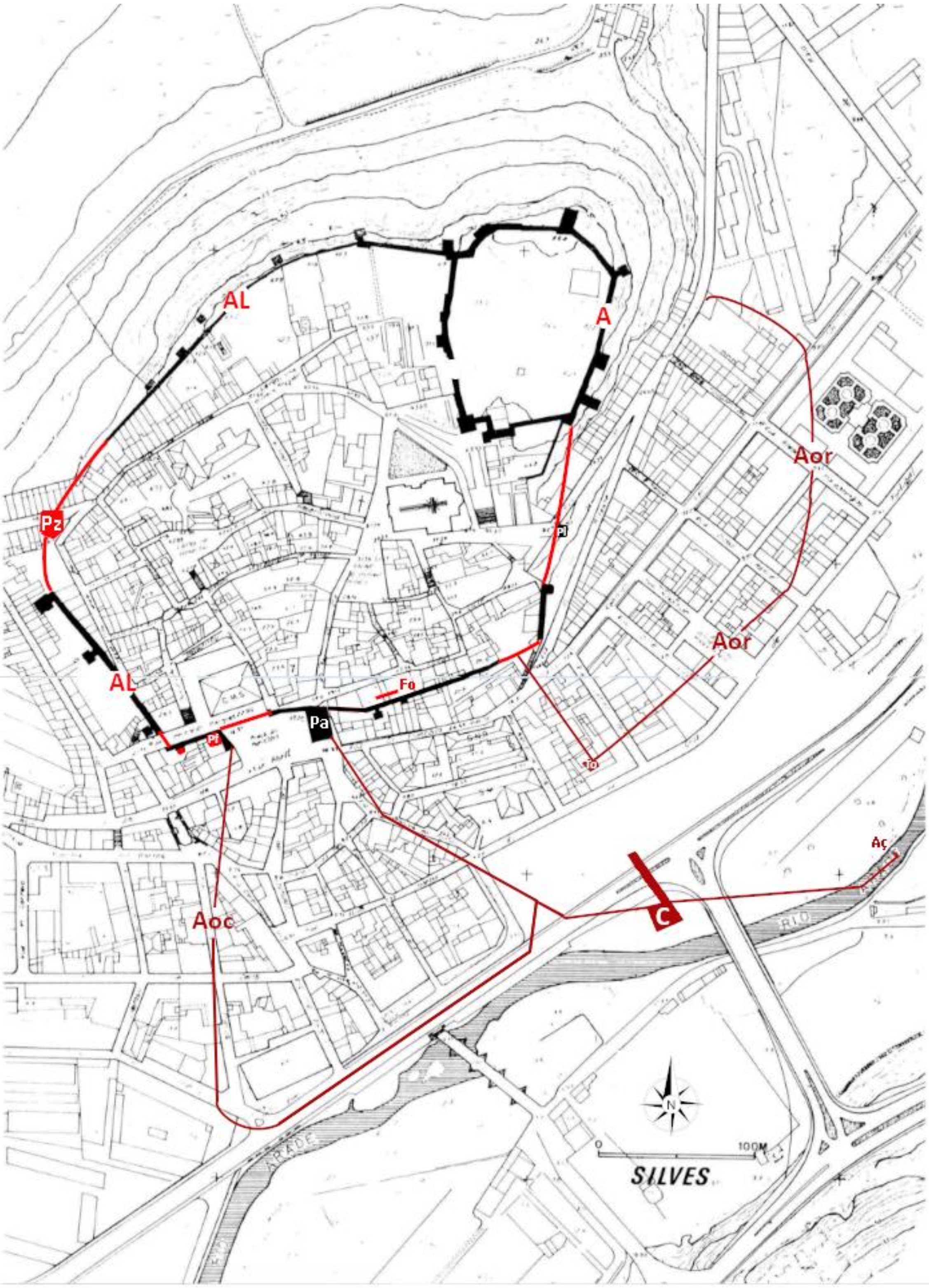


Figure 8: Hypothetical reconstruction of the fortifications of the Islamic city of *Xelb*. In black, the structures remaining to present day. In red is the hypothetical reconstruction of defensive structures and outskirts made by Gonçalves (2008): **A** – Alcazaba, **AL** – Almedina limits, **Pz –** Gate of the Azóia, **Pf** – Gate of the horseshoe arch, **Pa –** Gate of the Almedina, **Pl** – Gate of Loulé, **Fo** – Umayyad fortifications, **AOR** – limits of thr oriental outskirt hypothetical reconstruction, **AOC** – limits of the occidental outskirt hypothetical reconstruction, **To** – oriental outskirts tower, **C** – hypothetical localization of the couraça, **Aç** – hypothetical localization of the weir (adapted from Carta de Silves 1/2000).

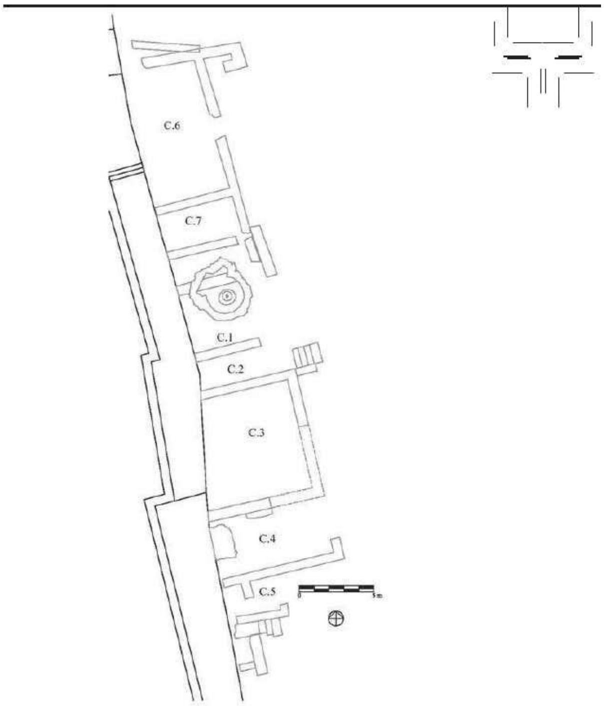


Figure 9: Schematic plan of the west sector of the Silves castle (R. V. Gomes, 2016). The material studied comes from C.1 illustrated in this figure.

Figures 10 and 11: Archaeological interventions in the western sector of Silves castle. (Photos: courtesy of Prof. Mário Varela Gomes, 2015).

2.3 MEN AND THE SHELLS

It is possible to associate humans and shells to a long period before the dawn of civilization, when the early modern humans started to gather oysters, mussels, snails, and other kinds of molluscs along the seashore and in rivers for food (Abbott, 1954). Molluscs have a high nutritional value and are very easy to cash. The presence of shell remains in archaeological sites is therefore mostly related to subsistence activities.

Molluscs gathering by modern humans goes back to Palaeolithic times (Jerardino & Marean, 2010), a behaviour also shared with Neanderthals (Callapez, 2000; Zilhão et al., 2010). The collection of shellfish has also become progressively recognized as an important component of human adaptation to aquatic environments. Erlandson (2001) has stated that marine adaptation played a significant role on human developments such as the increase of cultural complexity, a more sedentary lifestyle, higher population densities, and long distances of migrations of communities in comparison with the interior terrestrial-based populations. An example of such behaviours is found in Pinnacle Point Site (PP) 13B, a cave facing the Indian Ocean that has provided the earliest known evidence for shellfish collection, dated to ∼164 ka, and evidencing that a coastal adaptation was present in South Africa long before the postulated out of Africa migration ∼70-60 ka ago (Marean et al., 2007). Additionally, a large assemblage of mollusc shells used as food consumption and dated to approximately ∼125 ka (Middle Stone Age - MSA), was discovered on the Red Sea coast of Eritrea, together with lithic industries. These reflects the adaptation by the early human to coastal marine environments and the exploitation of nearshore marine food resources (Walter et al., 2000).

These two examples have been postulated has a key-adaptation of *H. sapiens* to the coastal marine environment, revealing the beginnings of modern human behaviour. The last example proves crucial to stablishing a potential coastline route by modern humans out of Africa and into Asia - via the Red Sea coast - circa 125 ka ago, and consequently support an African origin for modern humans (*op. cit.*). Although PP took place long before these migrations, it signals that intensive shellfish gathering was already a trait of early modern humans.

Later in the Palaeolithic, we begin to observe a symbolic behaviour by early humans that are connected to art, and associated expressions of language, music, and creativity (Cuenca-Solana et al., 2016). The utilization of marine shells in the Palaeolithic has thus been associated with a notion of “modern behaviour”. Examples of these behaviours are for instance, the production of engravings with shapes, such as geometric figures. These are representative signs of modern cognition and behaviour.

The oldest evidence of the use of shells has been documented by Joordens et al. (2015) from the Pleistocene Hauptknochenschicht of Trinil (Java). In this work, an assemblage of 190 valves and fragments of freshwater mussel shells excavated in 1890 was studied. One of these shells, an engraving made by the Java man (*Homo erectus)* was discovered. This is considered the oldest geometric engraving ever found. It consists of geometric engraved lines with a zigzag pattern on a mussel of the species *Pseudodon vondembuschianus trinilensis* (Dubois 1908). This evidence the earliest clearly artistic behaviour by a hominini (Joordens et al., 2015). One other shell with retouched edges, perhaps made by the *H. erectus,* of a thick clam shells used for meat extraction, from Sangiran (Central Java), which substantiate the use of non-lithic tools and the oldest evidence of the use of shells, documented by *H. erectus* (Choi & Driwantoro, 2007).

Additionally, Neandertals are also known for their modern behaviours, as observed through a series of archaeological findings of pigment-stained and perforated marine shells, body ornamentation, produce tools, rock art, etc. In the Neandertals context, shellfish gathering also appears to have been a typical behaviour of this specie, *e.g.* in the cave of Grotta Moscerini, Italy, marine shells with flaked edges have been found, it suggests that shell tools were used by Neandertals between 60 ka and 80 ka ago (Stiner, 1994).

The south of the Iberian Peninsula is well known for its Neandertal sites, many of which reveal examples of worked shells. In Cueva de los Aviones (southeast Spain), marine molluscs shells associated with bone remains and quartz lithic assemblages were excavated in 1985 and dated to ∼50 ka cal B.P. (Middle Palaeolithic). Among food remains in the site, three valves of *Acanthocardia* and *Glycymeris,* with their umbos perforated were found alongside lumps of yellow and red colourants were found. Additionally, residues inside of a *Spondylus gaederopus* valve were discovered, suggesting the use of these shells as containers for the storage of colourants or as a sort of paint cup for their preparation.

Close to the aforementioned site, another cave with similar findings has been discovered. The Cueva Antón, is a rock shelter excavated by the Mula river, situated about 60 km inland, with artefact-rich related to its period of Neandertal occupation, in levels dated to approximately ∼37.4 ka cal B.P. This location was yielded a perforated valve from the species *Pecten maximus* with adhering orange pigment residues on the external surface. This suggests that the surface may have been deliberately painted, to either to restore the original appearance or to render the external surface a similar colour as the internal one, which has retained its naturally red tone. It may had served an aesthetic propose as body decoration and probably symbolic meaning (*op. cit.*).

These two findings, alongside with others from Africa and the Near East lend support to the idea that symbolic implications of body painting and the ornamental usage of pigmented-stained and perforated marine shells have occurred not only in Upper Palaeolithic (UP), but also earlier in the MSA. These further indicate a level of behavioural modernity related to Neandertals (*op. cit.*).

Another cave in southern Spain, Banjondillo Cave (Málaga), located a few meters from the coastline and discovered in 1989. This cave is abundant in lithic industries, bones, shells, and hearths dated to ∼150 ka. Such dating is almost contemporaneous to that of the Pinnacle Point (South Africa) site, where shellfish gathering presents a situation where Neanderthals and Modern Humans might have been following parallel behavioural paths, albeit with different evolutionary outcomes (Cortés-Sánchez et al., 2011).

The exploitation of coastal intertidal resources, with reported mollusc remains from the Palaeolithic, has been most clearly established for sites in Israel, Greece, Italy, and Spain (Antunes, 1992, 2000; Barton, 2000; Bernárdez, 1988; Colonese et al., 2010; Finlayson et al., 2008; Manne & Bicho, 2011; Mayer, 2008; Richards et al., 2008; Stiner, 1994; Stiner et al., 2000; Zilhão et al., 2010). In Portugal, these ancient contexts are represented, among others, by the by the Figueira Brava cave (Zilhão et al., 2010).

Similarly to how early humans used the bones, skin, claws and other body parts of their prey for purposes other than food, so too were the shells of consumed molluscs also reused for other finalities. These included, among others, adaptations for usage as liquid containers, plates, spoons, paint pots, wood to engraving chisels, and fishing hooks (Cattaneo-Vietti et al., 2016). Over time, and as civilization became more complex, the usage of shells played not only an important role in survival but allowing for humans to further develop themselves.

Therefore, specialization in the use of shells increased over time. Some of these were prized for their shapes, colours, patterns, and the shininess of their natural forms. Because shells are symbolically linked with water and the sea, their value increases with distance from the coast. Besides the uses related to food, shells started to be used as currency, jewellery, ornaments, horns, communication, games, and later in literature and religion.

Molluscs in general, and shellfish in particular, have fascinated humankind for millennia. Their shells have acquired a set of cultural, religious, mythical, and ritual symbolic meaning, and usage as amulets, sexual symbols, ornamentation, etc. (Cattaneo-Vietti et al., 2016; Claassen, 1998). Shells have this has taken deep and strong roots on culture habits, tastes, and traditions. They have acquired an importance that has endured for millennia and stills lasts to nowadays, with a strong cultural significance in many communities.

Shells as ornaments and life-giving ornaments have been common in burials since the Stone Age. Perhaps, the oldest known example of a deceased human buried with personal ornamentation has been found in in Border Cave, KwaZulu-Natal, and is that of an infant, four to six months old at the time of passing. The infant was found with a perforated Conus shell inside a pit interpreted as a grave and dated to the Howiesons Poort lithic technology cultural period from the MSA in Africa. This shell, identified as *Conus bairstowi* (G. B. Sowerby III, 1889), according to Beaumont et al. (1992), was collected from the nearest coastline to the cave, about 80 km away (d'Errico & Backwell, 2016).

Another instance of human burials with shell ornaments are the Grimaldi burials in the Grotte des Enfants. On this site, several marine shells appear to have been deliberately placed as ornaments on the deceased. The reddish coloured skull of a young male was embellished by many pierced marine shells of *Tritia neritea* (Linnaeus, 1758) and 22 pierced deer canines (*Cervus elaphus*). Both form part of a headdress, alongside with other shells decorating the legs. The woman beside him bore shell bracelets on the arms, composed by four *Zonaria pyrum* (Gmelin, 1791), eighteen *Tritia neritea* (Linnaeus, 1758) and *Tritia corniculum* (Olivi, 1792), (Rivière, 1887).

In the Arene Candide Cave (Western Liguria, Italy), one of the richest burial sites of the period has been found. Among several burials, one stands out substantially: the skeleton of an adolescent male dated back to 12,000 and 10,000 cal BP (Mid Upper Palaeolithic). Nicknamed "Il Principe" (the Prince) with outstanding ornamentation, its head was surrounded by hundreds of perforated shells and canines of deer, probably forming a type of cap. The remains were found with shells (*Ciprea* sp.), pendants of mammoth ivory, and an ornamented blade held in the right hand (Pettitt et al., 2003). A beautiful example of care for the dead, and for the usage of ritual objects in very young children by Palaeolithic communities (Fig. 12).

One of the most striking common threads of early History is that of trade routes between ancient cultures. In these, seashells have played an important role in the exchange of goods. For instance, in 1895 a grave was found in France, belonging to a prehistoric Cro-Magnon man, buried with a Red Helmet Shell (*Cypraecassis rufa*). This remarkable archaeological finding substantial the existence of long-distance trade routes among early European humans, for the Red Helmet Shell can only be found in the Indian and Pacific Oceans (Abbott, 1954). Furthermore, it also represented evidence for a great level of care for the deceased, particularly in their burial ornamentations.

Figure 12: Arene Candide 1 - Il Principe, with perforated shell "cap" and a pendant with a cowrie (Science Photo Library, n.d.).

Many present and past religion behaviours relate to different types of shells. Evidence can be found throughout the world for usage of shells in worship. An interesting case is that of the large Eastern Pacific *Strombus* seashells, were important offering to the gods, with their large shells placed in temples, used for sacrificial rituals by the Moche religion (northern coast of Peru), from approximately 100 to 800 AD. These rare shells were symbolically very important to The Moche people and were used as ceremonial trumpet known as "pututu". Producing a strong deep sound, these were played in ceremonies associated with water (Bourget, 2006). *Strombus* were also used by warriors to announce battles (see Fig. 13). There is also a very frequently portrayed representation of the so-called "*Strombus* monster", combining a *Strombus* shell, a large-eared serpent head, a feline body with claws and fur markings, and a tail ending in a small-eared serpent head, that served as a figure of adoration and submission (Bourget, 2006).

Figure 13: Representation of an offering of *Strombus* seashells (Bourget, 2006).

In India, the large gastropod *Turbinella pyrum* called sacred *chank.* It is considered a divine shell with significant importance in both Hinduism and Buddhism. The *chank* is a sacred emblem of the Hindu preserver God-Vishnu, believed to be the giver of fame, longevity, prosperity. It is also regarded as the abords of Lakshmi – goddess of wealth and consort of Vishnu (Lipton et al., 2013).

In the Christian, and during the Medieval Epoch, the scallop or "Saint Jacques shell" (*Pecten jacobaeus* and *Pecten maximus*) became over the centuries a proof for the pilgrimage to Santiago de Compostela (Spain), a tradition that remains until today (Fig. 14). Furthermore, the pearl of the oyster was one of the symbols of the Mother of God, who holds and protects the pearl, Christ himself (Cattaneo-Vietti et al., 2016).

Figure 14: Scallop shell with the cross of Santiago, tied to a cane, usually with tiny pumpkins, used by pilgrims on the *Caminos de Santiago de Compostela* (St. James way).

Before the use of currency, the acquisition of goods was carried out through sporadic distributions often called the “silent trade” and “gift exchange”. These were based on the exchange of one good for another, for instance, the exchange of fish for cereals, or other good of equal value (Hingston, 1949). Later on, in the absence of coin, shells performed a great role in the history of currency, through the widespread usage of shell money as a form of exchange.

These included shells such as mother-of-pearl, widely diffused in America, the zimbo of tropical West Africa, and the most iconic of them all, cowry shells. The range of their usage extended farther than any other form of money before or since, spreading from Asia to Africa, Europe, and Australia. Shell currency became so widespread that it was used by several different communities around the world until the past century in certain localities (Hingston, 1949; Hogendorn & Johnson, 1986; Johnson, 1970). Even in many localities were gold, silver or bronze coins existed and circulated locally, cowries formed the common current currency throughout much of the trading world (Hingston, 1949).

These shells had several characteristics that made them suitable for usage as currency (*i.e.* as an intermediary means of exchange): they were rather durable, not easily degradable, easily identifiable, handy, portable, convenient, easy to count and difficult to counterfeit (Cattaneo-Vietti et al., 2016; Davies, 2002; Hingston, 1949). Furthermore, they attractive shapes, sculptures and colour mean that they could also be used as ornaments, talismans and amulets, a common form of wealth ostentation (Davies, 2002; Hingston, 1949; Johnson, 1970; Stearns, 1887). Thus, early monetary development appears to be based on the notion of value given to rare natural or artisanal products.

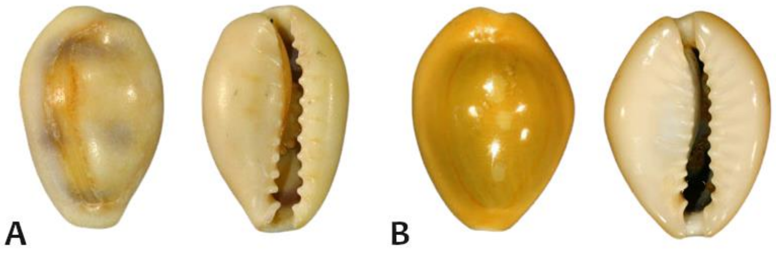


Figure 15: The cowries. A: *Monetaria moneta* (WORMS, 2012a). B: *M. annulus* (WORMS, 2012b).

The cowries *Monetaria moneta* and *M. annulus* (Fig. 15) feature small ovoid shell in various types, colours, and shapes. These species are widely spread over the shallower regions of the Indian Ocean, with the most prolific single source being the Maldives Archipelago.

For centuries, whole shiploads of these cowries have been distributed around the shores of Oceania, Africa, the Middle, and the Far East, and eventually the New World (Davies, 2002; Hingston, 1949; Johnson, 1970; Stearns, 1887). According to shipping contracts of the time, Portuguese merchants introduced the cowry shell to West Africa commerce in 1515, shipping 24 tons of cowries per year from the Maldives to West Africa. Thereafter, the Portuguese dominated the cowrie trade for most of the sixteenth century (Reader, 1998). With the decline of Portuguese naval supremacy in the Indian Ocean in the eighteenth century, by the eighteenth century the Dutch and British East India Companies had become the principal cowrie suppliers for the world (Reader, 1998).

In conclusion, mollusc shells have been an integral part of modern human life since the Palaeolithic, when humans started to gather shellfish for food. Thus, zooarchaeological studies contribute to a better interpretation and reconstitution of the past, and shell remains can provide an indication for extinct species and the evolution of certain families.

Taphonomic and taxonomic studies can also provide substantial data on the life habits and main ecological and environmental conditions of a site. These can also include the seasonality, harvest practices, diet, traditions, and experiences of individuals, communities, and cultures from distant historical periods to more recent times (Abbott, 1954; Callapez et al., 2016; Somerville et al., 2017).

2.4 TAPHONOMIC PROCESSES IN ARCHAEOMALACOLOGY

Under normal conditions, the formation of an archaeological site has an initial phase of material accumulation followed by another phase where that material is buried. After accumulation, as well as during and after burial, the material can suffer several modifications processes. The field of knowledge that studies of how these affect the materials in sites since their accumulation and until they are analysed after collection in an archaeological excavation, is named Taphonomy (Zugasti, 2010).

The concept of Taphonomy means “the laws of burial” (Olson, 1980). The Russian researcher Efremov (1940) proposed the concept of Taphonomy as a scientific branch that studies and analyses the transition of organisms from the biosphere to the lithosphere or geological record (Cadée, 1991; Lyman, 1994; Olson, 1980).

Indeed, Taphonomy represents a milestone in Palaeontology and on fossil the study of organisms. Nowadays, it is accepted that Taphonomy consists in three main processes: the *post-*

mortem changes that occur shortly after death, such as *rigor mortis* (necrolysis), biostratinomic processes that comprise the events since the time after death to burial, and the fossil-diagenetic processes, *i.e.* organism remains after burial (Cadée, 1991; Savrda, 2007; Selden & Nudds, 2012; Zugasti, 2010). All these processes influence the potential and quality of body fossil preservation, through taphonomic "filters" regulate the degree to which fossil assemblages reflect original faunal communities, while setting limits on the precision of palaeoecological reconstructions (Savrda, 2007).

A taphonomic analysis seeks ways to describe the physical and chemical alterations on individual specimens or in bone assemblages, exposing artificial alterations within the context of a greater collection of bone-altering processes (Morlan, 1984). These processes may harshly destroy the body fossil record, and are called "taphonomic agents" (Lyman, 1994). They include **biological agents**, such as scavengers and other faunal and floral agents, mechanical fragmentation, microbial decomposition, and dissolution; **anthropic agents**, for instance the excavation by non-specialists, the construction of roads, urban growth, etc.; **physical-geological agents**, including wind erosion, storms, sudden changes in temperature, fluvial, moisture and sunlight; and **chemical agents** including pH and the relative proportion of organic matter compounds such as phosphate, carbonate and salt, and other chemical processes (Butzer, 1982; Cadée, 1991; Forbes, 2014; Hammond, 2014; Lyman, 1994; Savrda, 2007; Zugasti, 2008). Each of these processes can have a different duration, lasting from minutes for insects trapped in amber or mammals in tar, to a number of years for the accumulation of bones or shells (Selden & Nudds, 2012).

Taphonomic studies in Archaeology were rare in the early twentieth century until a series of studies were published, applying the field to Taphonomy to Archaeology. A special mention is due to the work of Raymond Dart regarding the study of antelope remains recovered in an australopithecine cave in South Africa (Dart, 1960).

Presently, taphonomy has come to be seen as an important tool for understanding the formation of archaeological sites and to determining how and why floral and faunal remains are accumulated and differentially preserved. It analyses the formation processes of archaeological deposits, as well as the pre- and post-deposit processes. These are experienced by both deposits at the field level set, and those suffered by each material individually (Borrero, 1988; Lyman, 1994; Zugasti, 2010). The application of Taphonomy in Archaeozoology has the purpose of contrasting the agents responsible for the different processes and their pattern of action (Zugasti, 2010).

Faunal findings are abundant in an archaeological context and can provide a wide range of information. Remains are usually susceptible to offer information on social, religious, economic and dietary aspects of ancient human communities while also offering palaeoenvironment and palaeoclimate data. Biological action is frequently observed on these findings, whether anthropic, animal, or vegetal. Likewise, the changes produced on the sedimentary environment in which they are found (Butzer, 1982; Hammond, 2014; Lyman, 1994; Schiffer, 1983; Zugasti, 2008, 2010).

Regarding molluscs, the role of Taphonomy in the analysis of findings is essentially the same as the one for all archaeofauna. Thus, it is important to understand the taphonomic processes that have affected the shells during their pre- and post-burial. For example:

a) **Bioerosion,** the result of activity by other aquatic organisms. Such as perforation by animals boring into living shells to obtain calcium, or through the shell to reach the soft parts of the mollusc. Bioerosion can also take the formof encrustation, when aquatic organisms attach their bodies to other shells, to support their skeletons (other hard substrates or surfaces can also be chosen);

b) **Distortion,** corresponds to the change in size, shape, structure and/or texture of the elements due to action of some mechanical process. Fragmentation is the most common distortion process and consists in the fracture of the shell and subsequent separation of the fractured remains;

c) **Cementation,** through the formation of concretions and cavity cementation resulting from mineralization;

a) **Mineral stains,** mainly due to precipitation of minerals when in natural conditions. These can however have an anthropic origin, for instance, through the staining of shells with ochre;

b) **Abrasion,** as the consequence of the removal of calcium carbonate from shells, through physical processes or even by bioerosioners. Abrasion results in a polished and worn surface, in which the shell ornamentation is likely to disappear. As a consequence this process tens to hinder identification;

c) **Dissolution,** occuring when calcium carbonate or some other mineral component of the shells is dissolved due to chemical processes produced by the environment in which they are deposit. The results in the alteration of shell material, and in an often chalky appearance;

d) **Carbonization,** the carbon enrichment of organogenic remains, generally through the exposure of the shell to fire. It can also be produced by exposure to anaerobic conditions;

e) **Substitution of mineral components** by recrystallization, a process that consists on the change of texture through mineralogical inversion. This is a process in which consists a mineral component is substituted by another polymorph of the same class, with the same chemical composition but with a different crystalline structure;

f) **Chemical dissolution,** occuring through the dissolution of calcium carbonate, or some other mineral component of the shell, due to chemical processes produced in the environment;

g) **Sedimentary filling,** process that occurs when the shell cavities are filled with sediment;

h) **Biodegradation-decomposition,** a processed by which the protein web of shell is decomposed due to the action of organisms acting as decomposing agents (Claassen, 1998; Hammond, 2014; López & Rafael, 1999, 2000; Zugasti, 2008, 2010).

Taphonomical studies of individual shells and shell assemblage, besides the quantitative analyses of the fragmentation, often methodological tools to a better interpretation of archaeological contexts such as depositional sequences and site stratigraphy. In fact, they facilitate the separation between natural and cultural processes, the assessment of post-depositional disturbance in shell deposits, the evaluation of efficiency of retrieval methods, the estimation of shell weight loss, and biases in prey selection and shell size (Jerardino, 2018).

2.4.1 Fragmentation

Fragmentation, in other words, the breaking of skeletons or skeletal elements into smaller pieces without regard to their natural joints, can occur on a wide range of length scales and in several different ways (Leonard-Pingel, 2005; Speyer & Brett, 1988). In archaeological assemblages, the fragmentation of mollusc shells is the result of a combination of factors which include the properties of the exoskeletal shell and the taphonomic processes that act mostly after deposition (Jerardino, 2018).

This process can happen due to environmental energy (wind, water, temperature changes, gravitational action), through impacts with other shells, rocks or waves, sediment compaction, dissolution, or even by ecological interactions, such as shell-breaking, predation, and bioturbation (Jerardino, 2018; Leonard-Pingel, 2005; Zugasti, 2008; Zuschin et al., 2003).

It also can be due to anthropic activity, as the production of tools or stepping on. In fact, the very act of breaking the shells to eat the mollusc, or the sample handling ca also contribute to the degree of fragmentation observed in a sample (Andrews, 1995; Zugasti, 2008). Taphonomic factors however act upon shells even before human gathering and deposition, resulting in greater vulnerabilities to breakage.

The degree of fragmentation can also differ from species to species, depending on shell features. Some species are more robust, heavily ribbed, and resistant shells than others. These will break up less easily than fragile shells lacking these traits, which will likewise influence the analysis of assemblages (Coelho & Cardoso, 2011; Jerardino, 2018).

Fragmentation reveals negative consequences involving material identification and quantification, but also withdraws value of the malacological collection as for a certain loss of information as well. Moreno, 1994, and other authors have dedicated their attention to this conundrum and created categories or “grades” to systematize the fragmentation of some species in the Iberian Peninsula. These categories serve to reflect the degree of shell fragmentation, with a formulae to calculate the MNI (Minimum Number of Individuals; Moreno Nuño, 1994), but that will be elucidated more carefully further.

The fragmentation categories used for mollusc analysis were based upon their shell morphology (see figures 16 and 17):

Bivalves
  COMV – Complete valve
  FRAV – Fragmented valve
  FCH – Fragment with complete hinge
  AHF/PHF – Anterior/posterior hinge fragment
  FTS – Fragments (absence of hinge)

Gastropods
  COMI – Complete individual
  FRAI – Fragmented individual
  APIF – Apical fragment
  STOF – Stoma fragment
  UMBF – Umbilical fragment
  FCOL – Columella fragment

FTS – Fragments (absence of apex or stoma)

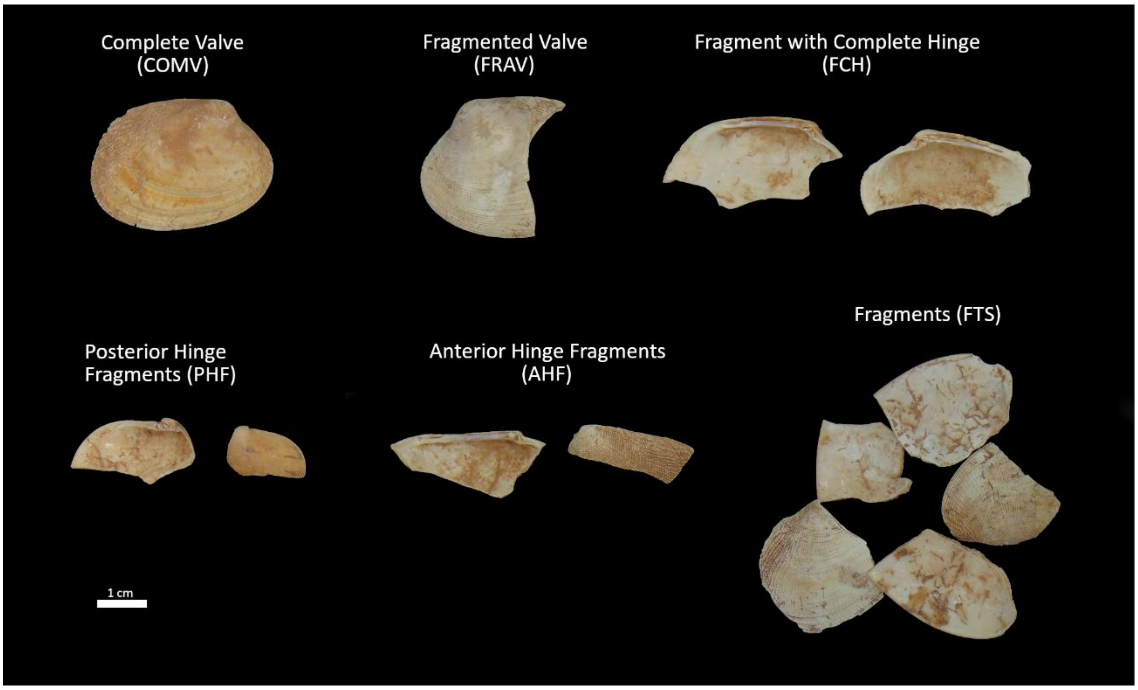


Figure 16: Fragmentation categories for bivalves (example: *Ruditapes decussatus*).

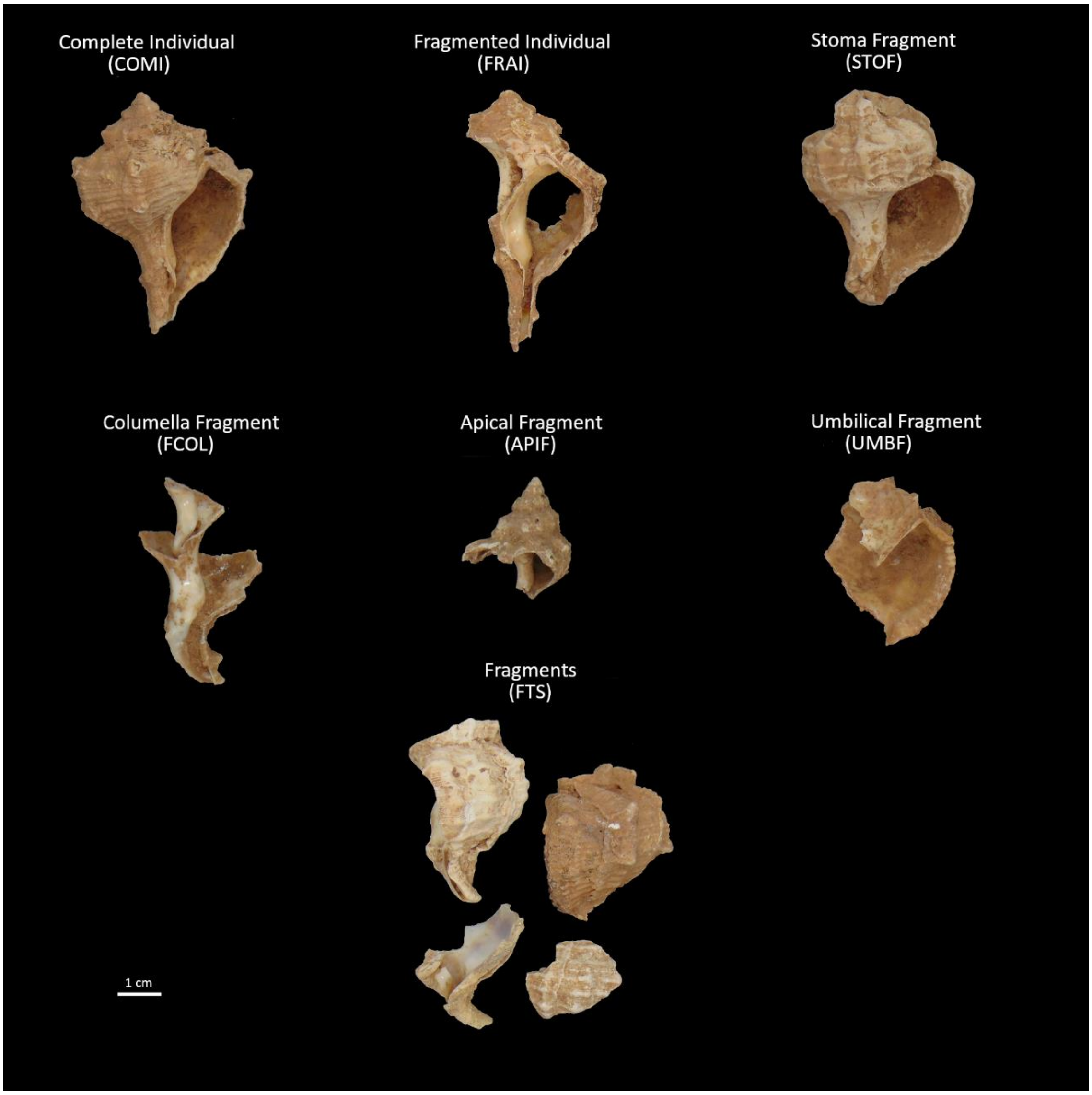


Figure 17: Fragmentation categories for gastropods (example: *Hexaplex trunculus*).

Chapter 3 MATERIALS AND METHODS

The present study is based on upon a collection of malacological material sampled from an archaeological context surveyed in Silves. As already mentioned, these shells were collected the Alcazaba located in the castle of the Islamic Medina called *Xelb* in south of Portugal.

The bulk material was first collected and labelled with reference of the site, and its related stratigraphic information observed *in situ* by the archaeologists. This is the first step of preparation of the material, where the label containing all the finding information is crucial for its next stud. If that information is lost, the specimens also lose many of their original importance, and in many cases, they became worthless. This registration comes along with other data regarding the spatial arrangement, the orientation, and the composition of the layer, among others, regarding that, this type of information is helpful for understanding all process that involve the formation of the deposit. Secondly, the findings were collected and correctly stored with proper identification in the Laboratory of Archaeology of the FSCH-UNL, under responsibility of Prof. Rosa Varela Gomes, as a repository available for investigators and further zooarchaeological studies.

The analysed material comprises two containers around 23kg each of shells of molluscs and crustaceans, totalling over 4000 individuals mostly marine such as clams, cockles and oysters, results of food waste. The research has used the material from 22 stratigraphic units corresponding to occupation levels collected from the Castelo de Silves site, with the site-codes: 537/538, -1, 2, 5 (all artificial layers); 1045-1B; 1075-1B, 2 (outer struct.); 1128-1B, 2; 1128-1B, 2 (outer struct.); 1129-1B, 2 (outer struct.); 1200-1A, 2; 1201-2; 1202-1B, 2; 1217-1B, 2; 1218; 1219-2.

3.1 PRACTICAL ASSUMPTIONS

This dissertation began with the collection and reading of available bibliography related to the study of Islamic communities in southern Portugal, including previous works about Silves and nearby areas of Algarve: Antunes (1996), Cardoso (1993, 2002), Correia (2002), El hour (1998), Epalza (1988), Fernandes et al. (2006), Ferreira et al. (2016), M. V. Gomes (2002), Gomes & Cabrita (2006/2007), M. V. Gomes & R. V. Gomes (1989, 1996, 2006), R. V. Gomes (1988, 1989, 1991a, 1991b, 1993, 1995, 2002a, 2002b, 2003, 2006, 2011a, 2011b, 2013), R. V. Gomes & M.

V. Gomes (1989, 1997), Gonçalves (2008, 2013), Gonçalves & Santos (2005), Guerra (2009), Maia (1980), Nunes (2017), Ramalho et al. (2000), Rei (2012), Torres Balbás (1953), and Veiga (1887).

Side to side with these works, special emphasis was done to monographs and other studies concerning the systematics and taxonomy of marine and land molluscs and other seashore invertebrates with relevance to zooarchaeological studies related or not to this period in the Iberian Peninsula, including Albers (1854), Allen (1856-58), Antunes (1992, 1996, 2000), Bernárdez (1988), (Branco & Valente, 2013; Callapez, 2012), Callapez and Pimentel (2018), (Callapez, 2011), Callapez et al. (2016), (Cantal, 1993), Cardoso (1994), Cardoso and Coelho (2012), Carrasquilla (1993), Coelho and Cardoso (2011), Colonese et al. (2010), Cossignani and Ardovini (2011), Costa and Braz (2007), Davis et al. (2008), Davis (2006), Drouët (1858), García et al. (2010), Gomes et al. (2005), Gonçalves et al. (2007), Guerreiro dos Santos and Mayoral Alfaro (2007), Lentacker and Ervynck (1999), Lowe (1831), Macedo et al. (1999), Morales Muñiz (1993), Morelet (1845, 1860), Nobre (1913), Rolan Mosquera (1983, 1989), Rosello Izquierdo (1993), Saldanha (1995), and Telles Antunes (1991). This early phase made it possible to develop a synthesis of the works and data available within the chronological period in question, serving as a basis reference for the lines of investigation later adopted.

For the methods of analysis applied in Zooarchaeology, the following bibliographic support was also used: Andrews (1995), Banning (2002), Borrero (1988), Butzer (1982), Cadée (1991), Efremov (1940), Fernández López (2000), Forbes (2014), García (2008, 2009), García et al. (2010), Gifford-Gonzalez (2018), Giovas (2009), Giovas and LeFebvre (2017), Hammond (2014), Harris et al. (2015), Jerardino (2018), Leonard-Pingel (2005), López and Rafael (1999), Lyman (1987, 1994), Morlan (1984), Múñiz (1988), O'Connor and O'Connor (2003), Olson (1980), Reitz (1993), Ruppert and Barnes (1996), Savrda (2007), Schiffer (1983), Somerville et al. (2017), Zugasti (2008, 2011), and Zuschin et al. (2003). These were consulted along with other classic works, atlases, and webpages have been consulted, including WORMS database, which contributed to improve the taxonomical identification of malacofauna assemblage described in this dissertation.

Also, the criteria, concepts, and premises related to the analysis of the malacofauna collection were considered, as in, the creation of a Microsoft Excel database to record all the information obtained, which allowed the data to be processed.

3.1.1 Laboratory work: the methodology of zoomalacology

The methodology adopted in laboratory is invariably conditioned by the state of preservation of the remains under study, which were good in general terms. Such a condition was due to a favourable taphonomic history of most skeletal parts, with low rates of bioerosion and abrasion, and fragmentation, together with post-burial conditions that allowed the preservation of all carbonated shells. This scenery common to many other contexts of relatively low age, but less evident pre-historic ones, facilitated identification down to the species level. However, as a consequence of the high fragmentation state of the material, some specimens were not possible to identify below genus.

The level of fragmentation reaches high percentages, sadly, within the factors already mentioned, one of the reasons for this high level stems from the treatment of the material after specimens have been collected, but also *in situ* during the excavation. The separation of material, the packaging, storage, and transportation are some of the reasons for the fragmentation of the shells. Nonetheless, many others were already found as fragments, revealing human intervention before the burial. Through the fractured line in the shells, it is possible to know if it is a recent fracture or not.

The material arrived properly packaged with all information regarding the origin of each element.

Then, at laboratory facilities, it was first washed with a soft bristle brush under running water and left to dry (Fig. 18-A).

3.1.1.1 Identification of the malacological remains

Firstly, and in order to ease the organization, categorization, and analysis of remains, these were divided between bivalves, gastropods, and crustaceans. After that, these were subsequently subdivided by species (Fig. 18-B). Simultaneously, taphonomic evidence of bioerosion caused by other species, encrustation, abrasion, fragmentation patterns, or evidence of anthropic action, such as fire marks or perforations, was documented based on the criteria described in chapter 2.

All species were separated by layer and stored with a label containing the bag number, species, and stratigraphic information to which they belonged. In edible bivalves such as *R.*

decussatus, C. edule and *O. edulis*, the amount of available remains was too large for a single bag. In these cases, each species was subdivided into RV, LF, Fch, and FTS sets, before being stored together in a larger and appropriately labelled bag (Fig. 18-C, D, E).

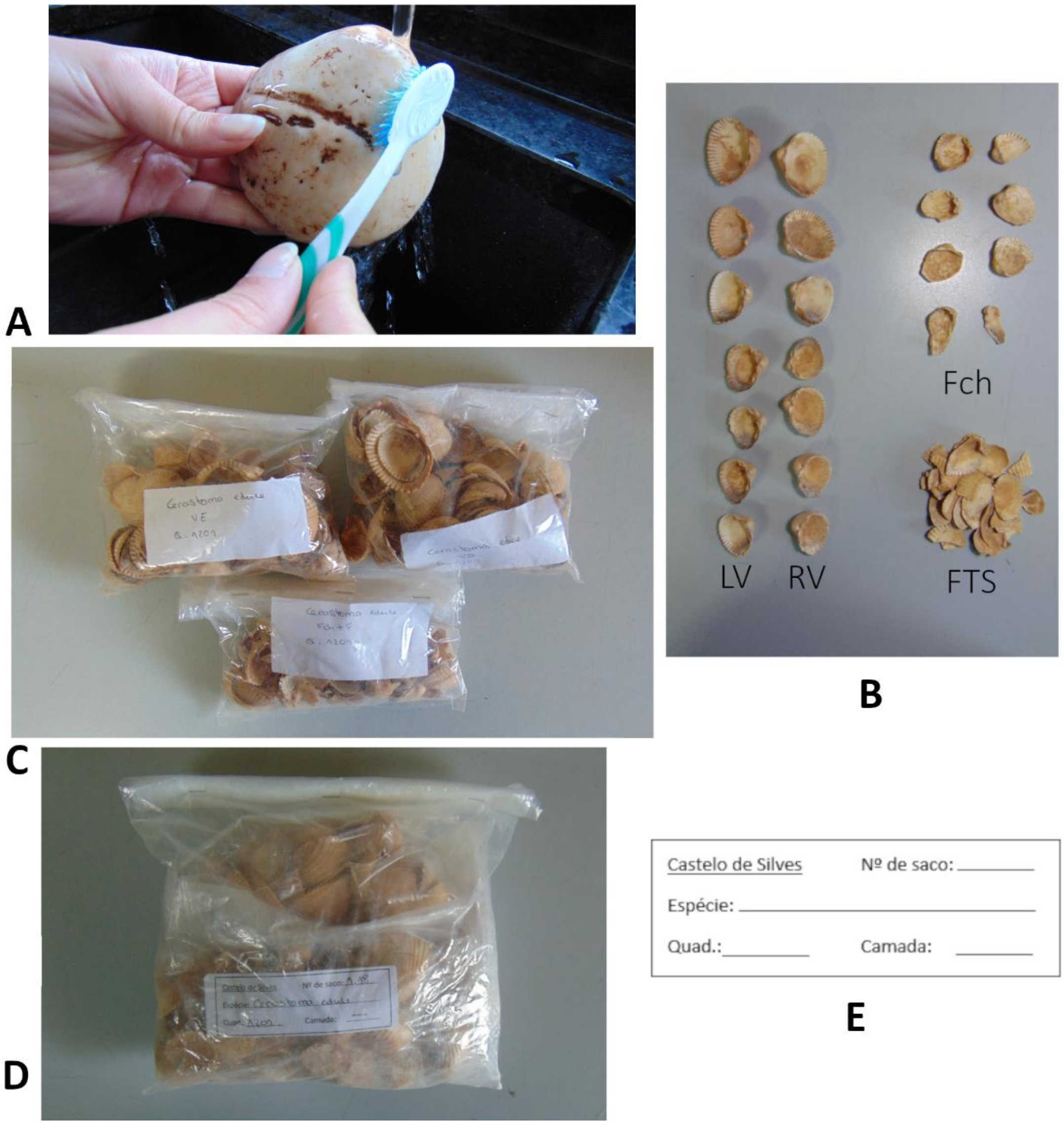


Figure 18: Methodical phases applied in this work. A – Cleaning of a *Glycymeris* specimen with a soft bristle brush and running water; B – D - Specimen separation and packing by species, including separate sets with complete valves, hinge fragments and fragments. E - Label used to identify the bags.

During this phase, a representative specimen of each species was selected as "specimen model" for photographic registration and plate representation in the dissertation. For this, each of the selected specimens was given a code with the initials CS (Castelo de Silves) plus a sequentially generated natural number, in sequence, starting with 1 and ascending (Fig. 19). For the marking, a thin layer of colourless nail polish was first applied. The code was then written with India ink, and again a second layer of polish was used to seal the ink.

The photographs of the inner and outer surface of the shells, accompanied by a 1 cm scale label, were taken using a Sony DSC-H300 camera. Subsequently, the photographs were processed with as software the program GIMP 2.10.20. These specimens were later stored back in a bag together with the photographed label. A note was also inserted in the layer bags informing that the specimen had been removed for photographic purposes and was stored in a different location.

Figure 19: Code of the specimen-model of the bivalve species *Lutraria lutraria* (CS18).

Once all material was identified and photographed, the MNI value was calculated for each species and layers in order to elaborate a matrix data set with statistical data, and to compare the quantitative representativeness of each species. To obtain the MNI, the methodology proposed by Moreno Nuño (1994) was dutifully followed. Nonetheless, these values do not directly translate into the absolute number of individuals, but rather to an estimate. This is due the fact that under the following descriptions, fragmented specimens are not counted.

The calculation of the MNI results from the combination of several variants. Thus, in the case of the disarticulated bivalve, only complete valves and those fragments with a preserved umbo were counted, considering separates sums for the left and right valves. At the end, the most abundant valve side is that which enters for the NMI. Moreover, all fragments that do not possess umbonal parts were catalogued as FTS and do not count.

Regarding gastropods, each complete shell was considered as an individual. The same counting was considered for those fragmented, but keeping the apex and the aperture area, the peristome, or an apical fragment, as well as a proportion above 50% of the original shell, or those presenting the columella intact.

The quantification analysis of the faunal collection was then plotted in a database using the Microsoft Excel program. This database registered the variables previously described for the identification of the zooarchaeological remains, such as the information of the archaeological context, anatomical and taxonomical identification, taphonomic observations, biological and biogeographical characteristics, range of each species, diversity, and species counts. The purpose of using a database was to gather as much information as possible on the same platform, including contextual information of the archaeological relevance, analysis and interpreting the data produced.

The next step was to develop univariate and bivariate statistical procedures with the database set, including the preparation of a variety of Excel graphics that allowed a better and more illustrative interpretation of the studied collection. Both data set and most significant graphics are presented and explained in the dissertation.

Chapter 4 TAXONOMY

4.1 PHYLUM MOLLUSCA: A BRIEF INTRODUCTION

The word Mollusca comes from the Latin *mollis* (“soft”), a clear reference to the body of the animal (Martinell et al., 2009). In 1795, Georges Cuvier proposed a new classification of an invertebrate animal group based on their anatomical features. The concept of molluscs, as representative of an exceptional type of morphological organization of metazoan animals, revolutionized invertebrate systematics. Before Cuvier, the term “molluscs” was used for referencing slugs and cephalopods with no external shells; meanwhile, all the shelled molluscs were placed in a different taxon, the Testacea (Vinarski, 2014).

Mollusca, a large and diverse invertebrate animal Phylum, is the second most diversified group of the Animalia Kingdom following Arthropods. According to the database website MolluscaBase, eds. (2020), there are 80,355 registered and accepted extant species and 16,151 fossils species within the Phylum Mollusca, including marine, freshwater, and terrestrial species. However, the real number should be much higher and every year new recent and fossil *taxa* are described for Science. It includes familiar organisms such as oysters, scallops, clams, octopuses, squid, snails, and chitons. The group is divided into eight extant Classes:

1) Bivalvia (oysters, scallops, clams and mussel);
2) Caudofoveata (shell-less vermiform molluscs);
3) Cephalopoda (octopus, cuttlefish and squids);
4) Gastropoda (limpets, conchs, whelks, snails and slugs) - the most diverse and disparate clades;
5) Monoplacophora (limpet-like “living fossils”);
6) Polyplacophora (chitons or coat-of-mail shells);
7) Scaphopoda (tusk shells);
8) Solenogastra (shell-less wormlike) - the least diverse and disparate (Fig. 20).

To these two extinct Classes: Cricoconarida and Rostroconchia (MolluscaBase-eds., 2020; WoRMS, 2020).

Mollusca presents an enormous diversity in both shape and size. Its ecology is also highly diversified, having conquered almost every possible ecological niches in marine, freshwater, and terrestrial environments. Animals of this Phylum have colonized all marine environments ranging from the deepest ridges in the ocean to intertidal zones. Although both bivalves and gastropods have adapted to freshwater habitats, only gastropods have successfully invaded terrestrial habitats from coastal and near waterlines to the most inhospitable places, from mountain ridges to the most arid of deserts.

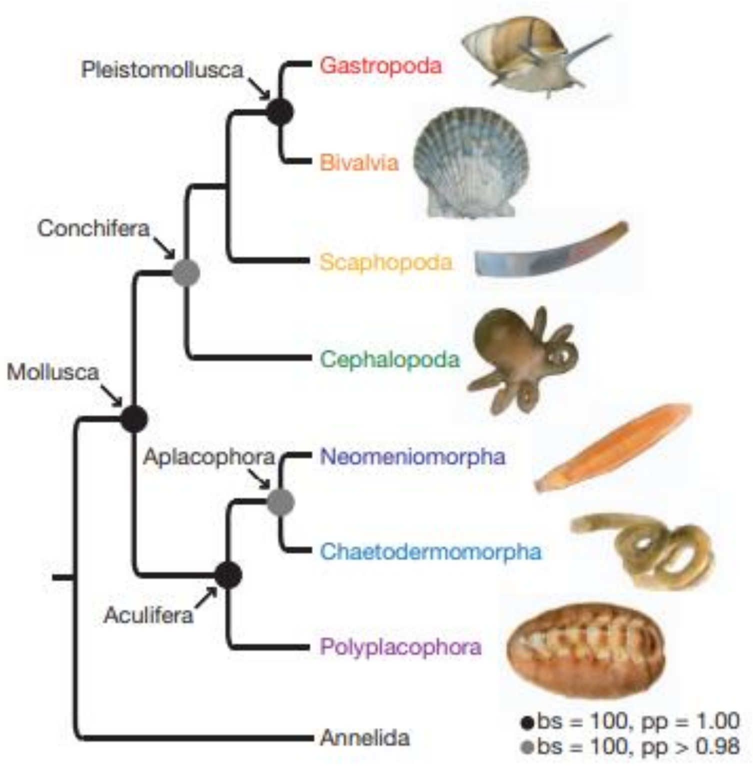


Figure 20: Molluscan phylogeny hypothesised in Kocot et al. (2011).

There is a scientific agreement that molluscs were originally marine animals that later occupied freshwater and terrestrial habitats. This event has occurred several times and independently for bivalves and gastropods. Such versatility is possible due to their diversified morphology, mode of life, and behaviour.

Their variable morphologies (shape, size, colour, robustness, etc.) reflect the diverse habits and modes of life of these animals. Molluscs can be sessile, vagile, benthonic, nektonic, and planktonic. Nutritionally they range from primitive filter-feeders to highly carnivorous predators, scavengers, herbivores, grazers, photosymbiotic, and suspension-feeders. Molluscs can also be oviparous or viviparous (e.g. Boss, 2003; Gould, 1841; Haszprunar, 1992; MolluscaBase-eds., 2020; Somerville et al., 2017; Vinther, 2015).

It is remarkable to see how an over eleven-meter-long carnivorous giant squid (*Architeuthis*; Roper & Shea, 2013) with bulging eyes, and no external shell, able to fight carnivorous whales, can be classified in the same Phylum as microscopic, interstitial, headless, spiculose aplacophoran, smaller than 1 mm in length, and living between grains of sand (Tunnell et al., 2010).

The incredible complete record for the Phylum Mollusca is mainly due to the mineral shells that have high probabilities of fossilization, which provide a rich fossil record that dates back to the Precambrian-Cambrian boundary, corresponding to the oldest records that can be reported for the existence of these animals. These records, together with those of “transitional forms”, are part of the mass skeletonization event, which could connect molluscs and their alleged ancestors.

Turbellarian flatworms, originally found in Precambrian rocks, have since then diverged, and radiated into many different lineages and the immense range of ecological niches of the biotopes of the world (Boss, 2003; Parkhaev, 2008, 2017). The first appearance of molluscs in the fossil record is not consensual. According to Parkhaev (2017), the first known molluscs (*Purella*) originate in the terminal Precambrian of Siberia (uppermost Nemakit-Daldynian Stage, *Purella antiqua* Zone). The search for the earliest representative of this Phylum can provide crucial data on the development and early evolutionary stages of major branches that belong to it (Parkhaev, 2017).

Molecular clock and fossil record analyses reveal a scenario in which molluscs diffused early in the Cambrian explosion. Molluscan sub-lineages were strongly rooted in this Period, while the bivalves and gastropod crown groups propagated in the Ordovician Biodiversification Event (Vinther, 2014, 2015). The combination of ancient evolutionary history with the occurrence of mineralized exoskeletons - hard parts present in the body plan of most shell-bearing taxa - has resulted in a fossil record far richer than most other groups (Parkhaev, 2008, 2017).

4.2 CHARACTERISTICS OF MOLLUSCA

Due to its ancestral history, it is possible to observe an extraordinary adaptation and specialization present in the extant Mollusca representatives. Time has made it possible for this Phylum to become an extremely diverse and complex clade. The plan structure of these animals involves a body divided into two interacting symmetries (Hickman, 1973; Martinell et al., 2009):

1) The Upper region – *visceropallium* - composed of a visceral hump and an overhanging mantle specialized in mucous secretion and ciliary action. It has a tendency toward biradial symmetry.

2) The lower region - head-foot complex – composed of the head and a foot whose activity is chiefly muscular. It is the most active zone and includes the entrance of the digestive tract, the sensory and locomotive organs. It has a definite bilateral symmetry and is composed of the. It is also the most active zone and includes the entrance to the digestive tract and, the sensory and locomotive organs. Has a definite bilaterally symmetry (Hickman, 1973; Martinell et al., 2009).

These two parts regions comprise a gut, brain, sex organs, heart, excretory system, sensory organs, and the methods for locomotion of the animal (Boss, 2003). The great majority of the groups have the ability to secrete a solid calcareous or proteinaceous structure, which can serve as habitation and protection for the soft parts – the shell. Because of that, these animals are called testaceous Mollusca or Testacea (Gould, 1841).

4.2.1 Morphology

It should be pointed at first that, although a few species from the SubPhylum Crustacea have also been found in the studied bulk sample, because they appear in a very residual way, and also not to extend this theme too much, that quite different invertebrate group will not be addressed here.

Concerning the molluscs, it is known that they are triploblastic, coelomate, unsegmented (except in the class Monoplacophora), and bilaterally symmetrical invertebrates. Members of the Phylum, although quite different from each other, can be schematized through a generalized anatomical "model". It features a bilaterally symmetric body, characterized by a muscular foot, a head with an exclusive alimentary function - the radula -, and a calcareous shell secreted by the underlying epidermis of the body wall - the mantle or *pallium* (Fig. 21; Martinell et al., 2009; Ruppert & Barnes, 1996).

Nevertheless, Pojeta (1985) draws attention to an important issue: "Any attempt at a morphological/anatomical definition of Mollusca results in so many qualifications and exceptions as to be meaningless. There is no unique structure found in every mollusk" (p.4). Wanninger and Wollesen (2015) expand the idea: "As a consequence of this wide phenotypic variation, clear-cut autapomorphies for the Phylum are scarce, since all potential characters have undergone significant remodelling from their ancestral state" (pp.109-111). Because molluscs have developed such diversified body structures, it becomes difficult to observe synapomorphies that apply to all modern groups, with each class displaying a distinct evolutionary path.

Animals in Mollusca have an immense variety and display adaptions for exceptionally diversified habitat and remarkable different ways of live. Nevertheless, some general features can connect them all. Since each class of molluscs has its worn distinctive morphology features, the basic molluscan plan only makes it possible to present an extremely generalized description of their characteristic organs. These general features are not always evident, for they are affected by the habits and habitats in which they are inserted (Hickman, 1973; Meglitsch, 1967).

A reconstruction of a hypothetical primitive mollusc, when reduced to its simplest features, would consist of a head, a foot, the visceral mass, the mantle, and a shell (Fig. 20; e.g. Barnes, 1974; Cuvier et al., 1834; Hickman, 1973; Hiscock, 1972; Martinell et al., 2009; Meglitsch, 1967; Ruppert & Barnes, 1996; Ruschenberger et al., 1843).

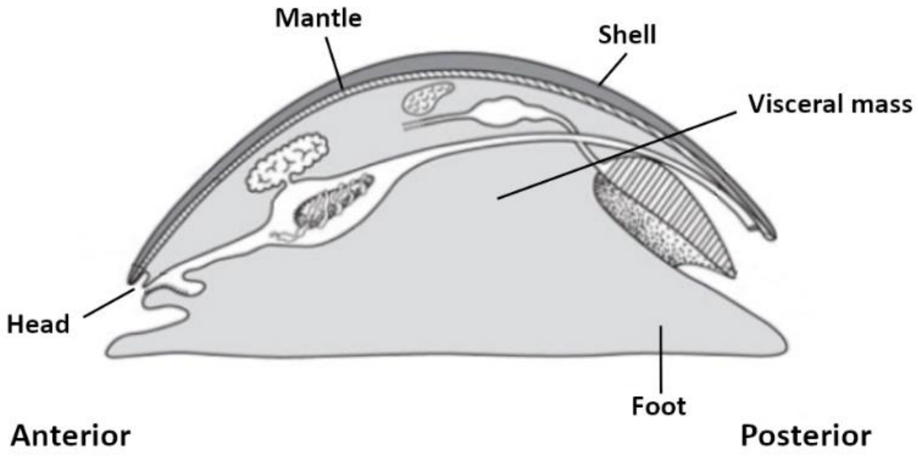


Figure 21: Basic molluscan morphology. Adapted from Milsom & Rigby (2010).

Most molluscs possess a well-developed **head**, carrying a mouth and certain specialized sensory organs. It is placed anteriorly and opens into a buccal cavity containing a peculiar feeding organ - the odontophore. This is a broad tongue-like ribbon operated by a complex musculature and covered with a membrane, the radula (Hiscock, 1972; Martinell et al., 2009).

The **foot**, a central muscle modified from the integument, is the organ adapted for locomotion, substrate attachment, or a combination of both functions. It is generally a ventrally positioned structure in the form of a flat sole to which a series of muscular contractions cause a crawling displacement. The foot is very distinct from the rest of the body - particularly from the head. It is highly modified for a variety of functions in different groups, such as the fixing disc of limpets, the laterally compressed hatchet foot of the bivalves, or the siphon used for jet propulsion in squid and octopi.

Also, for locomotion and attachment, the movement and adherence of the foot is aided by the secretion of mucus. This can be used as a sheet over which the foot can glide by ciliary action, or through the formation of a track along which small molluscs are glided by cilia. This powerful ventral musculature is considered as the remains of the dermo-muscular tube of the radial form, which attained greater development on the ventral side, as adaptation for crawling as a way of locomotion, while atrophying on the dorsal side as it become reduced, functionless, and useless by the hard shell (Hickman, 1973; Martinell et al., 2009; Pechenik, 1990).

In gastropods and bivalves, the foot expands hydraulically from the body as it fills with blood. Excavator forms can extend the foot into the muddy or sandy substrate, using it as an anchor to pull the body forward. In pelagic forms, the foot is modified for swimming in the form of fine movable fins (Martinell et al., 2009).

The **visceral mass**, *i.e.* all of the internal organs, is the portion that contains the digestive, circulatory, respiratory, and reproductive systems. The compact visceral mass is enclosed in a double integumentary fold - the mantle or *pallium* - which extends over the dorsal wall of the body (Hickman, 1973; Martinell et al., 2009).

This **mantle** or *pallium* is a thin, fleshy sheath of integument that extends from the visceral mass, covering each side of the body. It has adapted to protect the soft tissues, creating a space called the mantle cavity (or pallial cavity). This cavity plays a very important role in the life of molluscs, as it houses a pair of respiratory organs (lungs or gills known as *ctenidia*), siphons or apertures, openings of the digestive, nephridial, and genital systems. Furthermore, the surface of the mantle itself also serves for gas exchange. Each *ctenidium* consists of a central axis bearing a row of triangular filaments on both sides. These contain mucous cells and *cilia*. When present, *ctenidia* may only have a respiratory function or they may also participate in the gathering and sorting of food particles

The products of the digestive, excretory, and reproductive systems are released into the cavity of the mantle. Another key property of the mantle is its ability to secrete a “shell”. The active secretory centre is located mainly in the mantle edge, permitting the growth of the shell by marginal increment (Cuvier et al., 1834; Hickman, 1973; Martinell et al., 2009; Pechenik, 1990; Ruppert & Barnes, 1996; Singleton, 2018; Torres Balbás, 1953).

In aquatic molluscs, a continuous stream of water is kept in motion by superficial *cilia*, carrying oxygen and, in some forms, food. The mantle normally contains sensory receptors with the mission of "taste" the surrounding water. In cephalopods, the muscle mantle and its cavities create the jet propulsion used for locomotion (Martinell et al., 2009).

The **shell** is one of the most prominent features of molluscs. In some species it may however appear reduced or absent altogether. As stated above, molluscs that are provided with a shell are called *testaceous* or Testacea (Ruschenberger et al., 1843). There are many variations in structural organization among the different taxa with regard to form, colour, surface, substance, and brilliancy. The shell can be formed by a single piece, as is the cases for gastropods, scaphopods, monoplacophorans, and cephalopods - if they have one. Bivalves shells are formed by two pieces, and or in polyplacophorans by eight individual plates. In the case of Solenogastra and Caudofoveata, the surface of the body appears covered by small calcareous spicules. The shell has also been lost numerous times in gastropods and more than once in colleoid cephalopods (Cuvier et al., 1834; Hickman, 1973; Ponder et al., 2020; Ruschenberger et al., 1843).

Shell first appears during the veliger larva stage and grows throughout the life of the animal. The mantle secretes and limits the shell, which areusually external, but may sometimes be internal. Although the shell is secreted by the mantle in all molluscs, there are variations in the way that components are put together. The shell may be bivalved, univalved, spirally coiled or cone-shaped. Most molluscs shells are composed of three layers (Fig. 22):

1) The outermost pigmented layer - the ***periostracum*** - made of a thin horny organic substance, the conchiolin. It protects the shell from the corroding action of acid and is secret by the fold of the mantle edge.
2) The thick, calcareous middle layer - the ***ostracum*** (prismatic layer) - also secreted by the edge of the mantle. It is laid down in layers of crystalline calcareous plates running vertically.
3) The innermost layer – the **nacreous** or mother-of-pearl - a thin layer secreted constantly by the whole mantle surface, becoming thicker throughout the lifetime of the animal. Nacreous material is laminated and made of conchiolin and calcareous plates running alternately and longitudinally, forming light-reflecting prisms (Hickman, 1973; Martinell et al., 2009; Meglitsch, 1967; Pechenik, 1990; Pelseneer, 1906).

When the shell is internal, the mantle is turned back on itself (reflected) so that the shell is surrounded by the glandular epithelium (Meglitsch, 1967).

A firm shell acts as a support for the mantle cavity and as an anchor for the muscles along the shell. This allows the mollusc to pull down the shell into the substrate in order to isolate the animal and thus protect it (Barnes, 1974; Hiscock, 1972; Pyron & Brown, 2015).

Mollusc shells are highly modified in many ways. This makes it difficult to describe the massive particularities of the shells from different classes without extending into detail. Thus, the following section is a brief generalized description of the peculiarities of the shells of classes found in presently the studied collection, namely the Bivalvia and Gastropoda ones.

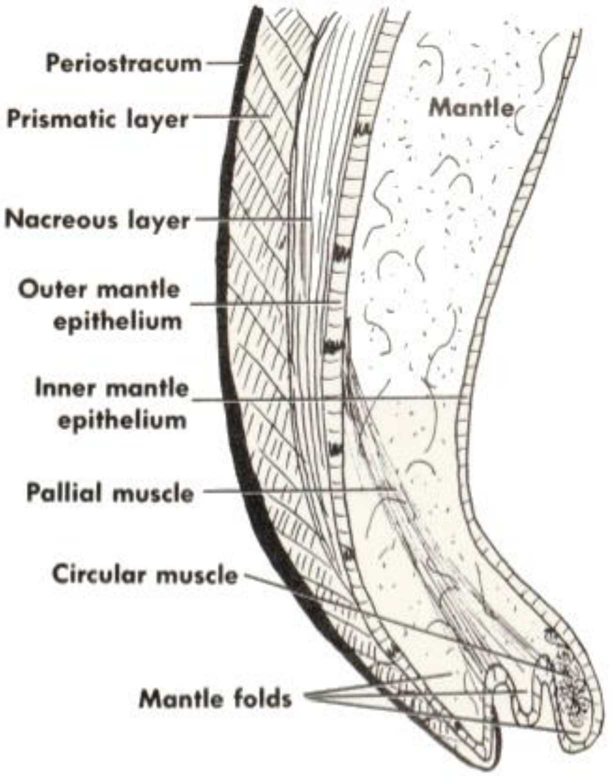


Figure 22: Structure of a typical mollusc shell and mantle (Hickman, 1973).

Bivalvia

Bivalve shells are found in a great variety of shapes, sizes, colours, and surface sculpture. They are typically made up of two similar, relatively oval, and usually convex valves of various shapes and contours (Figs. 24). These shells first appear in embryo as a single shell. In a later developmental stage, two separate calcareous plates are secreted by the left and right regions of the shell gland (Barnes, 1974; Hickman, 1973; Ponder et al., 2020).

Bivalves have symmetrical or asymmetrical paired shells or valves attached dorsally by an elastic band called the hinge ligament. The ligament - a persistent rudiment of the larval shell

- is composed of the same conchiolin of the periostracum. These valves are also usually articulated through a series of interlocking teeth located on the hinge line, just beneath the hinge ligament (Fig. 23-A and 24). These shelly teeth are an important taxonomic feature (Barnes, 1974; Claassen, 1998; Hickman, 1973; Ponder et al., 2020).

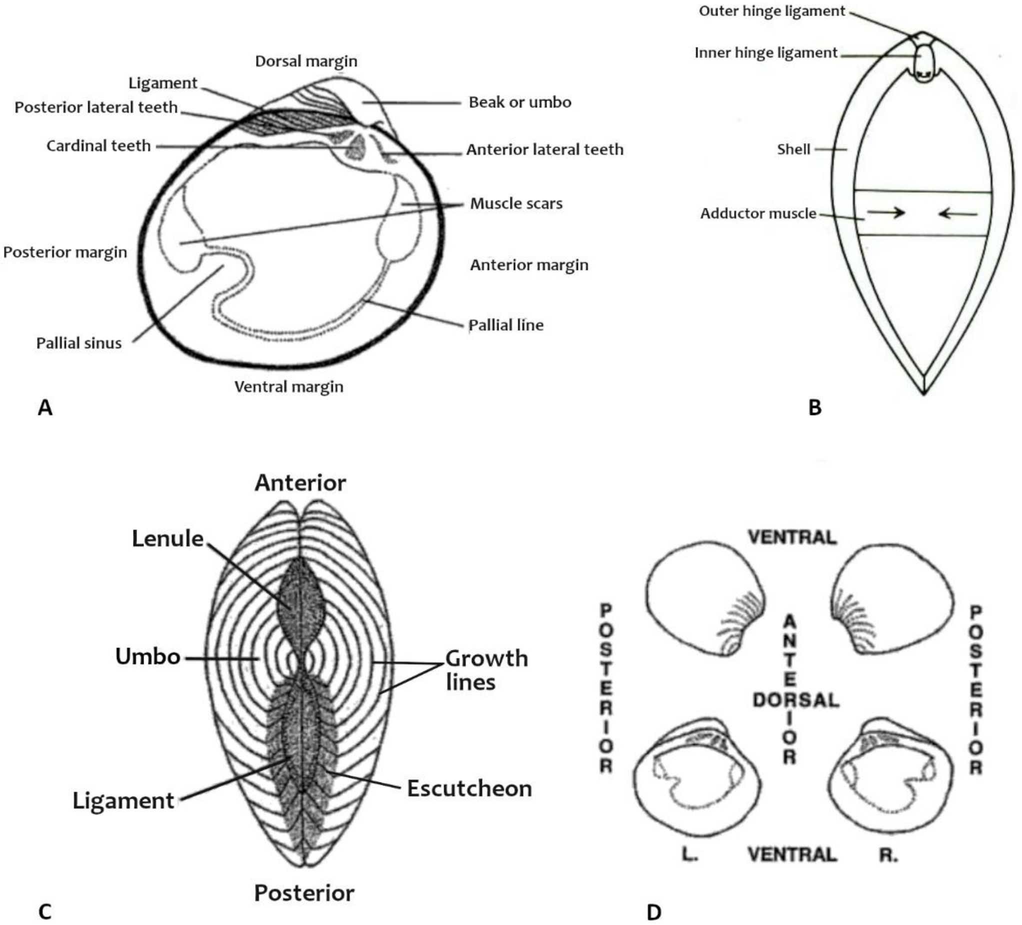


Figure 23: Bivalve shell morphology. A: Inner surface of a left valve. B: Bivalve shell transverse section. C: Dorsal shell view. D: Bivalve shell orientation. Adapted from Barnes (1974) and Claassen (1998).

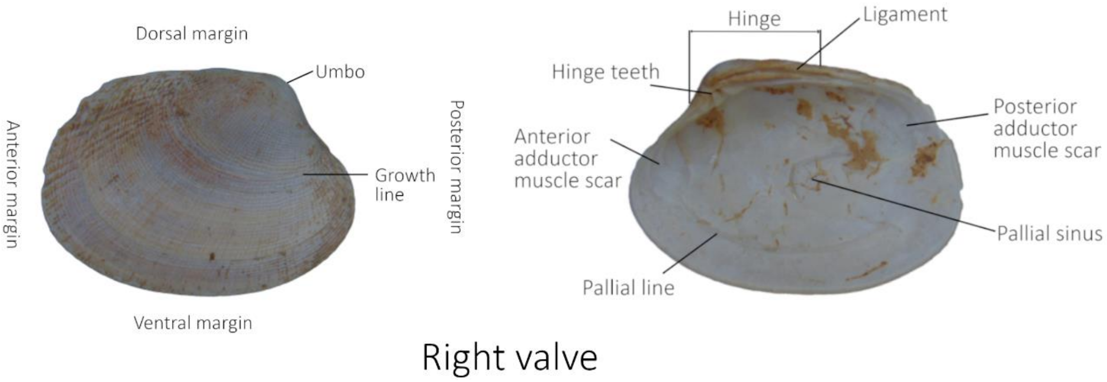


Figure 24: Internal and external shell features of a bivalve, the venus clam *Ruditapes decussatus.*

The shell is composed of the same three layers described above. The dorsal margin of each valve bears a prominence point near the hinge ligament where the teeth are found, rising above the line of articulation, which is called beak. The umbo is the most convex part of the valve. The hinge ligament is constructed so that when the valves are closed, the dorsal (outer) part is stretched, and the ventral (inner) part is compressed. Shell valves are pulled together by one or two adductor muscles - anterior and posterior- attached to the inner surfaces of their nacreous layers. When the adductor muscles relax, the ligament causes the valves to open (Fig. 23-B). Scallops and oysters have one single muscle, while mussels have two equal-sized adductor muscles, towards the front and the back. Scars on the inner side of the valves indicate where these adductor muscles are attached (see Figs. 23-A and 24), and can vary in size, or to be completely absent in oysters and scallops (Barnes, 1974; Claassen, 1998; Hickman, 1973; Ponder et al., 2020).

The beaks are the oldest part of the shell. It is around them that the shell grows through concentric lines. Each umbo may point slightly anteriorly, a fact that normally permits to determine right and left valves. The different areas of the external surface of each valve may be called the anterior slope, the posterior slope, or the central disk (Fig. 23-C; Barnes, 1974; Hickman, 1973; Ponder et al., 2020).

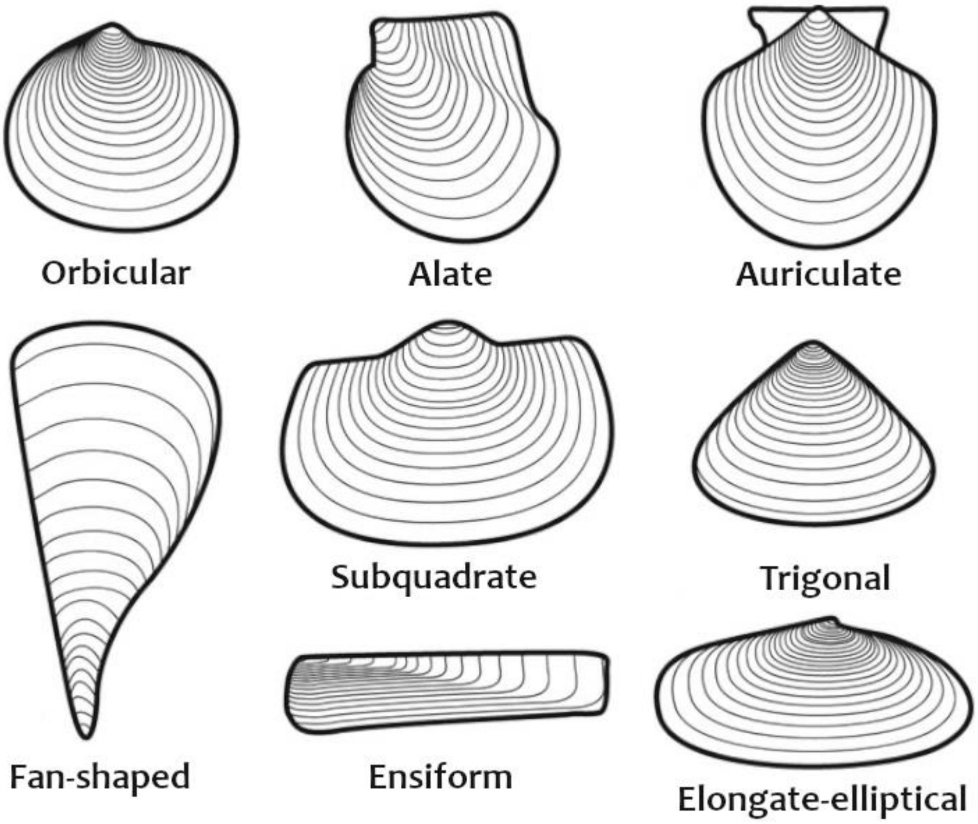


Figure 25: A few examples of terms used to describe bivalve shell shapes (Harris et al., 2015).

Gastropoda

The typical shell is spirally coiled into an approximately conical shape. Such a shell is made of tubular whorls and contains the visceral mass of the animal. The typical coiling grows around a shell axis called the columella and begins with the smallest and oldest whorl at the apex and successively larger ones to the aperture where the head and foot of the animal protrude (Fig. 26). The shell is said to be dextral or right-handed. Only a relatively few taxa have sinistral shells (e.g. Clausilidae, Planorbidae), although some species display both types of chirality. A shell possesses a dextral spiral when its aperture opens to the right of the columella and sinistral when it does so to the left (Barnes, 1974; Hickman, 1973; Ponder et al., 2020).

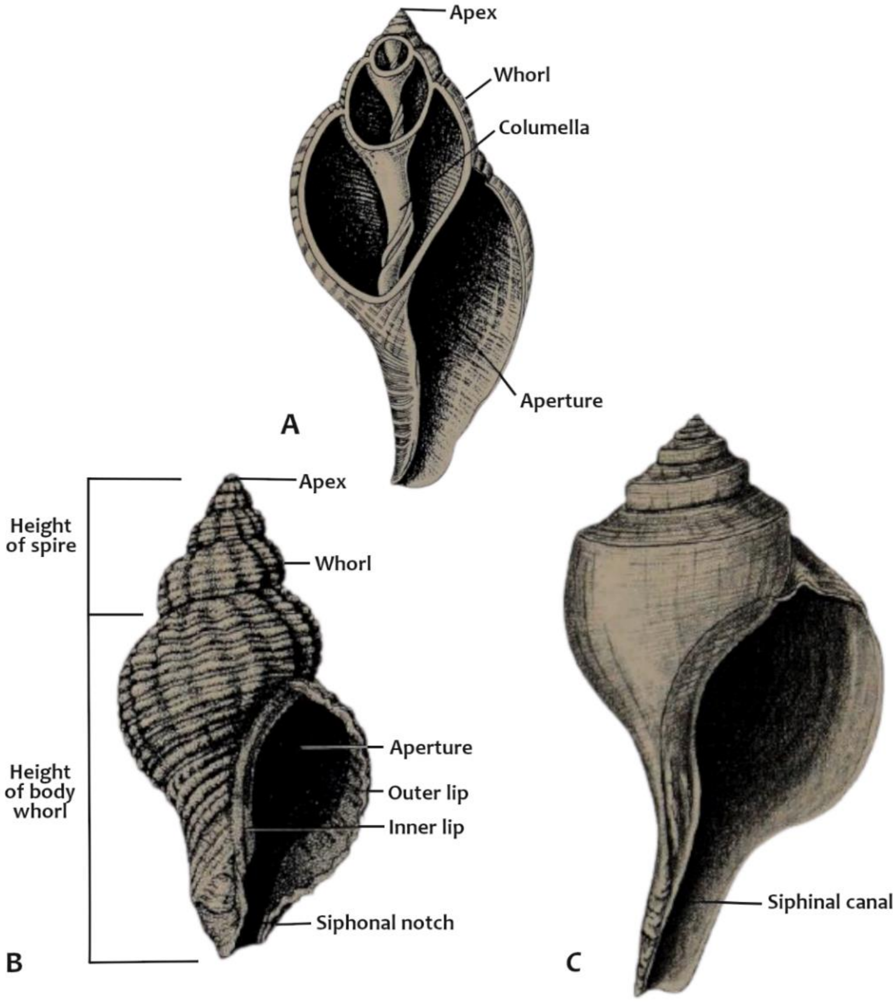


Figure 26: Gastropod shell. A: Longitudinal shell section. B: *Urosalpinx cinera* shell, with commonly designated features. C: *Busycon canaliculatum*, the common Atlantic Coast whelk (Barnes, 1974).

The first shell part laid down during the gastropods larval shape is called the protoconch. It corresponds to the smallest whorl at the apex of the shell and is usually a simple plate or caplike in its shape. Later, it forms a spiral plane, which usually changes gradually into a conical spiral. The protoconch is represented in the adults by the small apex whorl - usually smooth and not sculptured. During its ontogenic development, the protoconch becomes coiled by deposition of mineral salts around the mantle edges at the aperture end.

The aperture varies greatly in shape, adapted to the presence or absence of an inhalant siphon or anal slit, and to the extent to which the mantle is reflected over its margins. Gastropods shell also has the characteristic three layers of most mollusc shells (Barnes, 1974; Hickman, 1973; Meglitsch, 1967; Ponder et al., 2020).

They exhibit an infinite variety of shape, colour, sculpturing, and pattern (Fig. 27). Although primitively spiral, some shells have become uncoiled and cap-shaped (limpets, ear shells, and slipper shells). This form is characteristic of sedimentary species that cling to rocks. Detorsion - or the untwisting - is always associated with reduced or complete shell loss (Anaspidea, Gymnostomata). The edges of the mantle grow over the shell and cover most or all of its surface. This causes the shell to be internal and degenerate (slugs). Shell reduction is especially pronounced in opisthobranchs (Hickman, 1973; Meglitsch, 1967; Ponder et al., 2020).

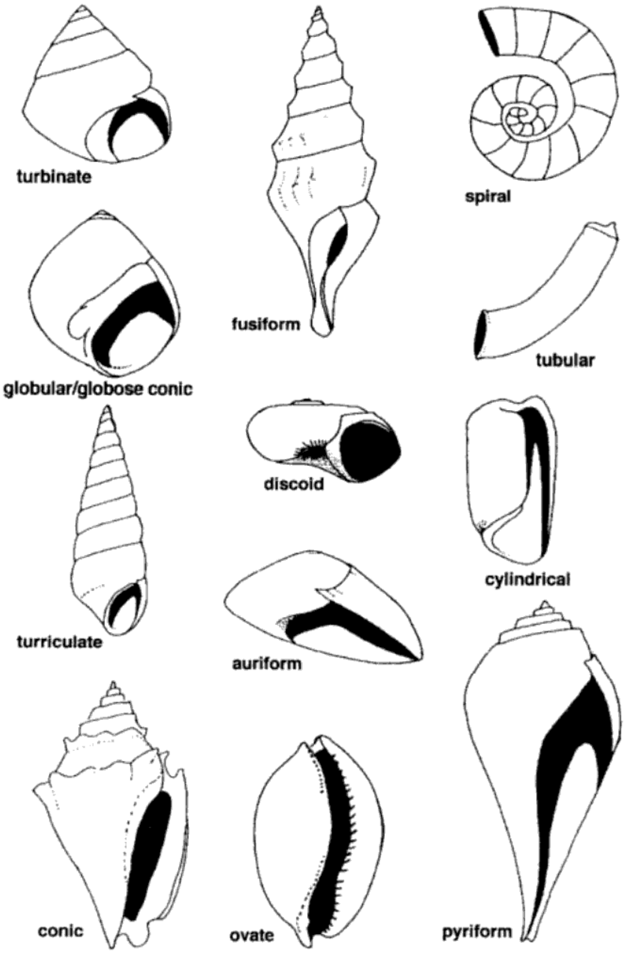


Figure 27: A few examples terms used to describe gastropod shell shapes (Claassen, 1998).

4.2.2 Internal anatomy

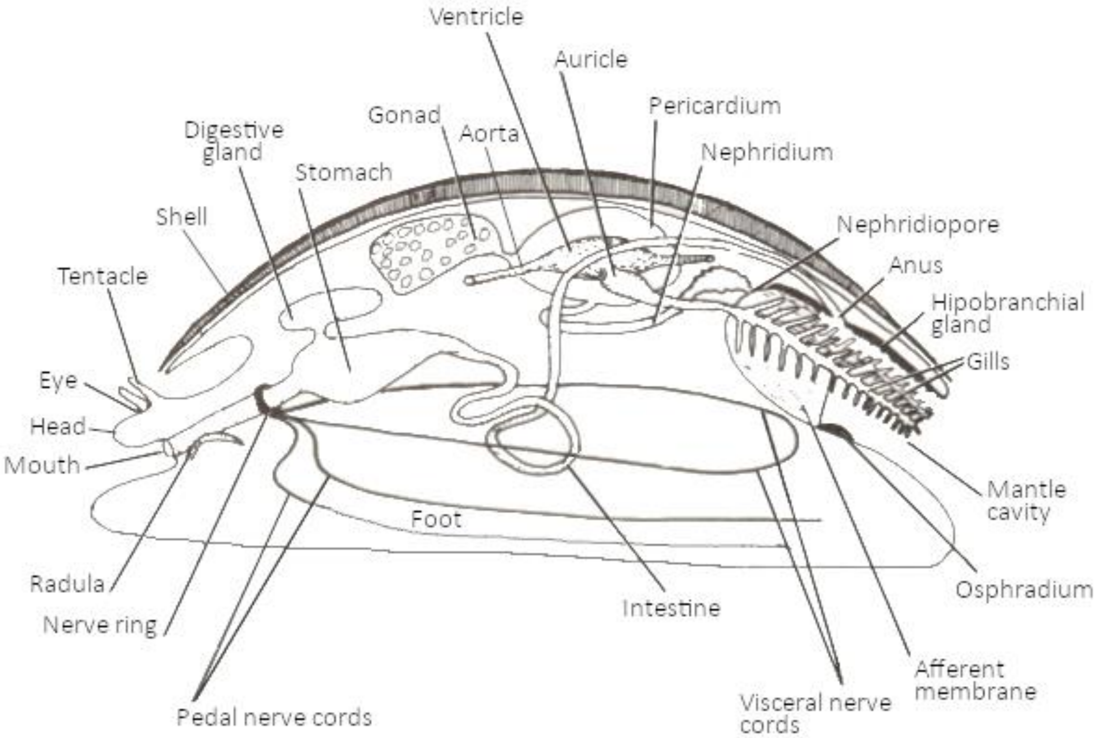


Figure 28: Hypothetical primitive mollusc (lateral view). External form: head; tentacle; eye; shell; mantle and mantle cavity; foot. Digestive tract: mouth; radula in radular sac; digestive gland; stomach; intestine; anus. Nephridial system: pericardium; nephridium; nephridiopore; hypobranchial gland. Reproductive system: gonad; Respiratory system: gills; osphradium; afferent membrane; Circulatory system: auricle; ventricle; aorta pericardium; nervous system: pedal nerve cords; visceral nerve cords; nerve ring. (adapted from Barnes, 1974; Hickman, 1973; Meglitsch, 1967; Pelseneer, 1906).

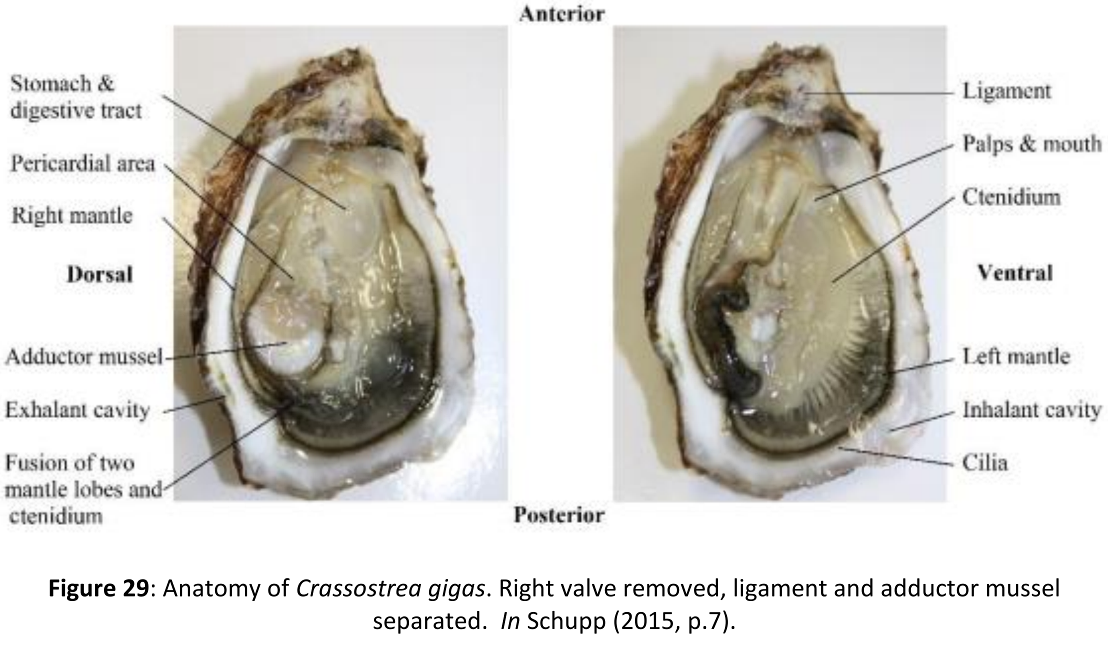


Figure 29: Anatomy of *Crassostrea gigas*. Right valve removed, ligament and adductor mussel separated. *In* Schupp (2015, p.7).

Digestive system

Molluscs have a complex digestive tract, divided into a foregut derived from the *stomodaeum*, a hindgut derived from the *proctodaeum*, and a midgut derived from the primitive gut and lined with cells originating from the endoderm (Figs. 28 and 29; Hickman, 1973; Meglitsch, 1967).

The mouth is placed anteriorly and gives way to an oral cavity covered by a cuticle. The floor of the oral cavity is occupied by a unique feeding organ composed of a mass of cartilage - the odontophore. Over the midline of this odontophore and surrounding the anterior portion of it, a membranous ribbon extends, which is name as the radula (Hickman, 1973; Hiscock, 1972; Meglitsch, 1967; Pechenik, 1990; Ruppert & Barnes, 1996).

The **radula**, formed from a deep sac called the radula sac, and it is located at the back of the oral cavity. A scraping organ hardened with chitin, it projects out of the mouth in the shape of a tongue in some cases. The radula apparatus is a feeding structure used by many molluscs, except for bivalves and almost all solenogasters. This radial structure has been found in the fossil record since the Lower Cambrian, although very sporadic as fossils. Microscopic in size, the radula has rows of sharp chitinous teeth arranged on cartilaginous supports (odontophore). A complex muscular system moves it back and forth (see Fig. 30). The teeth can be used to scrape, pierce, tear, and cut. Their number of teeth can vary from a few to 250 000. Herbivorous molluscs have a radula with a very high number of teeth, while those of carnivores tend to have a much smaller number. Carnivorous molluscs such as cephalopods possess powerful jaws for grabbing and tear their prey with the aid of the radula in the process. The habitual function of the radula is twofold: to remove small particles from the food material and to serve as a conveyor belt that carries these particles in a continuous flow towards the digestive tract. In some forms, very interesting radular specializations, such as the ability to pierce skeletal materials (in naticids and muricids, for example) or to spear their prey (in conids) are found. The shape, disposition, and number of teeth per row in the radula are unique for each species. Many species - especially bivalves – have developed modifications to their feeding habits that have resulted in a lack of mandibles, radula, or pharyngeal musculature, but have efficient ciliary-feeding devices (Barnes, 1974; Hickman, 1973; Hiscock, 1972; Martinell et al., 2009; Pechenik, 1990; Ruppert & Barnes, 1996).

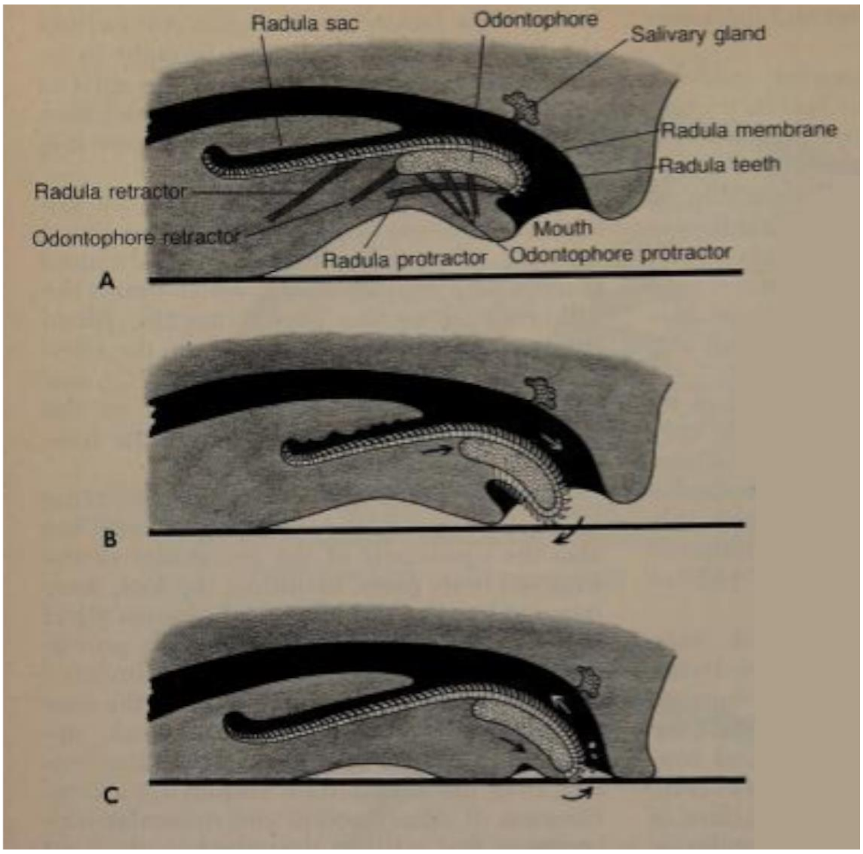


Figure 30: Molluscan radula. A: mouth cavity, showing radula apparatus (lateral view). B: Protraction of the radula against the substratum. C: Forward retracting movement, during which substratum is scraped by radula teeth (Barnes, 1974).

Molluscs have a least a pair of salivary glands that open into the dorsal wall of the oral cavity. These glands secreted mucus that lubricates the radula and envelops ingested food particles in a mucous string. This string passes from the oral cavity, through a tube-shaped oesophagus, and then to the stomach. The anterior region of the stomach is internally lined with chitin, except for a separating region formed by a series of ciliated edges (Barnes, 1974; Hickman, 1973; Meglitsch, 1967).

The contents of the stomach are rotated inside by cilia of the style sac. This rotation twists the mucous food string from the oesophagus and into the stomach cavity. This mucous mass is called protostyle. In a posterior phase, particles are carried to the separating region, where they are selected by size. Larger and rejected particles either enter the intestine directly or remain on the protostyle. Food particles are passed into one of two ducts, which lead them to the digestive diverticula, a ramifying mass of tubules, where they were intracellularly digested. The long and coiled intestine has a primary function of formation of faeces, mostly through ciliary action towards the rectum. The anus is located in a mid-dorsal position on the posterior margin of the pallial cavity, and faces are carried out by an exhaling current (Hickman, 1973; Hiscock, 1972; Ruppert & Barnes, 1996).

Circulatory system

The pericardium is in the middorsal region of the body, where it surrounds the heart. It is through it that the circulatory system of the primitive molluscs was probably similar to that of many modern ones. Two lateral auricles receive blood from the gills and pass it through the muscularized ventricle, which pumps the blood through the body. Blood vessels are constituted by arteries, veins, and sinuses. A single anterior aorta leaves the heart, collects the blood from the gills, and breaks up into smaller arteries that pass blood to the mantle and viscera. The arteries arise from a network of vessels that lead into veins and sinuses. In its return to the heart, blood goes through the kidneys and gills for purification and gaseous exchange. The colourless blood of molluscs is composed of a variety of amoebocytes and corpuscles (Barnes, 1974; Cuvier et al., 1834; Hickman, 1973; Hiscock, 1972; Meglitsch, 1967; Ruppert & Barnes, 1996).

Coelom and excretory organs

The molluscan coelom is very small, being mainly confined to the pericardium and gonadal cavity. Most of the body spaces in the animals of the Phylum are part the very extensive *hemocoel* (“blood cavity”). This *hemocoel* serves as a hydrostatic skeleton in the locomotion of some molluscs. In most molluscs both cavities are separated. Associated with the *pericardium* are the excretory organs, commonly called the “kidneys”. These are a pair of renal organs which originate in the *pericardium* and discharge into the mantle cavity in the exhalant area. The ducts of the renal organs, undergo various differentiations and act as reno-genital ducts, discharging both renal and gonadial products (Cuvier et al., 1834; Hickman, 1973; Hiscock, 1972; Pechenik, 1990; Ruppert & Barnes, 1996).

Nervous system

The basic structure of the nervous system of molluscs consists of a periesophageal nervous ring that surrounds the oesophagus. From this ring two pairs of longitudinal nerve cords protact. The pleurovisceral cords run into the visceral mass and mantle while the pedal cords run into the muscles of the foot. Nerve cells are probably diffused and not gathered into ganglia. Mollusc sensory organs consist of tentacles, *ocelli*, statocysts in the foot, and *osphradia* (Hickman, 1973; Hiscock, 1972; Ruppert & Barnes, 1996).

Respiratory system

The *ctenidia* are a pair of comb-like gills located in the mantle. Each *ctenidium* consists of a central axis. Within each these axes, incurrent and excurrent blood vessels provide for the exchange of respiratory gases. The beating *cilia* on the gill filaments generate a current of water that flows into the cavity. Blood circulates through the gill filaments while *cilia* on their surface swirl water over the filament, removing foreign particles. A hypobranchial gland between each gill and the rectum helps carrying waste particles into the dorsal branchial chamber for ejection. A small sensory path — the *osphradium* — at the base of each gill tests the chemical nature of the incoming current (Hickman, 1973; Hiscock, 1972; Meglitsch, 1967).

There are three types of respiration in molluscs:

1) Cutaneous, occurring in species without differentiated respiratory organs;
2) Branchial, in aquatic molluscs with gills;
3) Pulmonary, an adaptation for terrestrial survival (Hickman, 1973).

Reproductive system

Reproductive systems vary from the very simple to the highest complex and are best considered within each respective Class. Most molluscs are *dioecious*, although members of the subclass Pulmonata, Opisthobranchia, and a few others are hermaphroditic. Copulation with a penis occurs in cephalopods and certain gastropods. Fertilization may be external or internal when there is no penis, as in pelecypods. The fertilized eggs are typically spiral cleavage and may be hatched as trochophores. In a second stage, larvae develop a ciliated *velum* of lobes for locomotion, and became a veliger larva able to swim from a few hours to several weeks, with obvious implication on the biogeographic range of the species. Also, in others, the eggs are incubated inside the body of the parent (Barnes, 1974; Hickman, 1973; Hiscock, 1972; Meglitsch, 1967; Ruppert & Barnes, 1996).

Chapter 5 RESULTS

5.1 TAXONOMICAL CLASSIFICATION

When studying faunal assemblages, including the malacological ones, the identification of each specimen must precede any sample manipulation or interpretation (Múñiz, 1988). Anatomical and taxonomical identification is firstly based on the distinctive traits of the shells, such as colour, morphology, and sculpture features. In a later phase, identification also relies on stratigraphical and biogeographical distributions. Once a skeletal part has been morphologically identified, it proceeds into a process of taxonomic classification through the analysis of its diagnostic features that allow for further identification, ideally down to the species level (Zugasti, 2008).

Malacofaunal identification is a process that cannot arrive always to an absolute answer. A level of relative uncertainty arises from the several obstacles faced due to the morphologic diversity, the close cogenetic species with quite analogous shells, and complex circumstances related to the taphonomic processes and the preservation condition of the material that affect every sample, as expanded upon in previous chapters of this work. (e.g. Coelho & Cardoso, 2011; Múñiz, 1988; Somerville et al., 2017).

For the most assertive identification as possible, and to minimize the level of uncertainty associated to each specimen, a maximum control over determining variables is required. Thus, the usage of reliable reference collections, with both modern and archaeological specimens is deemed indispensable. Neither textbooks nor practice cannot compensate the absence of adequate comparative collections. (García, 2008; Harris et al., 2015; Múñiz, 1988; Somerville et al., 2017). These can be found in university departments, museums and similar institutions, and archaeological companies. Alternatively, one can take on the task of building their own reference collection.

Unfortunately, it was not possible to consult many reference collections during this research work, in part because of the pandemic status of most 2020 that delayed programmed visits to institutions and laboratories. Nevertheless, the identification of most specimens was personally validated by a researcher from the University of Coimbra with knowledge of the seashore and land mollusc faunas of mainland Portugal.

Therefore, for the purposes of taxonomic classification and systematic arrangement of the taxa, several monographs and field-guides on Atlantic European and Mediterranean faunas were consulted, including those of Allen (1856-58), Ardovini and Cossignani (2000), Bouchet et al. (2005), Cossignani and Ardovini (2011), Holoyoak et al. (2019), Huber (2014), as complete reference works. The WoRMS database was also extensively used as an updated resource, including for the actualization and present range of each genus.

For the purposes of identification of the bivalve specimens, aspects related to the general shape of the valve, umbo, hinge, muscles scars, paleal line, shape of the margins, thickness, paleal line, symmetry, and external, internal and marginal sculptures were taken in account.

In order to identify the specimens, the respective diagnoses were used to support the observation of plates. The following works and databases were also consulted: Abbott (1954); Abbott and Dance (1986); Ardovini and Cossignani (2000); Bruyne (2004/2006); Cossignani and Ardovini (2011); Dance (1974); FAO (2016); Huber (2014); Macedo et al. (1999); MarLIN (2006); MolluscaBase-eds. (2020); Nobre (1913, 1930, 1931, 1933, 1941); Oliver (1975); Poppe and Goto (1991, 1993); Pyron and Brown (2015); Rolan Mosquera (1983, 1989); Saldanha (1995); Tunnell et al. (2010); Valente (2010); Venkatesan (2010); and WoRMS (2020).

Despite the very fragmented state of the skeletal parts represented in the collection, it was possible to identify almost all specimens down to the species level; even so, there were several specimens in which it was not possible to reach so deep in classification and were let in open nomenclature (for example: *Glycymeris* sp., *Vermetus* sp., and *Callista* sp.). Fortunately, the percentage of specimens identified only to their genus was minimal, with no specimen being included in the indeterminate category.

5.2 TAXONOMIC CHECKLIST

In the studied collection, a minimal number of 4089 specimens belonging to 45 species of molluscs have been identified, of which 25 of bivalves and 18 of gastropods, in addition a crustacean decapod and barnacles. The species found are represented in Plates I to XV. The taxonomic checklist is as follows:

Phylum Mollusca

Class Bivalvia Linnaeus, 1758

Subclass Pteriomorpha Beurlen, 1944

Order Arcida Stolikzca, 1871

- Superfamily Arcoidea Lamarck, 1809
- Family Glycymerididae Dall, 1908
  - Genus *Glycymeris* da Costa, 1778
    - *Glycymeris glycymeris* (Linnaeus, 1758)
    - *Glycymeris nummaria* (Linnaeus, 1758)

Order Mytilida Férussac, 1822

- Superfamily Mytiloidea Rafinesque, 1815
- Family Mytilidae Rafinesque, 1815
- Subfamily Mytilinae Rafinesque, 1815
  - Genus *Mytilus* Linnaeus, 1758
    - *Mytilus edulis* Linnaeus, 1758
    - *Mytilus galloprovincialis* Lamarck, 1819
  - Genus *Perna* Philipsson, 1788
    - *Perna perna* (Linnaeus, 1758)

Order Ostreida Férussac, 1822

- Superfamily Ostreoidea Rafinesque, 1815
- Family Ostreidae Rafinesque, 1815
- Subfamily Crassostreinae Scarlato & Starobogatov, 1979
  - Genus *Crassostrea* Sacco, 1897
    - *Crassostrea gigas* (Thunberg, 1793)
- Subfamily Ostreinae Rafinesque, 1815
  - Genus *Ostrea* Linnaeus, 1758
    - *Ostrea edulis* (Linnaeus 1758)

Order Pectinida Gray, 1854

- Superfamily Anomioidea Rafinesque, 1815
- Family Anomiidae Rafinesque, 1815

Genus *Anomia* Linnaeus, 1758

Anomia ephippium (Linnaeus, 1758)

Superfamily Pectinoidea Rafinesque, 1815

Family Pectinidae Rafinesque, 1815

Subfamily Pectininae Rafinesque, 1815

Genus *Pecten* O. F. Müller, 1776

Pecten maximus (Linnaeus, 1758)

Subfamily Pedinae Bronn, 1862

Tribe Mimachlamydini T. Waller, 1993

Genus *Mimachlamys* Iredale, 1929

Mimachlamys varia (Linnaeus, 1758)

Subclass Heterodonta Neumayr, 1884

Infraraclass Euheterodonta

Order Adapedonta

Superfamily Solenoidea Lamarck, 1809

Family Solenidae Lamarck, 1809

Genus *Solen* Linnaeus, 1758

Solen marginatus (Pulteney, 1799)

Order Cardiida Férussac, 1822

Superfamily Cardioidea Lamarck, 1802

Family Cardiidae Lamarck, 1809

Subfamily Lymnocardiinae Stoliczka, 1870

Genus *Acanthocardia* Gray, 1851

Acanthocardia tuberculata (Linnaeus, 1758)

Genus *Laevicardium* (Swainson, 1840)

Laevicardium crassum (Gmelin, 1791)

Genus Cerastoderma Poli, 1795

Cerastoderma edule (Linnaeus, 1758)

Superfamily Tellinoidea Blainville, 1814

Family Donacidae J. Fleming, 1828

        Genus *Donax* Linnaeus, 1758
            Donax trunculus Linnaeus, 1758

    Family Tellinidae Blainville, 1814
    Subfamily Gastraninae M. Huber, Langleit & Kreipl, 2015
        Genus *Gastrana* Schumacher, 1817
            Gastrana fragilis (Linnaeus, 1758)

Order Venerida Gray, 1854
    Superfamily Mactroidea Lamarck, 1809
    Family Mactridae Lamarck, 1809
    Subfamily Lutrariinae Gray, 1853
        Genus *Eastonia* Gray, 1853
            Eastonia rugosa (Helbling, 1779)
        Genus *Lutraria* Lamarck, 1799
            Lutraria lutraria (Linnaeus, 1758)

    Superfamily Veneroidea Rafinesque, 1815
    Family Veneridae Rafinesque, 1815
    Subfamily Venerinae Rafinesque, 1815
        Genus *Callista* Poli, 1791
            Callista chione (Linnaeus, 1758)
        Genus *Chamelea* Mörch, 1853
            Chamelea gallina (Linnaeus, 1758)
            Chamelea striatula (da Costa, 1778)
        Genus *Dosinia* Scopoli, 1777
            Dosinia exoleta (Linnaeus, 1758)
        Genus *Ruditapes* Chiamenti, 1900
            Ruditapes decussatus (Linnaeus, 1758)
        Genus *Venerupis* Lamarck, 1818
            Venerupis corrugata (Gmelin, 1791)
        Genus *Venus* Linnaeus, 1758
            Venus verrucosa Linnaeus, 1758

Class Gastropoda Cuvier, 1795

Subclass Caenogastropoda

- Order Littorinimorpha
    - Superfamily Cypraeoidea Rafinesque, 1815
    - Family Cypraeidae Rafinesque, 1815
    - Subfamily Pustulariinae, Gill, 1871
        - Genus *Zonaria* (Jousseaume, 1884)
            - *Zonaria purum* (Gmelin, 1791)

    - Superfamily Vermetoidea Rafinesque, 1815
    - Family Vermetidae Rafinesque, 1815
        - Genus *Vermetus* Daudin, 1800
            - *Vermetus triquetrus* (Bivona-Bernardi, 1832)

    - Superfamily Tonnoidea Suter, 1913 (1825)
    - Family Charoniidae Powell, 1933
        - Genus *Charonia* Gistel, 1847
            - *Charonia lampas* (Linnaeus, 1758)

- Order Neogastropoda Wenz, 1938
    - Superfamily Buccinoidea Rafinesque, 1815
    - Family Nassariidae Iredale, 1916 (1835)
    - Subfamily Nassariinae Iredale, 1916 (1835)
        - Genus *Tritia* Risso, 1826
            - *Tritia nitida* (Jeffreys, 1867)
            - *Tritia reticulata* (Linnaeus, 1758)

    - Superfamily Muricoidea Rafinesque, 1815
    - Family Muricidae Rafinesque, 1815
    - Subfamily Muricinae Rafinesque, 1815
        - Genus *Bolinus* Pusch, 1837
            - *Bolinus brandaris* (Linnaeus, 1758)
        - Genus *Hexaplex* Perry, 1810
            - *Hexaplex trunculus* (Linnaeus, 1758)

Subfamily Rapaninae Gray, 1853

Genus *Stramonita* Schumacher, 1817

Stramonita haemastoma (Linnaeus, 1767)

Superfamily Volutoidea Rafinesque, 1815

Family Volutidae Rafinesque, 1815

Subfamily Cymbiinae H. Adams & A. Adams, 1853 (1847)

Tribe Cymbiini H. Adams & A. Adams, 1853 (1847)

Genus *Cymbium* Röding, 1798

Cymbium olla (Linnaeus, 1758)

Order [unassigned] Caenogastropoda

Superfamily Cerithioidea J. Fleming, 1822

Family Cerithiidae J. Fleming, 1822

Subfamily Cerithiinae J. Fleming, 1822

Genus *Cerithium* Bruguière, 1789

Cerithium vulgatum Bruguière, 1792

Superorder Siphonarimorpha

Family Siphonariidae Gray, 1827

Genus *Siphonaria* G. B. Sowerby I, 1823

Siphonaria pectinata (Linnaeus, 1758)

Subclass Patellogastropoda

Superfamily Patelloidea Rafinesque, 1815

Family Patellidae Rafinesque, 1815

Genus *Patella* Linnaeus, 1758

Patella depressa Pennant, 1777

Subclass Vetigastropoda

Order Trochida

Superfamily Trochoidea Rafinesque, 1815

Family Trochidae Rafinesque, 1815

Subfamily Cantharidinae Gray, 1857

Genus *Phorcus* Risso, 1826

Phorcus edulis (Lowe, 1842)

Phorcus lineatus (da Costa, 1778)

Family Turbinidae Rafinesque, 1815

Subfamily Turbininae Rafinesque, 1815

Genus *Bolma* Risso, 1826

Bolma rugosa (Linnaeus, 1767)

Subclass Orthogastropoda

Order Pulmonata

Superfamily Achatinoidea Swainson, 1840

Family Subulinidae P. Fischer & Crosse, 1877

Subfamily Ruminidae Wenz, 1923

Genus *Rumina* Risso, 1826

Rumina decollata (Linnaeus, 1758)

Superfamily Helicoidea Rafinesque, 1815

Family Helicidae Rafinesque, 1815

Subfamily Helicinae Rafinesque, 1815

Genus *Otala* Schumacher, 1817

Otala lactea (O. F. Müller, 1774)

Genus *Theba* Risso, 1826

Theba pisana (O. F. Müller, 177)

SubPhylum Crustacea

Superclass Multicrustacea

Class Malacostraca

Subclass Eumalacostraca

Order Decapoda Latreille, 1802

Suborder Pleocyemata Burkenroad, 1963

Section Eubrachyura Saint Laurent, 1980

Superfamily Eriphioidea MacLeay, 1838

Family Eriphiidae MacLeay, 1838

Genus *Eriphia* Latreille, 1817

Eriphia verrucosa (Forskål, 1775)

Class Thecostraca Gruvel, 1905

Subclass Cirripedia Burmeister, 1834

Superorder Thoracicacalcarea Gale, 2015

Order Balanomorpha Pilsbry, 1916

Superfamily Balanoidea Leach, 1817

Family Balanidae Leach, 1817

Subfamily Concavinae

Genus *Perforatus* Pitombo, 2004

Perforatus perforatus (Bruguière, 1789)

5.3 QUANTITATIVE ANALYSIS

Quantification is fundamental to Archaeozoology and malacological analyses. Several different techniques are commonly used in order to ensure data quality, comparability, and repeatability. These vary in suitability depending on the particular assemblage and research questions. Mollusc shell quantification is generally based on the weight and/or count. These variables are established through the numerical quantification of shell assemblages, weight, and the determination of the Number of Identified Specimens Present per taxon (NISP) and the Minimum Number of Individuals (MNI) and weight (Harris et al., 2015; Szabó, 2017).

The concept of MNI was introduced into Archaeology from Palaeontology by Theodore E. White in the 1950s. This analytical process is important for zooarchaeological studies, since the faunal remains are often found fragmented or partial and, in this way, we can approach the number of individuals present in that context; for that, it is required to account for all identified specimens (Giovas, 2009; Somerville et al., 2017).

NISP counts can provide a valuable index of fragmentation, by counting all recognizable specimens, both complete and fragmentary, in a certain taxonomic category. However, this value can be easily inflated due to fragmentation. Furthermore, it does not count or estimate the number of original whole entities, such as invertebrates that are represented in a sample or that integrated the original population or biocenosis (Banning, 2002; HNZPT, 2014; Szabó, 2017).

The quantification of molluscs from the bulk sample is usually based on certain kind of remains, generally whole or semi-whole skeletal parts. Therefore, shells are grouped into categories, according to their state of preservation:

a) **Complete shells** (COMV), as those that illustrate 90% or more of the original shell and individual diagnostic element, known as Non-Repetitive Elements (NRE). This means the part of a shell that is diagnostic for each species or genus, which can be counted several times to infer the presence of an individual, such as the apex, columella, and aperture of gastropods or the hinge (with teeth) or the umbo, to be differentiated right from left in bivalves. Counts are performed only in case of the occurrence of a unique element, whether they be a spire, aperture, hinge, or other distinctive feature. In the case of bivalves, left and right valves are counted separately, with the higher number taken to represent the MNI. On complete shells, biometric measurements are also performed, including length, width, and height, but these measurements were not, however, applied in this dissertation, thus, will not approach this matter;

b) **Diagnostic shell fragments** (FRAV) correspond to those that preserve less than 90% of the shell but that still contain an NRE. Gastropod fragments were assigned to one of two categories: FRAI - fragments with intact columella ends but lacking the buccal area. FRAI contains the apex and part of the shell; and APIF are fragments that include apex or portions of it. On bivalves, identifiable fragments were subdivided into FRAV and FCH;

c) **Fragments** (FTS) are shell pieces lacking diagnostic elements. These do not contribute to abundance measures, including NISP and MNI (Giovas, 2009; Hammond, 2014; HNZPT, 2014; Somerville et al., 2017; Zuschin et al., 2003).

In the case of the fragmentation categories, the MNI is calculated according to the following formulae:

For bivalves: COMV + FCH + FRAV [AHF or PHF (taking the highest value)]. Right and left valves counted separately, MNI being the greater of the two totals.

For gastropods: COMIV + FRAI + [APIF or (STOF + UMB), whichever is superior]; (García, 2008; García et al., 2010; Hammond, 2014; Zuschin et al., 2003).

The use of fragmentation categories based on several anatomical components to calculate the MNI and NISP produces more accurate results than traditional elements – apices and umbos. Fragmentation categories are therefore used for the quantification of malacological material, and to measurement of its degree of fragmentation. These provide a greater degree of reliability to the results and their interpretation with regard to subsistence strategies and taphonomic processes affecting a site (Zugasti, 2011).

The quantitative analysis of the studied malacological assemblage has resulted in a total of 12,605 skeletal remains. These were separated by species, and their respective absolute and relative frequencies determined by the archaeological grid and totals. The MNI calculation, following the formulae mentioned above, identified a total of 4089 individuals belonging to 45 species from the Classes Bivalvia and Gastropoda and the SubPhylum Crustacea.

Decapods and cirriped crustaceans, were revealed to be minor presences in this assemblage, with just two species identified: *Perforatus perforatus* - all the specimens were complete - and *Eriphia verrucosa* - with only two clamp halves founded.

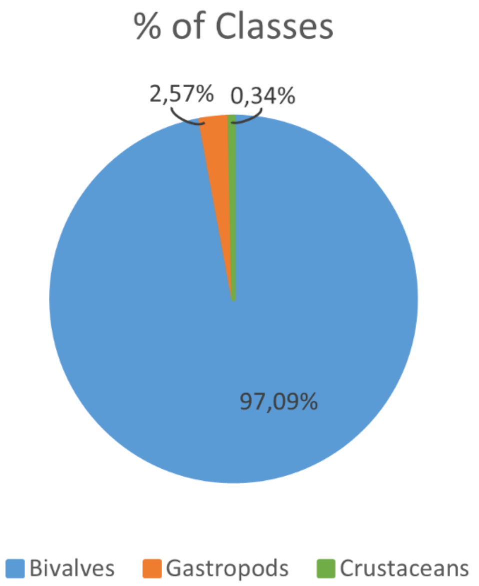


Figure 31: Relative abundance in the percentage of the present groups, with 97.09% of bivalves, 2.57% of gastropods and only 0.34% of crustaceans.

The numerically dominant species correspond to edible bivalve molluscs (25 species = 97.09%; Fig. 31). Five predominant species were observed: venus clams (*Ruditapes decussatus* – 38.15%, 1560 MNI), oysters (*Ostrea edulis* – 26.44%, 1081 MNI), cockles (*Cerastoderma edule* 25.90%, 1059 MNI), mussels (*Mytilus galloprovincialis* – 2.15%, 88 MNI) and other clam species *(Solen marginatus* – 1.05%, 43 MNI; Fig. 32). When compared to the aforementioned, all other recorded species appear residually in the fauna bulk sample under study, with relative frequencies under 1%.

Gastropods species belonging to terrestrial (3 species = 0.49%), and marine and brackish water (15 species = 2.08%) environments were found. There are also some infrequent crustacean species (2 species = 0.34%; Fig. 31).

Considering the taphonomic context of the deposit, it can be inferred that only 0.49% of the assemblage is autochthonous, represented by the terrestrial gastropods *Rumina decollata, Otala lactea* and *Theba pisana*, which are common natural inhabitants of the area. The remaining majority of the skeletal remains should result from intentional or accidental transport of marine invertebrates from the Arade estuary and nearby seashore, or even from more distant areas such as the Ria Formosa lagoonal system or the Vicentine coast near the Medina, being related to shellfish and fishing activities, and food consumption.

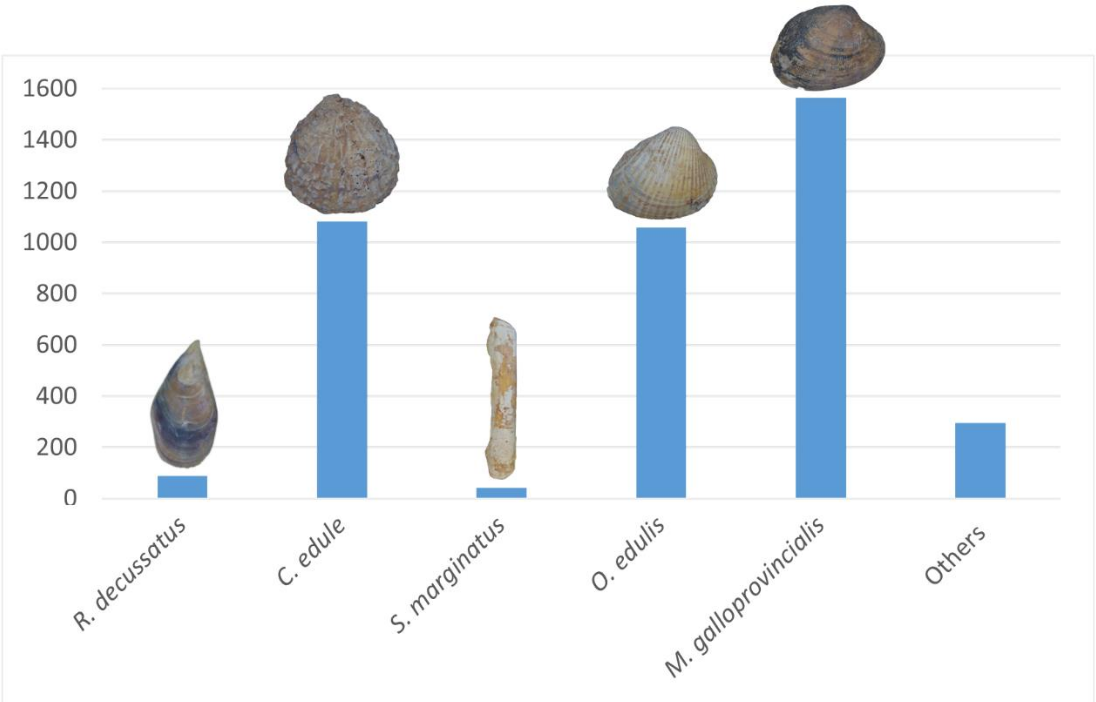


Figure 32: MNI of the most abundant species, all of them edible bivalves.

There is a notably greater affluence of three species: (*O. edulis, C. edule* and *R. decussatus*). These exhibit a similar abundancy throughout all the layers, greater that all others found in the bulk-sample. This is observed through their presence in nearly every grid and layer of the collection. A single notable exception is grid 1200 layer 2, containing only a single complete left valve from the species *Ostrea edulis* (Fig. 33).

As for the remaining species, some also exhibit a relatively constant presence in the layers, albeit with a very small frequency, such as mussels, razors, clams of the genus *Glycymeris* and *Venus*, scallops, *Vermetus* sp. encrusted in oyster shells, and a few land and freshwater snails.

Both figures 34 and 35 show a quantitative analysis of this assemblage, considering the absolute frequencies and relative abundances of all identified bivalves and gastropods species.

In all layers, with the exception of 1127-1B, 1128-1B, 1200-2, 1202-1B and 1219-2, there is a species much more abundant then all other. This is usually of the venus clams *R. decussatus*, with an overwhelming predominance in layers 537/538 and -1, 1217-1B and 2, and 1218. Oysters are more noticeably dominant in layers 1075-1B and 2, 1127-2 and 1202-2. Cockle *Cerastoderma edule* are the most frequent in layers 537/538-5 and 1128-2, albeit less visibly.

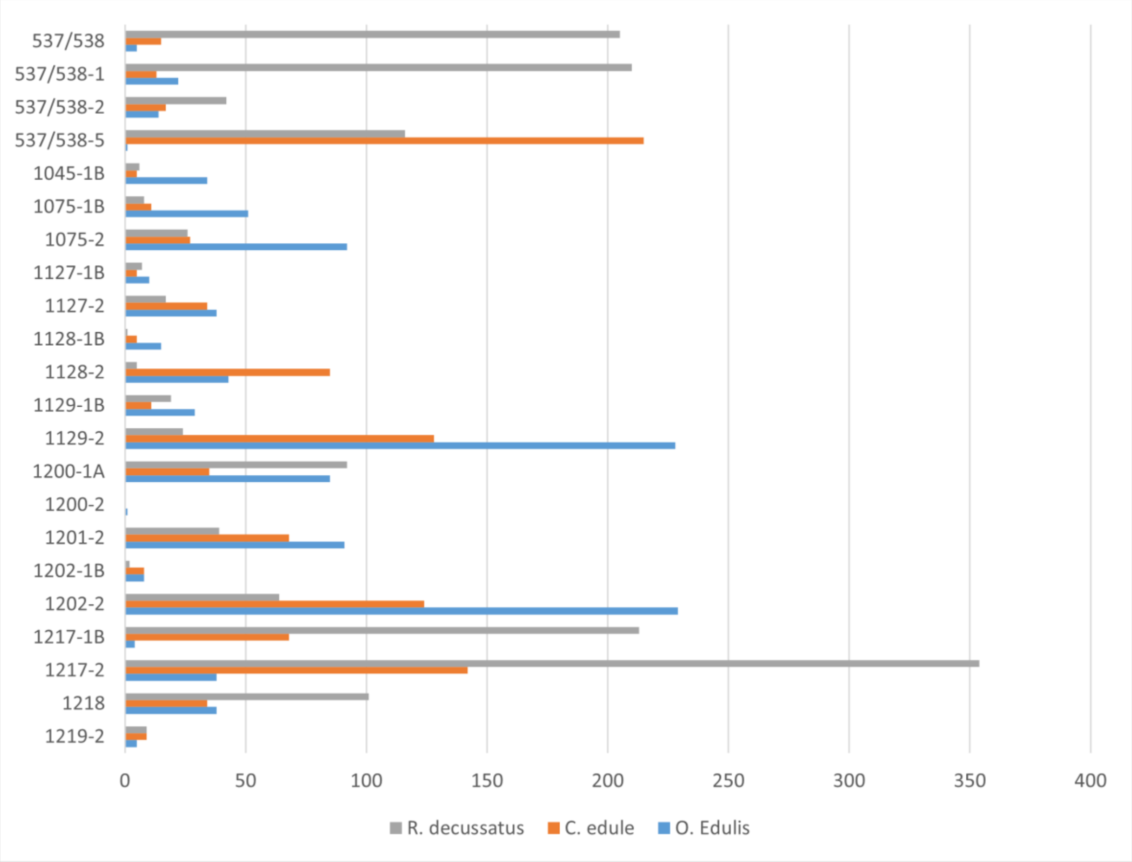


Figure 33: Relative abundance of the MNI of the species *Ostrea edulis* with 1081 NMI*, Cerastoderma edule* with 1059 MNI, and *Ruditapes decussatus* with 1560 NMI over the sampled layers.

The discrepancy between cockle and oyster species is not very large when accounting the totality of all layers, in the order of two dozen. This number is surpassed by the clams by about 500 more specimens, being able to point this species as the most appreciated by the local Islamic community. It should be pointed that these results also assume the regular and uninterrupted supply of fresh seafood from the estuary of the Arade river or other distant lagoonal areas, to the Medina.

The variation between the most abundant species in different layers may be related to variations in marine resources over time. Nevertheless, it is possible to state with all certainty that these three represented the main shellfish species consumed in the *Xelb* during the period in question.

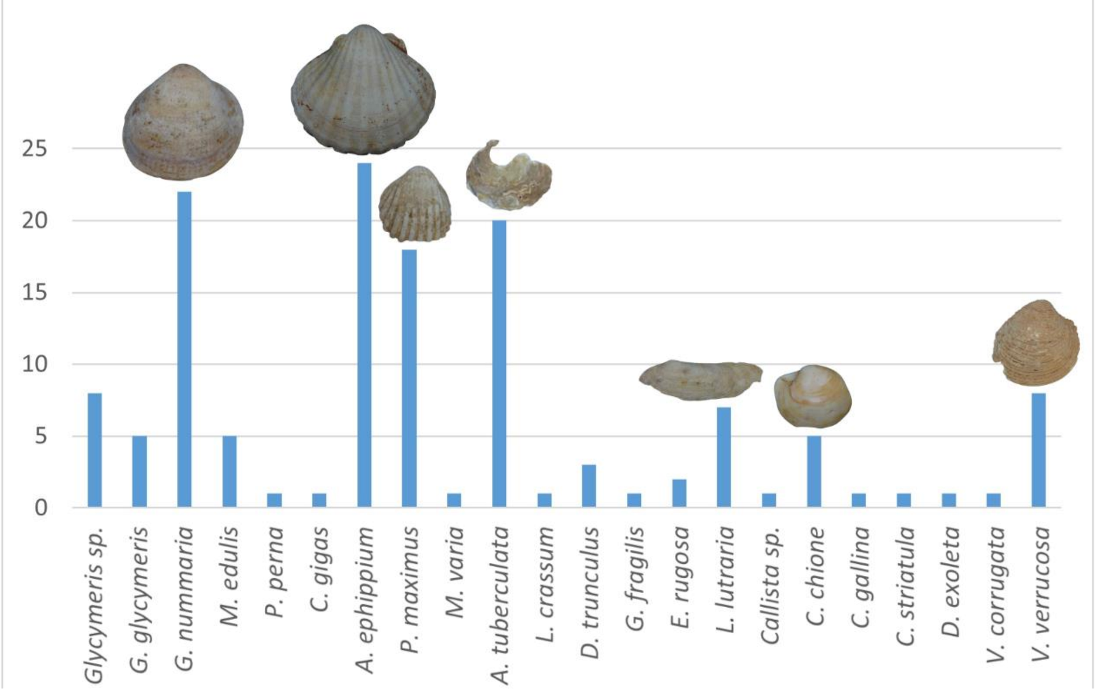


Figure 34: MNI of the bivalve species, excluding *Mytilus galloprovincialis, Ostrea edulis, Solen marginatus, Cerastoderma edule*, and *Ruditapes decussatus.*

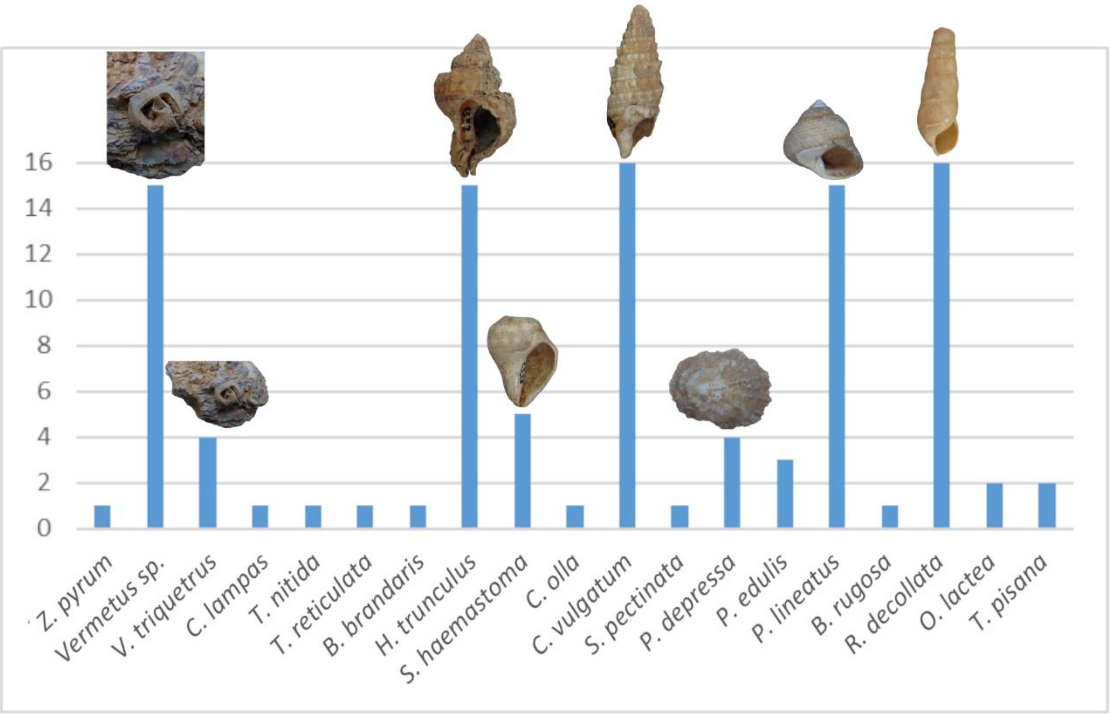


Figure 35: MNI of the overall gastropod species.

These molluscs are eurytopic forms (*i.e.,* species with a wide distribution of environments and tolerant to different environmental factors) present in estuarine and lagoonal environments with wide varieties of salinity and turbidity. In present times, these species are common in the estuary of the Arade river and in the Ria Formosa, where they are still being caught by local fishermen as a traditional shellfish activity that persists for centuries, almost as the same way of those fishermen that supplied the Medina (Gonçalves et al., 2007).

5.4 GENERAL TAPHONOMICAL ASPECTS

As mentioned in the Chapter 3, an inventory of specimens with evidence of marine abrasion was elaborated. This study is considered determinant for the investigation of malacological remains with evidence of *ante* or *post-mortem* acquisition.

In the analysis of a zooarchaeological collection with shells and other invertebrate remains, several indicators may suggest and substantiate anthropic intervention. Thus, it was considered important to differentiate between *ante* or *post-mortem* acquisitions, based on material evidence. This includes the context of provenance, eventual transformations, and the presence of traces of use. An attempt to understand the functionality attributed to the shells was performed through the exhaustive description of each identified case.

An importance was given to a fouling and bioerosive colonization analysis. This implied the identification of colonizing organisms, corresponding degree of intensity, and respective location of these occupations. Such factors are conclusive in gauging colonizer acquisition in molluscs and shellfish hard parts. The localization and intensity of these occupations has distinct patterns that depend on shell characteristics (Claassen, 1998), colonizing organism requirements (Santos & Mayoral, 2008), moment of occurrence, and considerations regarding the shell position, and degree of exposure of its surface (*op. cit.*).

A considerable incnodiversity of bioerosive structures was observed in this collection, more frequently in certain species. Algae, fungi, sponges, and certain gastropods may have been important agents of biostratinomic processes in this environment.

The genus *Ostrea* appears as the group with the highest percentage of erosion remains, followed by the genus *Glycymeris*. The other species, this process is more residual, without viable statistical translation. On the contrary, in other species, the absence of cases or the reduced percentages translate the reduced number of eroded marine remains. The collection of the genus *Ostrea* presents the highest traces of bioerosion. During the analysing remains for evidence of bioerosive occupation (performed an accounting in relation to the NISP), 844 out of 3108 accounted remains contained bioerosive traces (27.16%). It should be noted however that there are very few cases that explicitly reveal a *post-mortem* bioerosion.

In bivalves, they are mostly summarized in skeletal parts belonging to genera *Glycymeris, Ostrea, Mytilus, Ruditapes* and *Callista.* It should be noted that the latter of these corresponds to a residual value of the total analysed remains and does not constitute a representative number of evidences of bioerosive occupation. However, cases of are greatly reduced. Similarly, in gastropods, of *Stramonita haemastoma* and *Hexaplex trunculus* specimens present occasional cases of bioerosion.

The analysis of the 4089 NISP points to a generally residual number of changes due to incrustation and/or perforating action. The highest incidence of these was observed in specimens of *Ostrea edulis*. These presented a generalized bioencrustation, with a great presence of serpulid tubes, bryozoans, and juvenile oysters (Fig. 36).

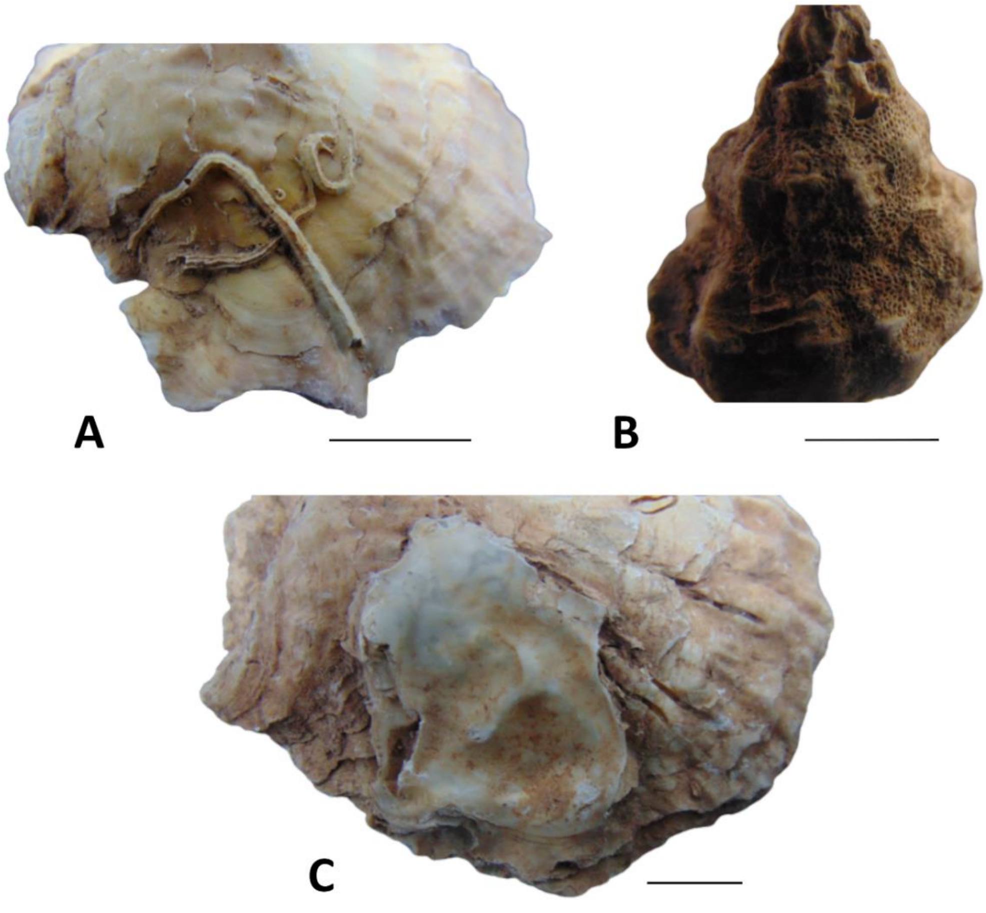


Figure 36: Examples of epizoans incrustation by serpulid worm tubes in A, bryozoans in B, and juvenile oysters in C. The valves in A and C are both of *Ostrea edulis*, collected on the layer 1201-2, the gastropod in B Is from the species *Hexaplex trunculus* collected on the layers 1202-2. Scales of 1 cm.

There was also a considerable presence of Spirorbinae tubes, *Anomia ephippium* foot, and *Vermetus* sp. (Fig. 37).

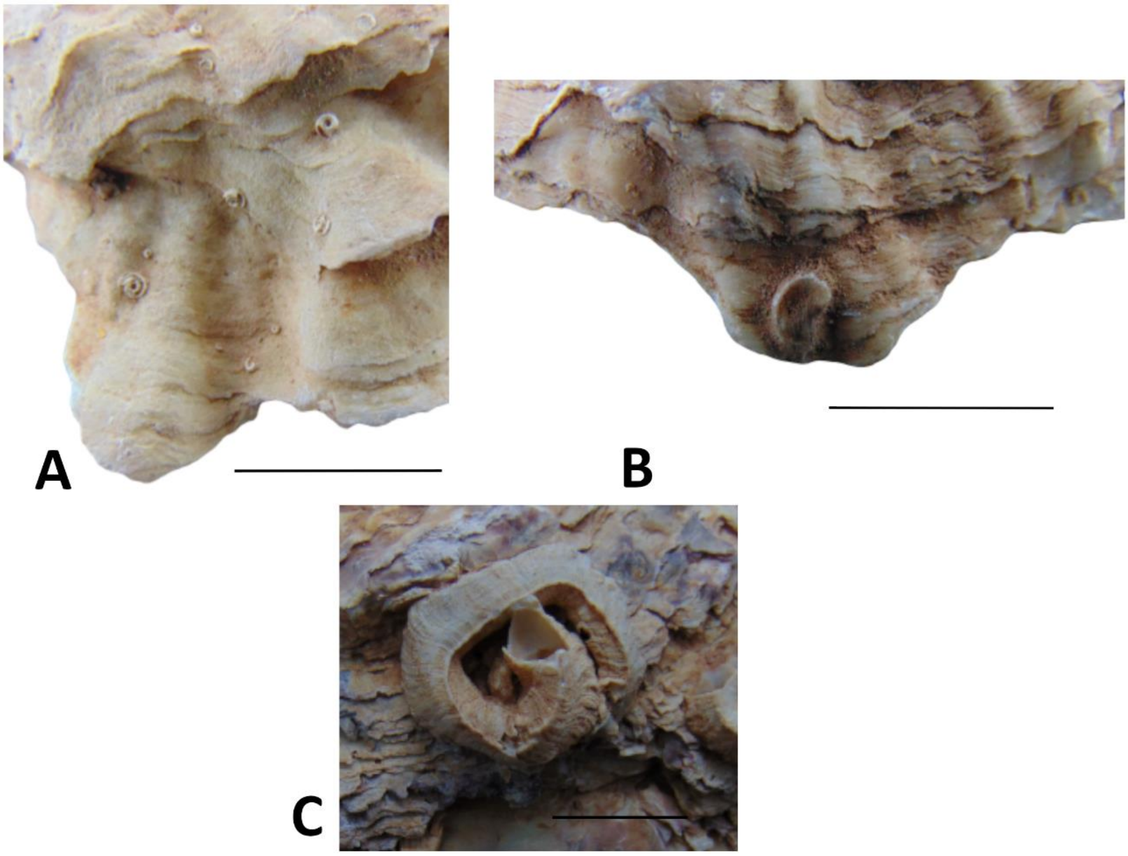


Figure 37: Examples of incrustation in *Ostrea edulis* valves by Spirorbinae tubes in A, *Anomia ephippium* foot in B, and *Vermetus* sp. in C. The A and B belong to the layer 1201-2, and C 1218. Scales of 1 cm.

Less often appears the balanids and the Maeandropolydora isp. (Fig. 38).

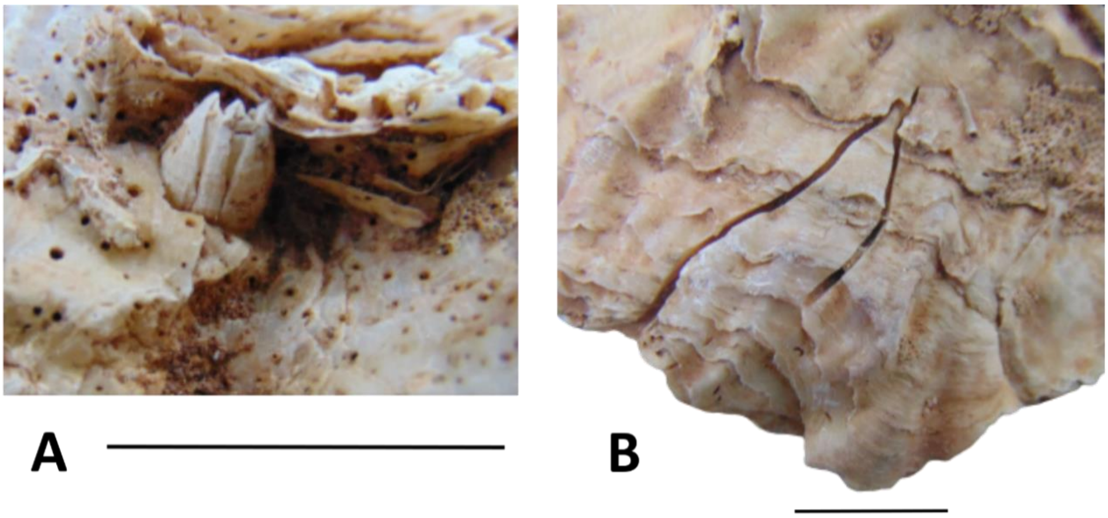


Figure 38: Examples of incrustation in *Ostrea edulis* valves by balanids in A from the layer 537/537-2, and *Maeandropolydora* isp. in B from the layers 1201-2. Scales of 1 cm.

As more of a residual presence, the *Entobia* sp. formed by encrusting sponges (Fig.39 A and B) and predatory drill holes made by Oichnus isp. (Fig. 39 C and D).

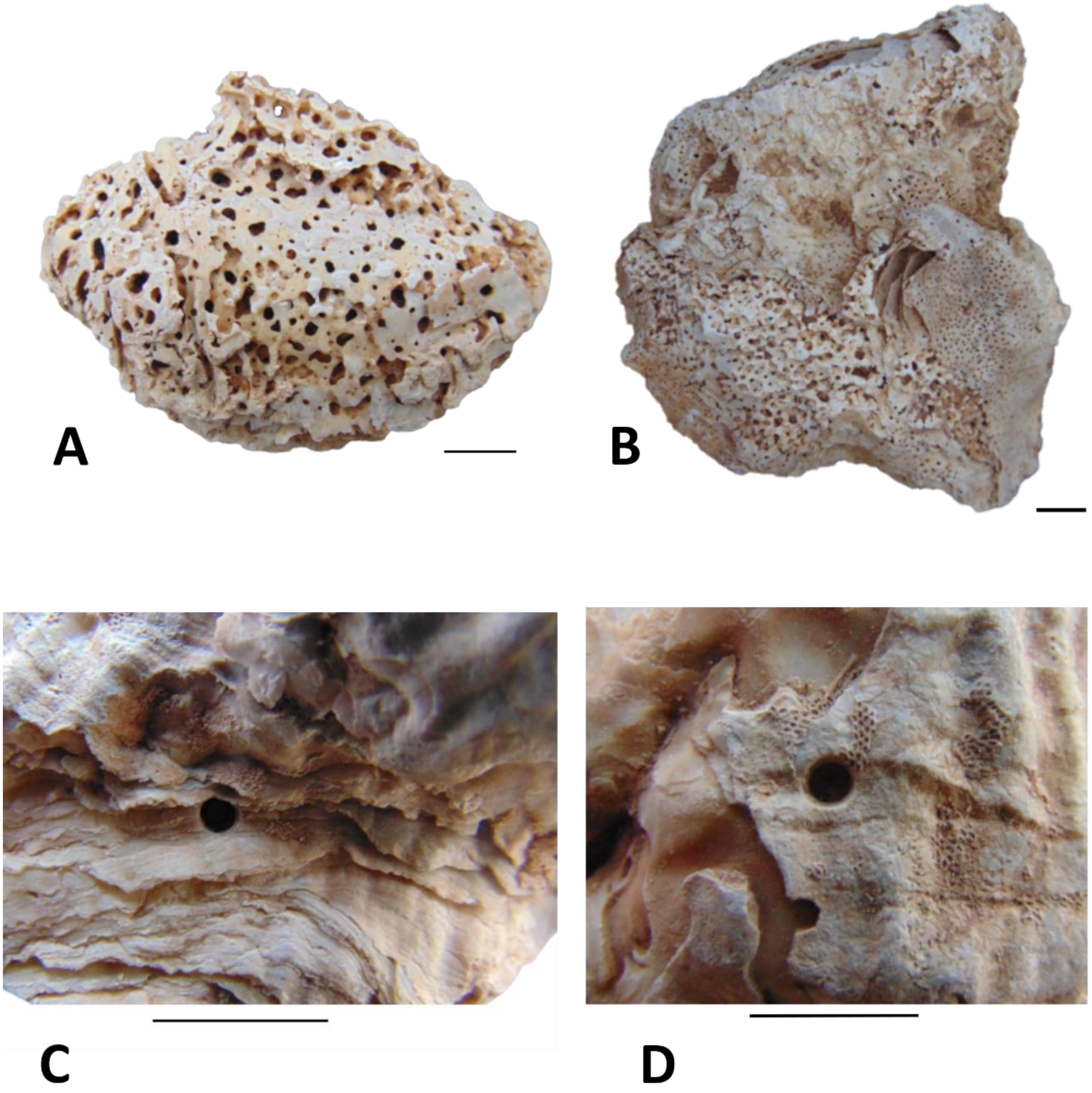


Figure 39*:* Examples of incrustation in *Ostrea edulis* valves by *Entobia* sp. in A from the layer 1201-2 and B from the layer 537/537-2, and *Oichnus* isp. drill holes in C and D from layers 1201-2. Scales of 1 cm.

It is also registered, but only in ostreids, the case of several dead shells cemented by these individuals (Fig. 40), acting as a larval fixation base. As interesting examples, several valves of the species *Anomia ephippium* (1), *Solen marginatus* (1), *Cerastoderma edule* (6), *Gastrana fragilis* (1), *Dosinia exoleta* (1)*, Ruditapes decussatus* (4)*, Venerupis corrugata* (1), *Venus verrucosa* (3), *Cerithium vulgatum* (5) and *Tritia reticulata* (1) have been recorded. Moreover, the occurrence of the bivalves *G. fragilis, V. corrugata* and the gastropods *T. reticulata* in this collection was only registered as elements cemented by *Ostrea edulis* shells.

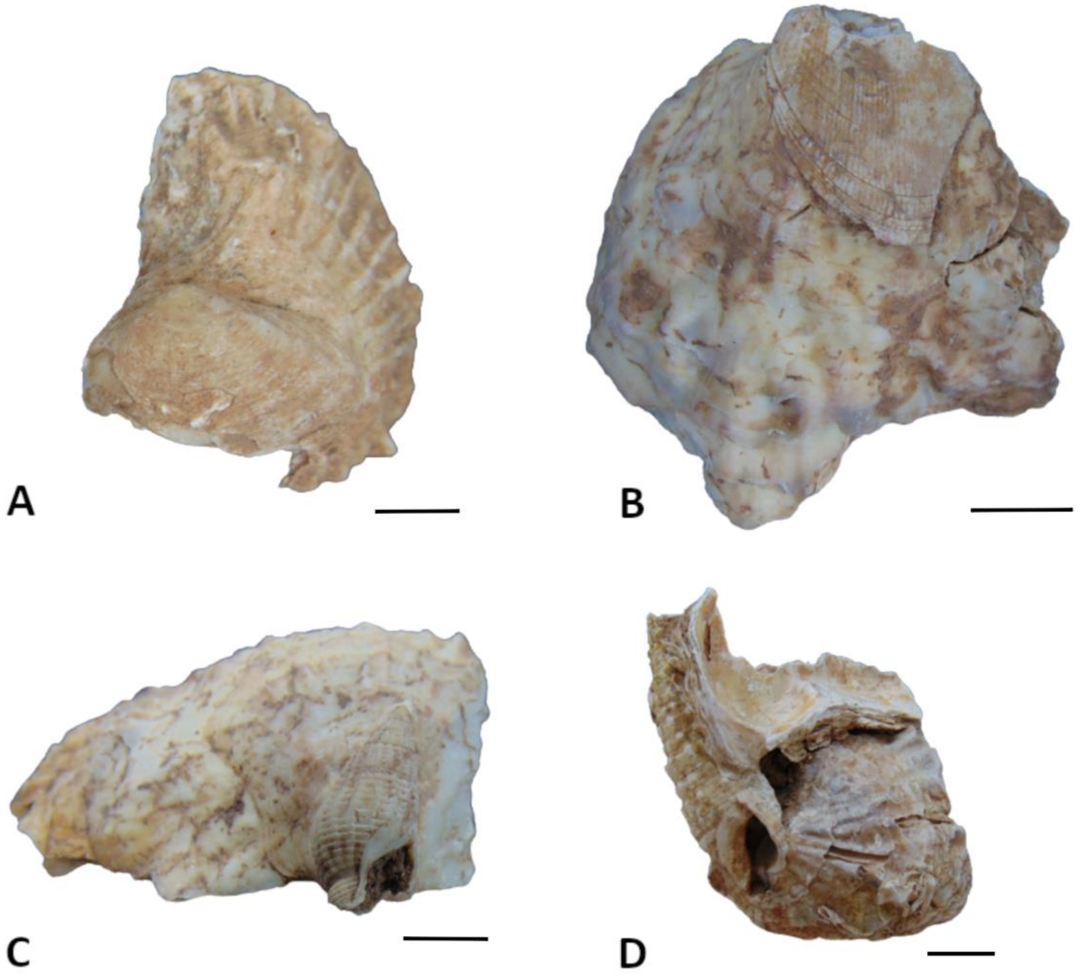


Figure 40: Examples of cemented shells. In A, the specie *Gastrana fragilis* from the layer 1200-2. In B, *Venerupis corrugata* from the layer 1075-2. In C, *Tritia reticulata* from the layer1202-2. In D, *Cerithium vulgatum* from the layer 537/538-5. Scales of 1 cm.

The macro-remains from the genus *Glycymeris* also record bioerosion and bioencrustation features, many of them *post-mortem* (Fig. 41). This is inferred from the observation of internal and external surfaces of the valves, where these skeletal parts also commonly show a high level of abrasion (54.8% of the valves and fragments). This value is justified by anthropic valve applications that occur after consumption. This genus, due to their relatively large size, robustness, and heavy valves, were commonly used as fishing weights in past centuries. In this collection, valves with perforations, traces of abrasion, loss of natural colours, and umbilical abrasion facets that were used for fixing cables are frequent are quite frequent (Gonçalves et al., 2007). Hence their identification down to the species level sometimes is not possible, in this case, 25% of the remains.

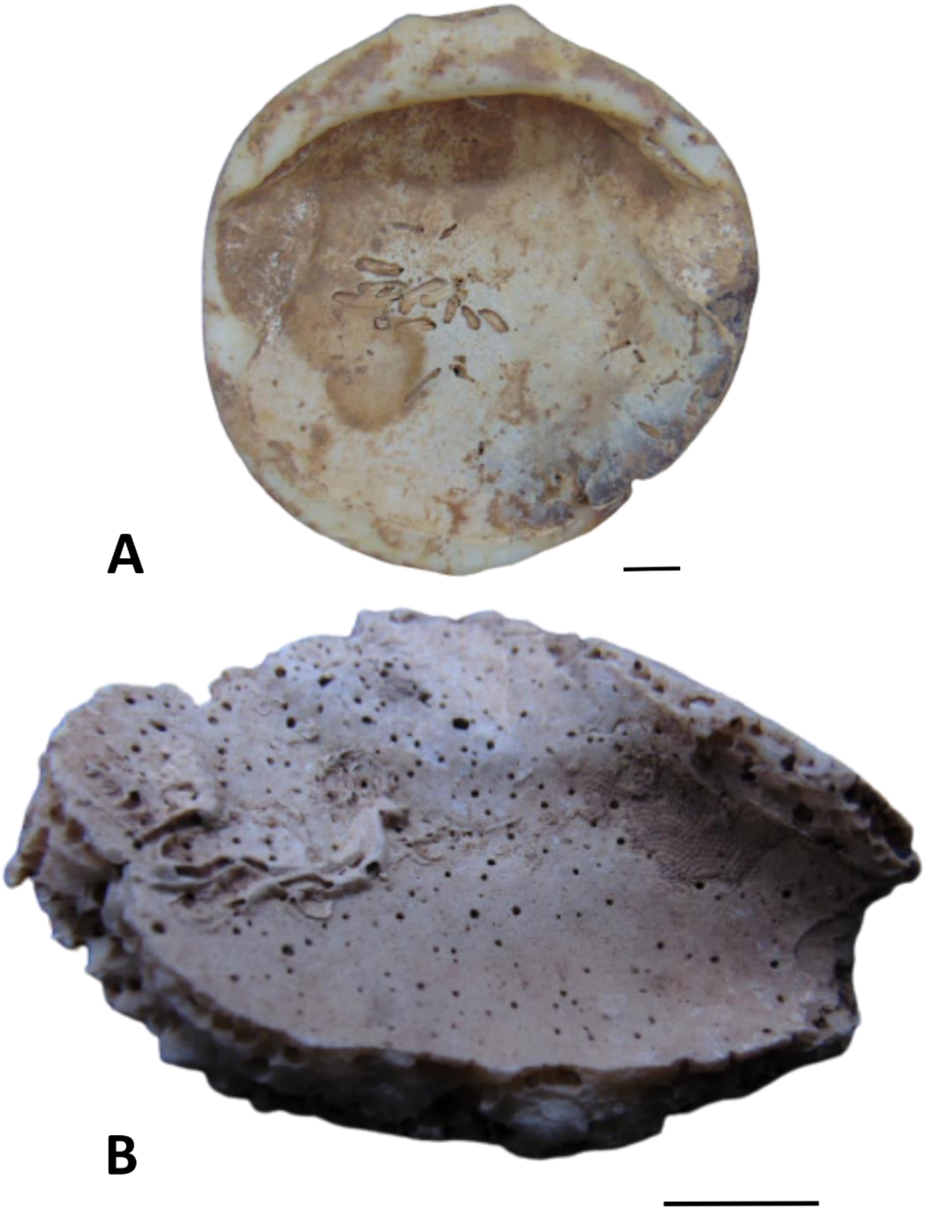


Figure 41: Bioerosion and bioencrustation in internal surface on *Glycymeris sp.* valves. In A, bioerosion by *Maeandropolydora* isp., from the layer 1201-2. In B, bioerosion by bryozoans and serpulid tubes, and bioencrustation by *Entobia* sp., from the layer 1129-2. Scale of 1 cm.

The delicate bivalve, gastropod, and crustacean structures have a generally remarkable preservation quality, with the presence of protoconch and spines in gastropods and growth lines in bivalves being frequent (Fig. 42).

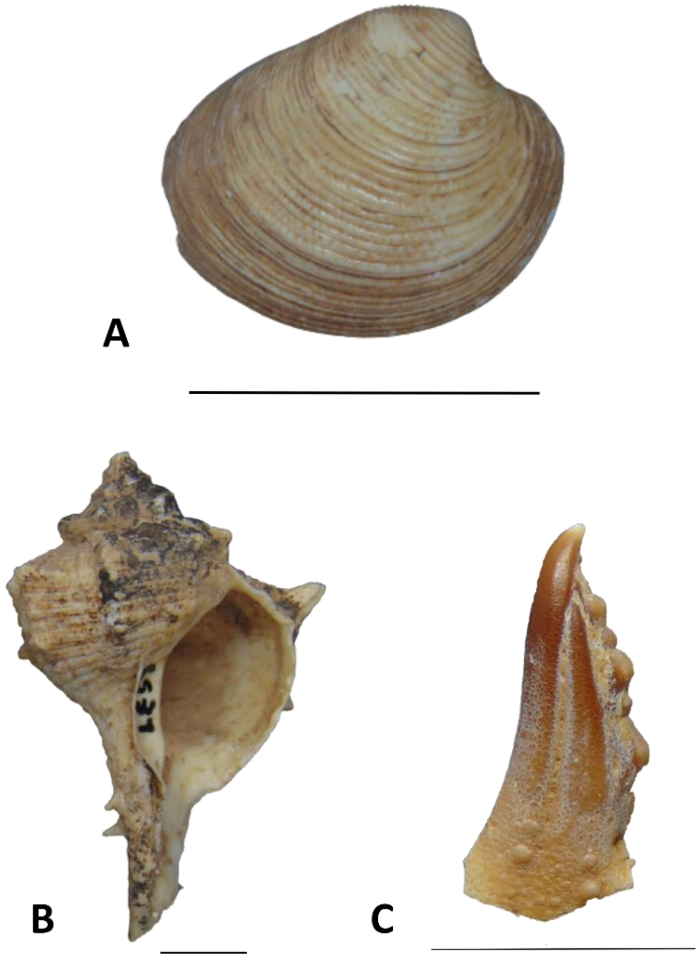


Figure 42: Preservation of structures in the different groups. In A, *Chamelea striatula* from the layer 1202-1B. In B, *Hexaplex trunculus* from the layer 1202-2. In C, *Eriphia verrucosa* from the layer 537/538-1. Scales of 1 cm.

Generally, individuals in life position were not observed since we are facing a context of food waste. An exception to this is the presence of epibiotic organisms such as serpulids, bryozoans, vermetids and balanids, which were often observed encrusted on shells.

Nevertheless, cases of colonization of the internal surface of the specimens occur, albeit in a residual form, demonstrating the *post-mortem* harvest of bivalve shells. In the rest of the macro-remains, once they consist of occupations of the external surface, colonisations could occur while the mollusc lifetime, without prejudice to its survival.

5.5 FRAGMENTATION RATE

For the determination of the fragmentation index, five of the most abundant species were considered (regarding the MNI): *Ruditapes decussatus, Solen marginatus, Cerastoderma edule, Ostrea edulis* and *Mytilus galloprovincialis* (Fig. 43).

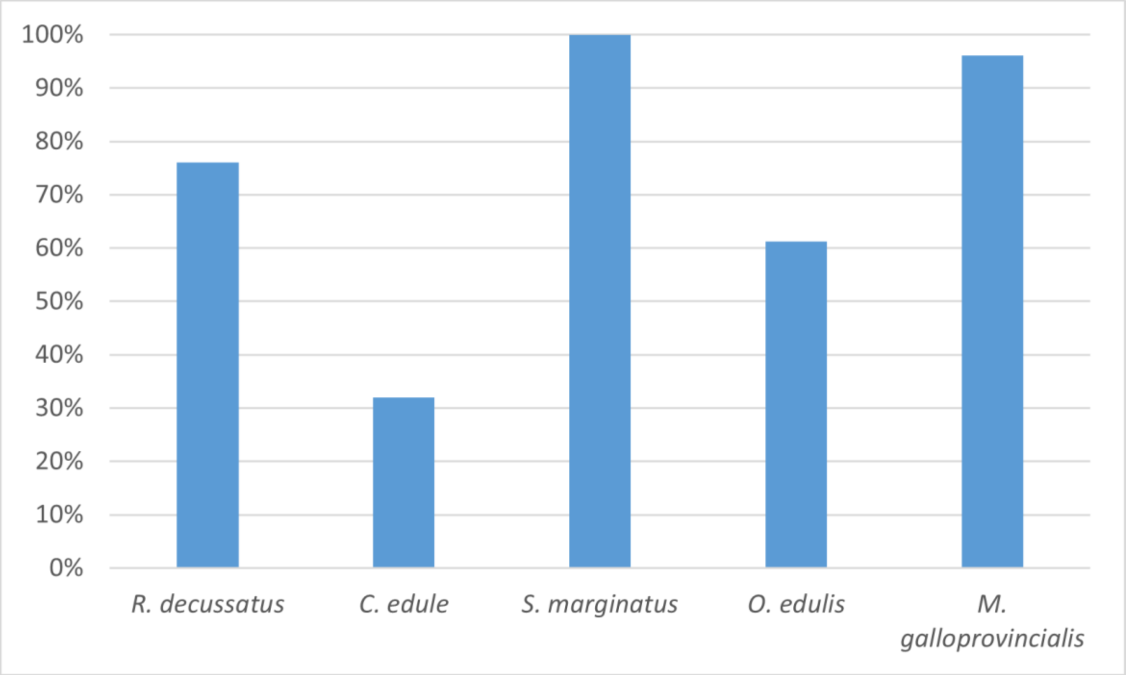


Figure 43: Fragmentation percentage of the most abundant species in the collection.

The most abundant species, *R. decussatus*, shows a high fragmentation rate (FR: 76.1%). This is supplanted by *S. marginatus*, with a degree of fragmentation of 100%, followed by *Mytilus galloprovincialis,* also displays a high rate (96.1%), and *Ostrea edulis,* with 61.2% of fragmentation. The least representative species, *C. edule,* was also the one that showed the best state of conservation, due to the low degree of fragmentation (32.1%), see figure 41.

One of the reasons that can be pointed to explain the conservation discrepancies between these five species is, undoubtedly, the robustness of the shell inherent to each species, wherein the structure and characteristics of the shell will condition its resistance to taphonomic phenomena, from burial to *in situ* collection. Another factor that is hypothesis to contribute to these discrepancies is the variation in manner of mollusc preparation for consumption.

For *Ruditapes decussatus*, an FTS analysis according to stratigraphic divisions stipulated at the time of the intervention, has demonstrated a predominance values in layers 1217-2, with 965 NISP, followed by 538/538-1 with 864 NISP, 537/538 with 819 NISP, and 1217-1B with 782 NISP. The degree of fragmentation on these layers averages 69%. Remaining contexts show low NISP values in relation to these but a higher FTS rate. In the sum of all layers, this species has 76.06% of FTS (Fig. 44).

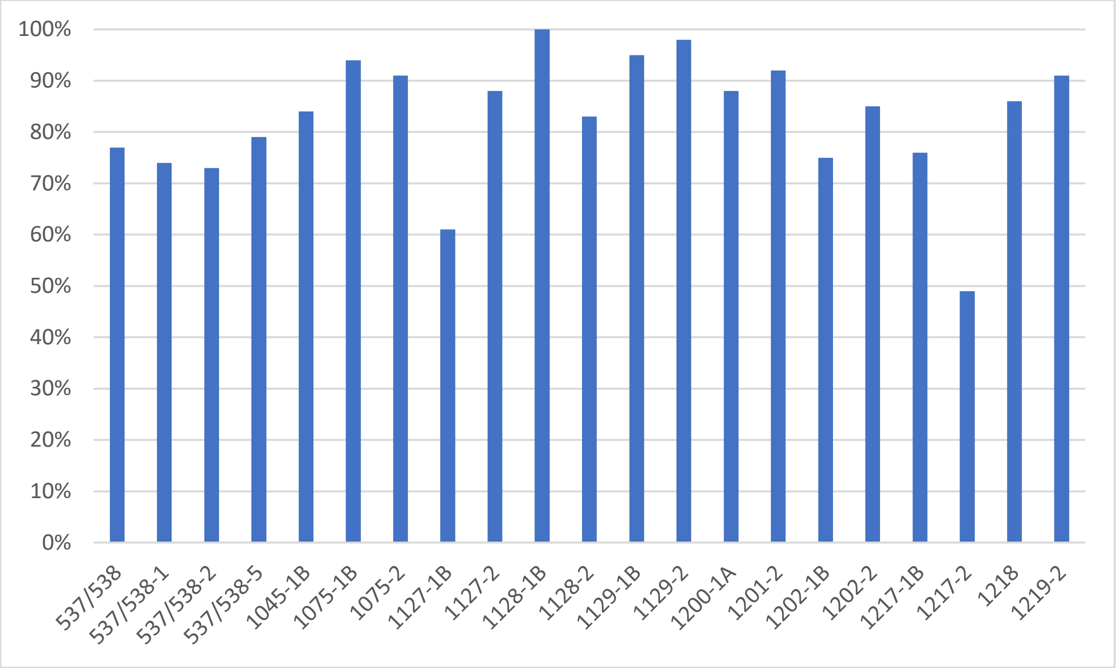


Figure 44: Fragmentation percentage of *Ruditapes decussatus* per layer.

Lastly, if we regard the fragmentation rates of all species in the studied collection (Fig. 45), the results are not very conclusive from a statistical point of view, since 19 of the identified species are known by a single occurrence, making it impossible to create a reliable estimation. The total average fragmentation rate of all layers and specimens is 52.5%.

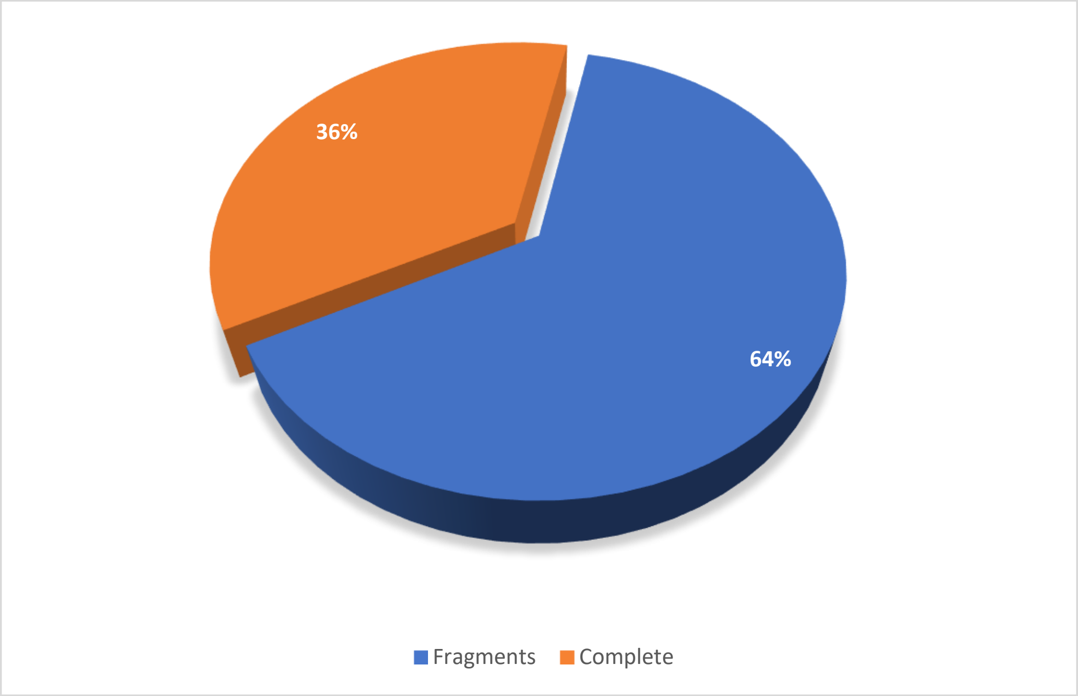


Figure 45: Percentages of faunal remains, separated into fragmented, and complete and partially remains, in the assemblage.

From the global point of view, this fauna collection has a strong presence of fragments (64% of the cases), and a low expression of complete anatomical elements (only 0.36% of the cases), see Fig. 46, in relation to the total of 12,605 remains counted.

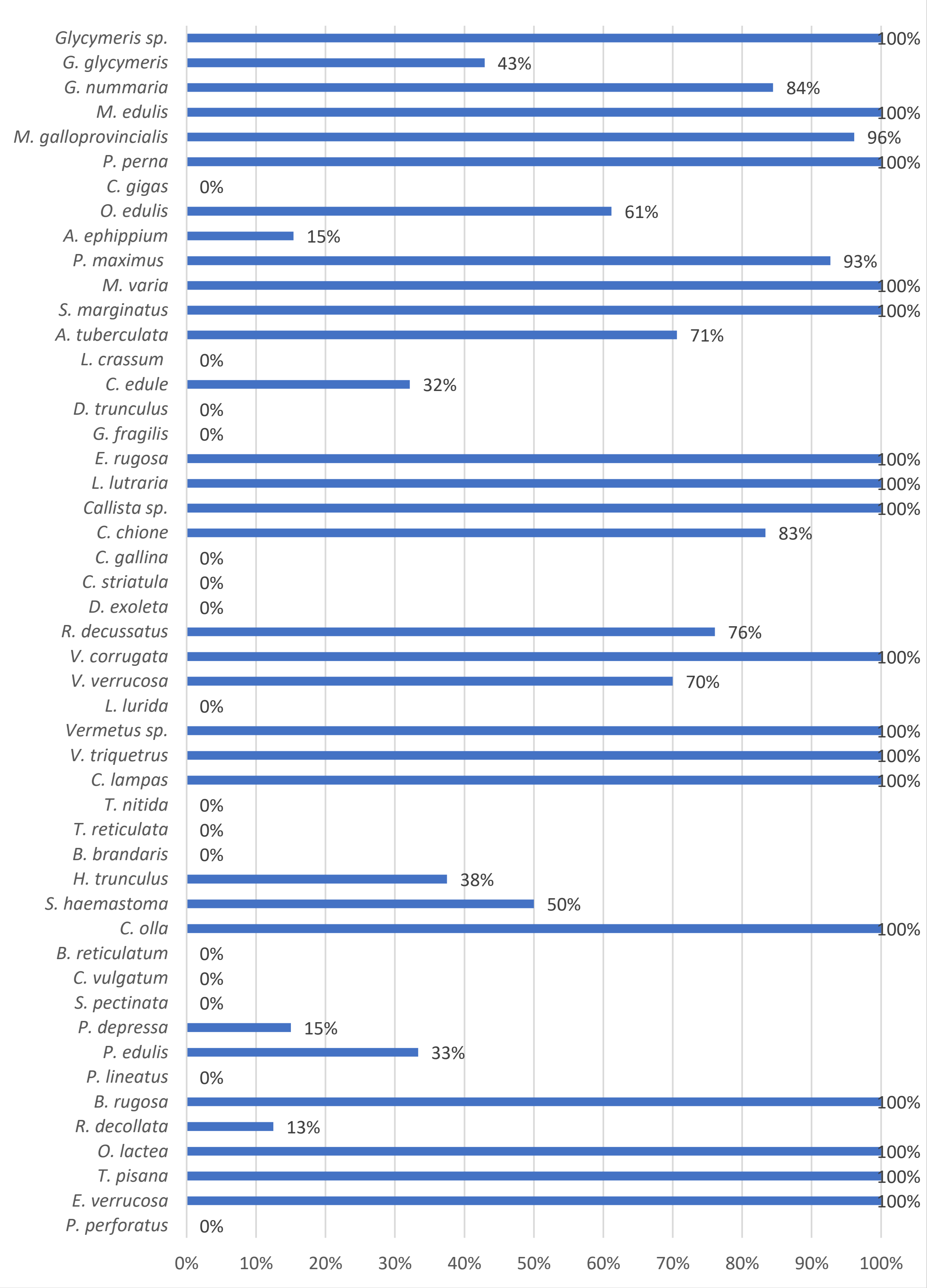


Figure 46: Fragmentation percentages of the counted species in this collection.

Chapter 6 DISCUSSION

The identification according to the taxonomic and anatomical classification resulted in the distinction of 45 taxa*:* 25 species of bivalves, 15 species of aquatic (marine and/or estuarine) gastropods and three terrestrial, and two species of crustaceans, distributed over 22 local stratigraphic units (layers) and resulted in 4089 MNI and 12,605 NISP.

6.1 STRATIGRAPHIC DISTRIBUTION

Table I shows the stratigraphic distribution of mollusc, barnacle and crab assemblages identified in the different layers of the studied castle. Analysing these mostly malacological composition, there is a substantial bivalve abundance when compared to gastropod and crustacean groups, both of which have a very residual presence. The discrepancy in quantitative terms is enormous.

In three of the identified species, more than 1000 individual remains were found in the following groups: *Ostrea edulis* with 1081 (26.44% of the MNI quantified in the collection), *Cerastoderma edule* with 1068 (25.90%), and *Ruditapes decussatus* with 1560 (38.15%). Regarding their relative expressions, stands out the records of individuals form the genera *Glycymeris* (0.83%)*, Mytilus* (2.27%)*, Anomia* (0.51%)*, Pecten* (0.51%)*, Solen* (1.05%)*, Acanthocardia* (0.56%)*, Hexaplex* (0.37%)*, Cerithium* (0.39%)*, Phorcus* (0.44%)*,* and *Rumina* (0.39%).

When compared to these genera, other species appear in a residually way in the faunal group studied with less than 10 MNI. The numbers for the three most common species, together with representatives of other edible ones, such as *Mytilus, Pecten, Solen* and *Hexaplex*, allows us to obtain a clear quantitative dietary evaluation for the population of *Xelb,* who used the location of the studied archaeological site for garbage purposes.

Regarding variations of quantity and diversity along the stratigraphic succession, it is not possible to confidently achieve a conclusion. This lack of stratigraphic results can be explained by the fact this work did not study the complete malacological collection of the Silves castle. Furthermore, analysed layers are neither linear nor continuous and there is the possibility that these layers may not be complete must also be pointed.

Table I: Absolute frequencies of the species of molluscs sampled (MNI=4089) and the total species per grid: 537/538 (1,2 and 5), 1045 (1B and 2),1075 (1B and 2), 1127 (1B and 2), 1128 (1B and 2), 1129 (1B and 2), 1200 (1A and 2), 1201 (2), 1202 (1B and 2), 1217 (1B and 2), 1218, and 1219 (2), present in the castle from the Islamic context of Silves.

Species	537/ 538	537/ 538-1	537/ 538-2	537/ 538-5	1045 1B	1075 1B	1075 2	1127 1B	1127 2	1128 1B	1128 2	1129 1B	1129 2	1200 1A	1200 2	1201 2	1202 1B	1202 2	1217 1B	1217 2	1218	1219 2	Total
Glycymeris sp.				2	1	1	1						1			1							7
G. glycymeris										1		2		1		1							5
G. nummaria	9		1						2		1			2		3	1		2	1			22
M. edulis																4						1	5
M. gallop.	1	16	4		6	1	3	1	2	3	3	6	16	6		1		8	1	2	7	1	88
P. perna																					1		1
C. gigas																		1					1
O. edulis	5	22	14	1	34	51	92	10	38	15	43	29	228	85	1	91	8	229	4	38	38	5	1081
A. ephippium	1	1							2	1	1		4	1		4		5			1		21
P. maximus	1	1			1	1	3	1	1		1		3	1		1		2	2		1	1	21
M. varia	1																						1
S. marginatus	2	17		4	2	2	6		1		1	2	3			2				1			43
A. tuberculata	4	1		2	1		1	1	1	1	1	3	2	1		1		1	1	1			23
L. crassum	1																						1
C. edule	15	13	17	215	5	11	27	5	34	5	85	11	128	35		68	8	124	68	142	34	9	1059
D. trunculus									1												2		3
G. fragilis																1							1
E. rugosa	1			1																			2
L. lutraria		5	1															1					7
Callista sp.	1																						1
C. chione	1		1	1					1							1							5
C. gallina									1														1
C. striatula																	1						1
D. exoleta																1							1
R. decussatus	205	210	42	116	6	8	26	7	17	1	5	19	24	92		39	2	64	213	354	101	9	1560
V. corrugata							1																1
V. verrucosa				2					1									3		1	1		8
Z. pyrum					1																		1
Vermetus sp.		1			1	1	1				2		1	1		1		1		2	3		15
V. triquetrus									1				3										4
C. lampas																					1		1
T. nitida																				1			1
T. reticulata																		1					1
B. brandaris																		1					1
H. trunculus						4							6	1				4					15
S. haemastoma	1			1								1						1		1			5
C. olla																1							1
C. vulgatum		1	1		1	5	2					1		2		1		1			1		16
S. pectinata																					1		1
P. depressa							1		1									1			1		4
P. edulis													2			1							3
P. lineatus							4							1		1		9					15
B. rugosa			1																				1
R. decollata			3	1		1	4		2							2		2	1				16
O. lactea		1	1																				2
T. pisana	1			1																			2
E. verrucosa		1																					1
P. perforatus		4				1					2		1	2				2			1		13
Total	250	294	86	347	59	87	172	25	106	27	145	74	422	231	1	226	20	461	292	544	1412	26	4089

Through further study, it is the intention to extend our analysis to the whole large collection housed in the Laboratory of Archaeology of the FCSH-UNL.

According to the data obtained from the stratigraphical study, it is possible to conclude that grid 1218 contains the highest number of sampled individuals (MNI=1412), followed by 1217-2 with MNI=544. In these layers, counts were based on a sampling dimension of several thousand shells and fragments.

Contrastingly, in square 1200-2 only one oyster valve was recorded, making it the less abundant layer in both quantitative and diversity. In addition to this one, layers 1127-1B, 1128-1B, 1202-1B, and 1219-2 have also yielded diminutive records, with less than 30 MNI each. On average, 186 MNI were identified per layer. The average MNI values per layer also varied with species *R. decussatus* (MNI=71), *O. edulis* (MNI=49) and *C. edule* (MNI=48).

In terms of species diversity (d), the various studied layers are characterized by moderately diversified malacological associations, as we can see from figure 45. Additionally, there is a balance between the number of species per layer and the average oscillation between d=11 for layers 537/538-2, 1045-1B, 1128-2 and 1217-2, and d=14 for layers 537/538-1, 1075-2, 1129-2 and 1200-1A. This variable finds its maximums in layers 1201-2 and 1202-2, with values of d=21 and d=20 respectively. A drastic drop is also present for the aforementioned layer 1200-2 (d=1). Additionally, very low values are also observed for layers 1127-1B, 1202-1B and 1219-2 with d=5/6.

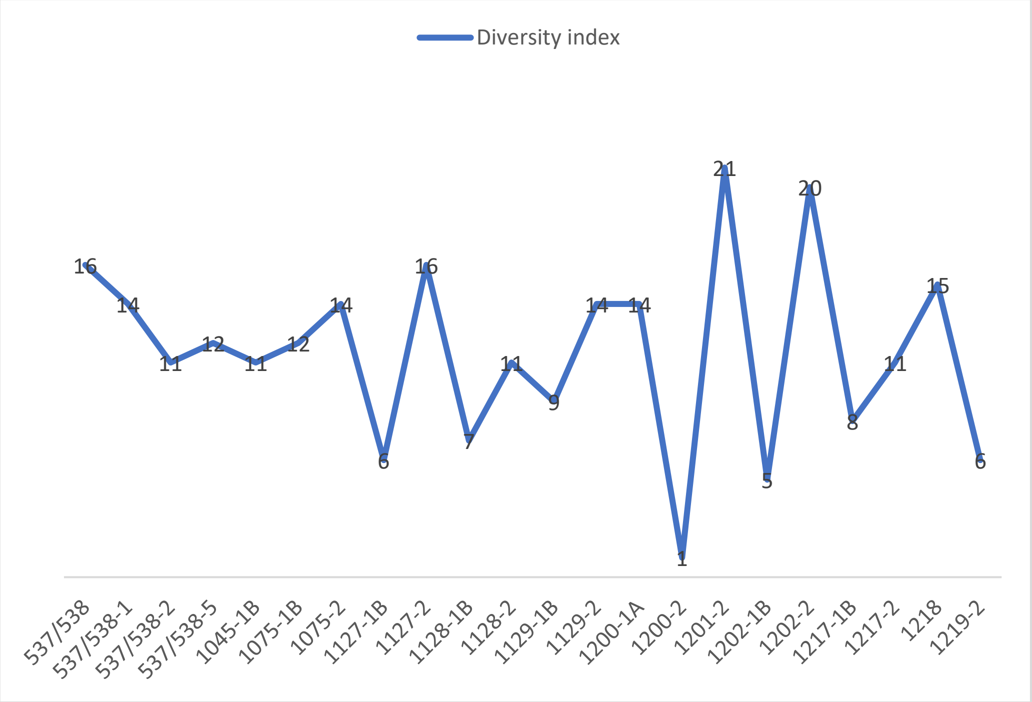


Figure 47: Species diversity index per layer.

Consideration was given to the layers with the highest diversity index, those belonging the grid 537/538. Despite having sixteen recorded species, 10 of these have a MNI=1, and five a MNI≤15. Only *R. decussatus,* known for its considerable number of individuals, presents a higher value (MNI=205).

Furthermore, in layers 1127-2, 1201-2 and 1201-2, a great number of the species are registered with an MNI≤2 - 13, 15 and 12, respectively. From this, one can assert that a large number of species does not directly translate into high quantitative values. In a general plan of this collection, around 61.5% of the registered species have an MNI≤2 per layer (Fig. 47).

6.2 FRAGMENTATION DEGREE

The collection is characterized by high fragmentation rates. These are common in food waste contexts. In the analysis of the fragmentation index, the three most abundant species (with regard to MNI) were considered: *Ostrea edulis, Cerastoderma edule,* and *Ruditapes decussatus* (Figs. 48 and 49).

R. decussatus, the most abundant species, shows a high fragmentation rate (76.06%), followed by *O. edulis* (61.17%). On the other hand, *C. edule* (32.13%) displays the best conservation condition due to its low fragmentation degree (1:1 for MNI/NISP).

As for reasons that can explain the conservation discrepancies between these edible bivalves, one can be point to the inherent shape, sculpture, structure, and shell robustness of the shells, as well as its All together, these characteristics will condition its resistance of each species. Put together, these characteristics will invariably condition resistance to taphonomic processes. Another influencing factor is the way a shell is opened to extract the mollusc when consumed.

Additionally, one can also point to biostratinomic or diagenetic mechanisms such as the sediment compaction, biochemical shell deterioration, and specimen fragmentation during the excavation of the grids itself or subsequent material treatment.

For *Ruditapes decussatus*, the fragmentation degree analysis, according to the squares and stratigraphic layers stipulated at the time of the intervention (Fig. 50), has revealed predominant fragmentation values above 90%. These occur in squares - 1201-2, 1219-2, 1129-1B, 1128-1B, 1129-2, 1075-1B, and 1075-2. Only 1217-2 has shown fragmentation values below 50%.

Edible sea snails also appear very fragmented in the collection. This can be attributed to deliberate crushing for consumption of these species (*H. trunculus, S. haemastoma, and C. lampas*).

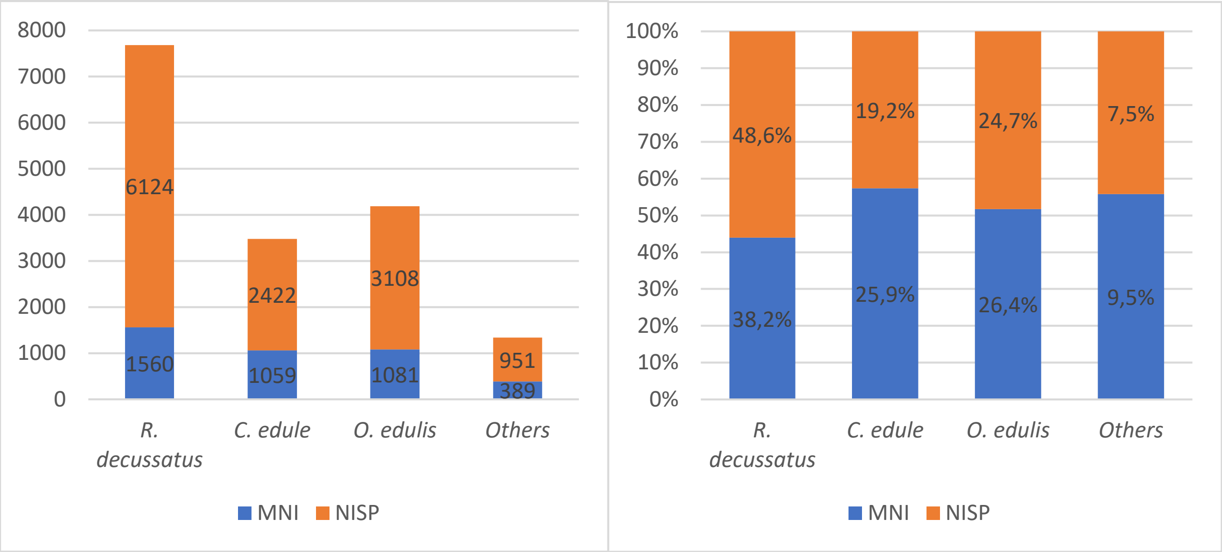


Figure 48 and 49: Degree of fragmentation: MNI/NISP relation in *Ruditapes decussatus, Cerastoderma edule, Ostrea edulis*, and remaining species.

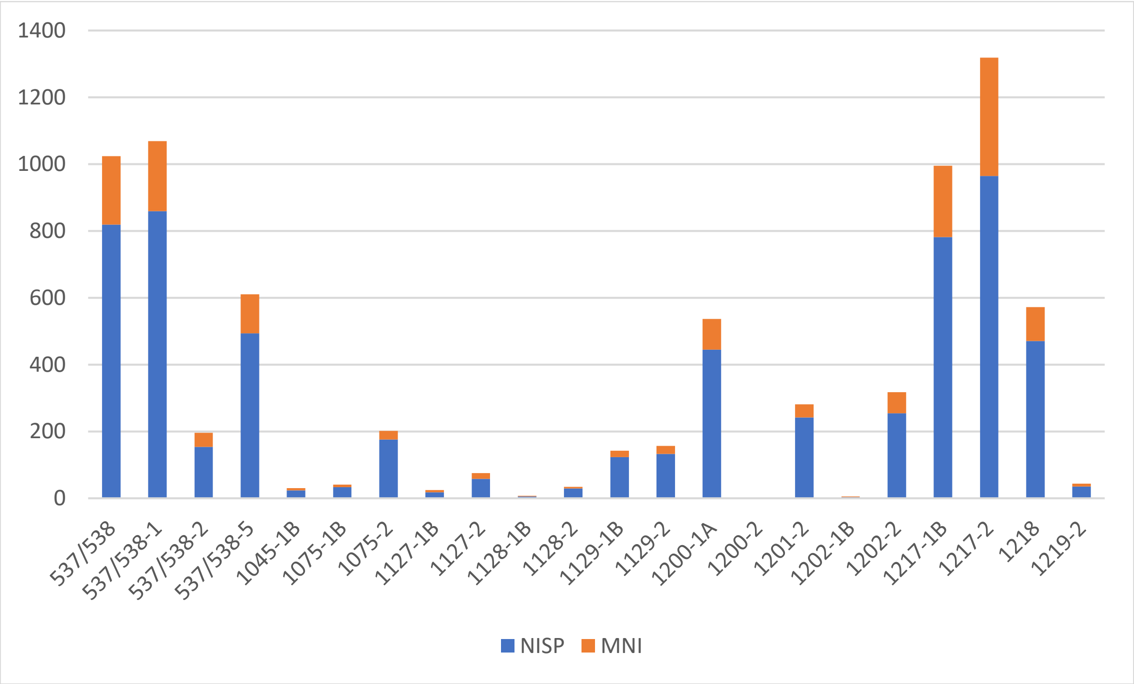


Figure 50: Degree of fragmentation in *Ruditapes decussatus*: MNI/NISP relation per stratigraphic context.

6.3 PALAEOECOLOGICAL AND PALAEOENVIRONMENTAL INTERPRETATION

Invertebrate species found in benthic faunas of aquatic biotopes can be characterized according to several ecological parameters. These relate to the main abiotic and biotic factors that control their environment.

As an extremely significant topic of palaeoecological studies, a host of factors such as substrate type and position, fixation modality and mobility, bathymetry, tidal zonation, tolerance to salinity, temperature, turbidity, trophic type, and biotic relations with other species are usually considered by authors. For such purposes of this work, several categories within each of these characteristics have been established and listed in Table II and III.

Relevant information on such topics was consulted from literature on both recent molluscan faunas and general literature on mollusc ecology: e.g. Abbott (1954); Abbott and Dance (1986); Ardovini and Cossignani (2000); Bruyne (2004/2006); Cossignani and Ardovini (2011); Dame (2011); Dance (1974); FAO (2016); Huber (2014); Macedo et al. (1999); MarLIN (2006); MolluscaBase-e;ds. (2020); Nobre (1913, 1930, 1931, 1933, 1941); Oliver (1975); Poppe and Goto (1991, 1993); Pyron and Brown (2015); Rolan Mosquera (1983, 1989); Saldanha (1995); Tunnell et al. (2010); Valente (2010); Venkatesan (2010); and WoRMS (2020).

Information about the palaeobiological nature inherent to species or associations of molluscs - collected in an archaeological context - constitutes an important source of data on aspects of the physical environment and local or regional biotic communities. In this type of analysis, it is considered essential to apply specific criteria based on observed ecology of each species, as well as their tolerance to the main abiotic factors that regulate the dispersion of benthic communities from coastal and transition environments.

The relationship between one species and its respective bathymetry becomes then crucial to determine whether the species is directly or indirectly collectable, *i.e.* in shallow water without tools, or with tools or techniques of indirect gathering such as the use of nets, traps, vessels and dredgers). Daily collection is possible for species that live in shallow waters down to the intertidal zone. More exceptionally, this activity can also occur at lower bathymetric levels through fishing activities and fishing nets cleaning at the harbour.

Table II: List and meaning of abbreviations used in the characterization of the species in relation to their position on the substrate, mobility, substrate preference, bathymetry, biotope, and diet.

Category	Abb	Description	Category	Abb	Description
Substrate position	IF	Infaunal	Biotope	ES	Estuary
	EF	Epifaunal		LA	Lagoon
	EZ	Epizoary		SM	Sandy marine
				RM	Rocky marine
				TR	Terrestrial
Mobility	BU	Sessile-burrow			
	AT	Attached			
	VA	Vagile	Diet	FF	Filter-feeders
	BY	Byssal		DF	Deposit-feeders
				MG	Microalgae herbivores
				SC	Scavengers
Substrate	SA	Sandy		OM	Omnivorous
	RO	Rocky/ Hard substrate		PC	Predatory carnivorous
	SL	Sandy-loamy		AG	Herbivores of macroalgae and epiphytes
	LA	Land			
Bathymetry	IF	Infralittoral			
	ME	Mesolittoral			
	SU	Supralittoral			

Table III: Main ecological characteristics of marine invertebrate species assemblage in the Islamic context in Silves. Abbreviates for substrate position (PS), mobility, substrate, bathymetry (Bathym), biotope, diet, and edible species marked with a dot, at the bottom, there is the frequency in percentage, as listed in Table I.

	PS			Mobility				Substrate				Bathym			Biotope					Diet	ED
Species	INF	EPI	EZ	BU	AT	VA	BY	SA	RO	SL	LA	IF	ME	SU	ES	LA	SM	RM	TR	FF	●
G. glycymeris	●					●		●				●			●	●				FF	●
G. nummaria	●					●		●				●			●	●				FF	●
M. edulis		●					●		●				●					●		FF	●
M. galloprovincialis		●					●		●				●					●		FF	●
P. perna		●					●		●			●						●		FF	●
C. gigas		●		●					●			●			●	●				FF	●
O. edulis		●			●				●				●		●	●				FF	●
A. ephippium		●					●		●			●						●		FF	
P. maximus		●				●		●				●					●			FF	●
M. varia		●					●		●			●						●		FF	●
S. marginatus	●			●						●			●		●	●				FF	●
A. tuberculata	●					●				●		●					●			FF	●
L. crassum	●			●						●		●					●			FF	●
C. edule	●					●				●			●		●	●				FF	●
D. trunculus	●			●				●					●		●	●				FF	●
G. fragilis	●					●		●					●			●		●		DF	●
E. rugosa	●			●						●		●					●			FF	●
L. lutraria	●			●						●		●			●	●				FF	●
Callista chione	●					●		●				●					●			FF	●
C. gallina	●			●						●		●					●			FF	●
C. striatula	●			●						●		●					●			FF	●
D. exoleta	●			●						●		●					●			FF	●
R. decussatus	●					●				●			●		●	●				FF	●
V. corrugata	●			●						●		●			●	●				FF	●
V. verrucosa	●					●		●				●			●	●				FF	●
Z. pyrum		●				●			●			●						●		MG/OM	
V. triquetrus		●			●					●			●		●	●				FF	
C. lampas		●			●					●		●						●		SC	●
T. nitida		●				●				●			●			●	●			SC	
T. reticulata		●				●				●			●			●	●			SC	
B. brandaris		●				●				●			●				●			FF	●
H. trunculus		●				●			●			●						●		PC	●
S. haemastoma		●				●			●			●						●		PC	●
C. olla		●				●			●				●				●			PC	●
C. vulgatum		●				●				●		●				●	●			MG	●
S. pectinata		●			●				●					●				●		MG	
P. depressa		●			●				●				●					●		MG	●
P. edulis		●				●			●				●					●		MG	●
P. lineatus		●				●			●				●					●		MG	●
B. rugosa		●				●			●			●						●		MG	
R. decollata		●				●					●	-	-	-					●	OM	
O. lactea		●				●					●	-	-	-					●	AG	●
T. pisana		●				●					●	-	-	-					●	AG	●
E. verrucosa		●				●			●			●						●		PC	●
P. perforatus			●		●				●			●						●		FF	
Percentage (%)	38	60	2	22	13	53	11	16	40	38	7	60	38	2	-	-	-	-	-	-	82

In the studied context of Silves, the collection of molluscs such as limpets alongside the rocky coast would have implied a considerable journey to the shores of Portimão and Lagos, reason because it would have been passed over at the expense of shellfish of estuarine bivalves. This collection highlights the predominance of this kind of edible species subject to a daily gathering.

The bathymetric range of this assemblage is wide. They can be found from the supralittoral zone up to a depth of a few tens of meters. Nevertheless, these are species that are most commonly found at easily accessible, shallow depths. They are also species that support a range of salinity variations from 18 to 40‰; for instance, the Family Mytilidae, *Ostrea edulis,* and *Cerastoderma edule*, all quite abundant in this collection.

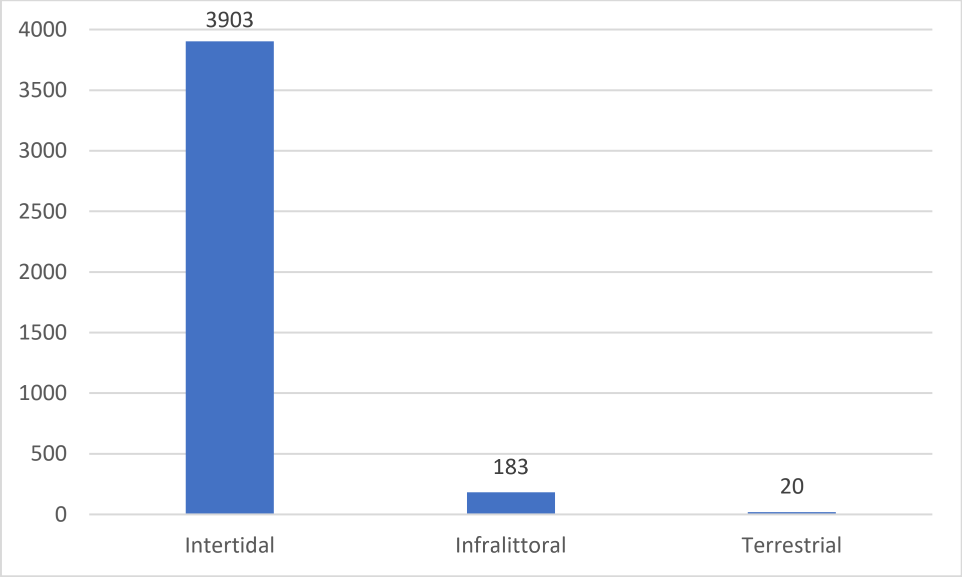


Figure 51: Distribution (MNI) of species according to bathymetric levels.

In the studied faunal associations, there are also several species of bivalves, gastropods, and crustaceans, mainly adapted to live in coastal areas with rocky substrates. These are periodically exposed during tidal cycles and subject to the dynamics of coastal waves in the foreshore (mesolittoral and supralittoral zones).

Among the most characteristic forms of this type of environment are mussels (*Mytilus edulis, M. galloprovincialis*), limpets (*Patella depressa* and *Siphonaria pectinata*), oysters (*Crassostrea* gigas and *Ostrea* edulis, this last one is likely to develop in several types of substrate), other gastropods (*Phorcus lineatus* and *P. edulis)*, and crabs (*Eriphia verrucosa).*

Still on the rocky substrate, but from the inshore (infralittoral zone), several species appear, especially gastropods, but the vast majority represented by a single individual appearance in the collection. There are the cases of: *Anomia ephippium, Hexaplex trunculus, Stramonita haemastoma, Cymbium olla,* and the cirriped crustaceans *Perforatus perforatus*.

Although the number of species identified is mostly from the coastal environment, if we consider the percentage of MNI per type of environment, intertidal benthic communities of lagoon and estuarine environments will be valued due to the dimension that the infaunal bivalves *Cerastoderma edule* and *Ruditapes decussatus* acquire in this collection (Fig. 51). These species are divided into sandy and sandy-mud substrates in moderately or weakly energetic environments, with a certain tolerance to more substantial variation in turbidity, salinity and/or temperature of the water bodies. The most significant species belong to the brackish water infauna (Glycymeris spp*., Solen marginatus, Acanthocardia tuberculata, Cerastoderma edule, Lutraria lutraria, Ruditapes decussatus, and Venus verrucosa*).

The terrestrial gastropods are autochthonous to the site and appear in the collection as a fortuitous way, not representing food consumption.

Figures 52 and 53 allude to the current scenario of the Arade river estuary, where in this Islamic period the fishing community of Silves would have produced and collected molluscs for consumption in saltmarsh and shoals, the remains of which were later found in a closed palatine residential context.

Figures 52 and 53: Arade river estuary nowadays (Photo: courtesy of José Manuel Pedroso da Silva, 2020).

6.4 SPECIES CONSUMED

As expected in the present archaeological context, almost all macroremains belong to edible species (82.22%) identified as food waste, and originally collected from estuarine and coastal areas of the Arade river system.

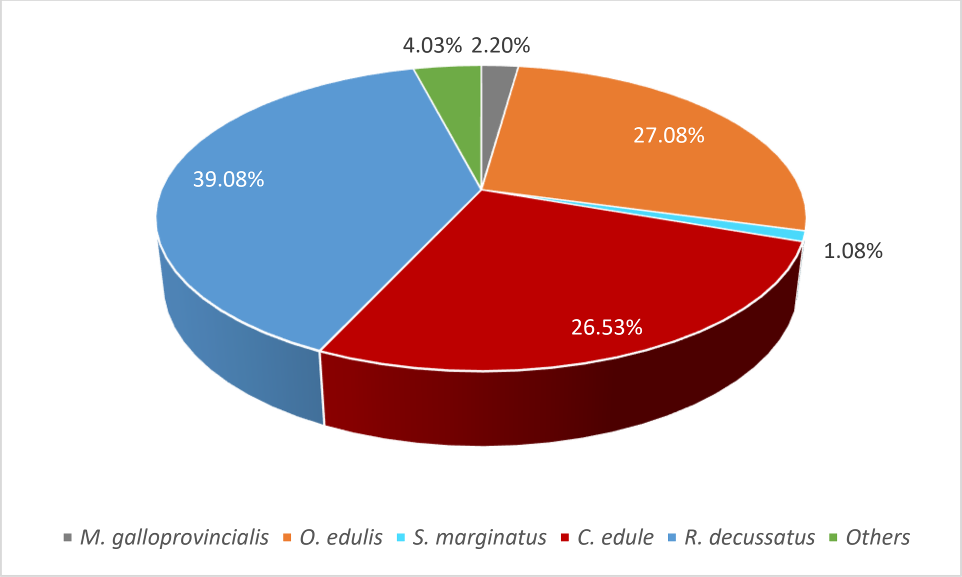


Figure 54: Relative abundance (%MNI) of the most representative edible species, in relation to the other edible species.

Of the 42 marine molluscs represented, 32 correspond to edible forms (table III). In the bivalves, only *Anomia ephippium* is not considered as edible, and in marine gastropods, of the 15 species identified, only eight are edible; one of them - *Siphonaria pectinata* - also known as the "striped false limpet", confused due to the morphological appearance with the limpets (*Patella* spp.), however, it is not edible. As for crustaceans, only 1 of the 2 forms is edible (*Eriphia verrucosa*). In the case of recovered terrestrial molluscs, 2 of the 3 species are edible (*Theba pisana* and *Otala lactea*). Nevertheless, although they are quite appreciated in the Iberian Peninsula, including during the Islamic period, their small number in the bulk sample does not reflect consumption. This is the same of the majority of the counted species which, despite being edible, do not reflect consumption, or at least regular consumption, since their presence is residual, that is, less than 5 individuals in the total layers: *Glycymeris glycymeris, Mytilus edulis, Perna perna, Crassostrea gigas, Mimachlamys varia, Laevicardium crassum, Gastrana fragilis, Eastonia rugosa, Callista chione, Chamelea gallina, Chamelea striatula, Dosinia exoleta, Venerupis corrugata, Charonia lampas, Bolinus brandaris, Stramonita haemastoma, Cymbium olla, Siphonaria pectinata, Patella depressa, Phorcus edulis* and *Eriphia verrucosa.*

Subsequently, the shellfish diet of this Islamic community consisted mainly of *Ruditapes decussatus, Ostrea edulis,* and *Cerastoderma edule*. These species may have been cultured in traditional aquaculture, an activity that certainly dates back to the Roman period in Algarve (Gonçalves et al., 2007). Also, relatively abundant are the bivalves *Mytilus galloprovincialis* and *Solen marginatus* (Fig. 54). All these species are part of benthic communities who lived in ecotones of the river Arade estuary, revealing different kinds of adaptation, but always being common and easily collected at low tide.

The relative contribution of each of these species to the possible diet of the inhabitants of Silves cannot be established from the remains that studied in this dissertation, although it appears that there was substantial use of the venus clam *Ruditapes decussatus* (Fig. 54), a point that has yet to be confirmed with the results of the remaining collection not analysed here. But, considering the data presented in this dissertation and those of Gonçalves et al. (2007), the tendency is for an increasing number of individuals of this species in relation to the others.

The presence of non-edible species such as *A. ephippium, Z. pyrum, V. triquetrus, Tritia spp., S. pectinata, B. rugosa, R. decollata, and P. perforatus* in this context of food waste will have resulted from the fortuitous gathering. Wherein the gastropod *Vermetus* sp. and the cirriped crustacean *P. perforatus* appear encrusted in other molluscs, namely oysters.

6.4.1 Consumption evidence

As it would be expected in a context of food waste, most shells evidence a degree of anthropic interaction over their natural biostratinomic imprint, which resulted from the food consumption of the molluscs. These intentional marks are mostly found in the main consumed species, with an emphasis on oyster, cockles and venus clam specimens.

Consumption marks have been identified in mollusc shells, the record has resulted in several examples of *Ruditapes decussatus* and *Cerastoderma edule* displaying clear evidence of trauma on their edges. These traumas may have been a result of the action of some instrument used to open the valves. It is, however in valves *Ostrea edulis* that the higher index of consuming marks can be observed.

In fact, the vast majority of these valves appears to display some kind of scraping marks that result from the valves separation. A sharp tool, possibly a knife has been used (Figs. 55 and 56).

Figures 55 and 56: Shells consumption marks. Left: *C. edule* from layer 1128-2. Right *O. edulis* layer 1201-2.

Combustion episodes are residual, which may indicate that a substantial part of the molluscs was eaten raw (possibly with some seasoning), or after a quick pass through the fire. They might have been cooked in a skillet for instance, which would leave no marks besides those to open the valves and facilitate access to the mollusc itself. Carbonated samples display dark brown and black coloured remnants, and thermal fissures and are mostly fragmented. From the collection, there are only four carbonated valves of *C. edule*, all of from layer 1128-2; from 537/538-5 a fragment of *Glycymeris* sp.; three fragments of *R. decussatus,* two of them from layer 537/538-5, and the other from 537/538-2; a fragment of *P. maximus* from 1075-2; and a fragment from 1127-2 assigned to *G. nummaria* (Fig. 57).

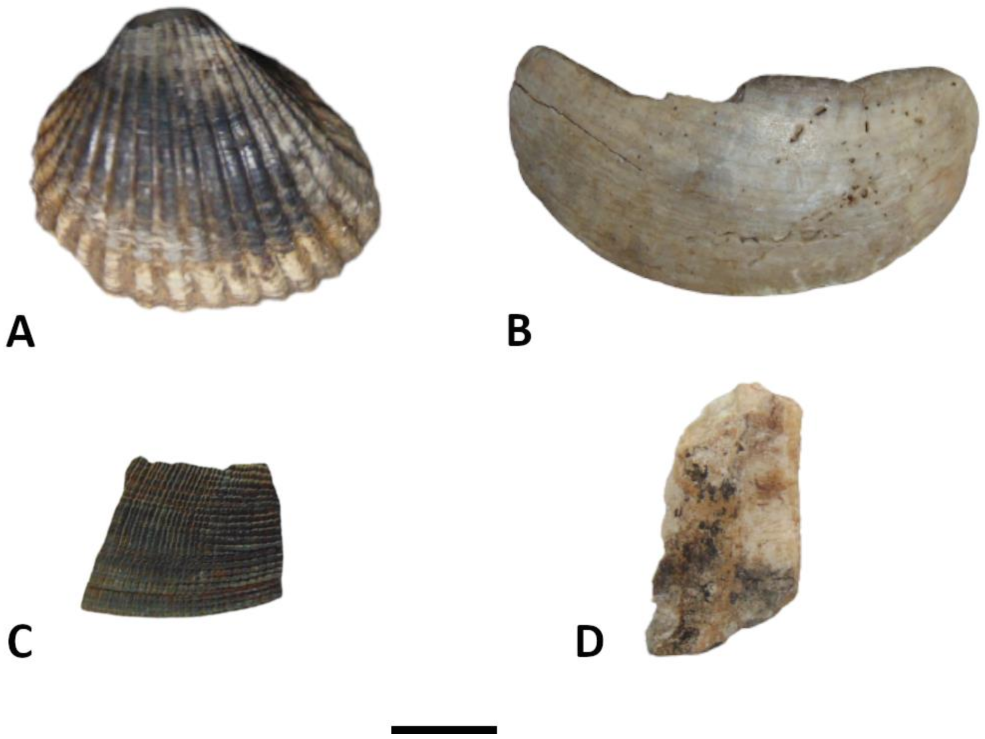


Figure 57: Specimens with evidence of combustion. A*: Cerastoderma edule* from layer 1128-2; B: *Glycymeris* sp. From 537/538-5; C: *Ruditapes decussatus* from 537/538-5; and D: *Pecten maximus* from 1075-2. Scale of 1 cm.

6.5 TRANSFORMATION AND USE MARKS

Examples related to marine mollusc shell usage have been reported by many researchers, as both adornments and a variety of tools. It is known that such practices have existed since remote times and remain until the present day.

Among these, the possible use of *Glycymeris* valves as weights for fishing nets stands out. This usage may be explained by the large, thick, and heavy valves of these species, which are regularly found with umbonal facets presenting biostratinomic abrasion. This traditional practice was already used before and during the Roman period (Callapez, 2011; Gonçalves et al., 2007), and likely persisted until a very recent time. It stands as an interesting and ingenious example of how an available natural resource can be sucessfully repurposed by local fising communities. Likewise, a concave valve of the large scallop *Pecten maximus*, also susceptible of having been used as a fishing weight or as a domestic container (Callapez, 2011).

As previously mentioned, mollusc shells found in this collection may have been used in situations that extend beyond their dietary character. It was thus deemed necessary to attempt to ascertain these different functionalities, whether there has been a transformation of the valves or marks of use.

This being a context of food waste, significant evidence of reused shells was not found. Nevertheless, despite scarce amounts of evidence, it was possible to identify this type of activity on this context, namely *Glycymeris* spp. shells. Presenting signs of abrasion of the umbonal facets, possibly used as fishing weights (Fig. 58). About 72% of valves and fragments that preserve the umbo, are altered. These specimens are normally found with bioerosion, traces of abrasion and natural colour loss (Fig. 59). In some cases, this loss of colour has made identification to the species level not possible.

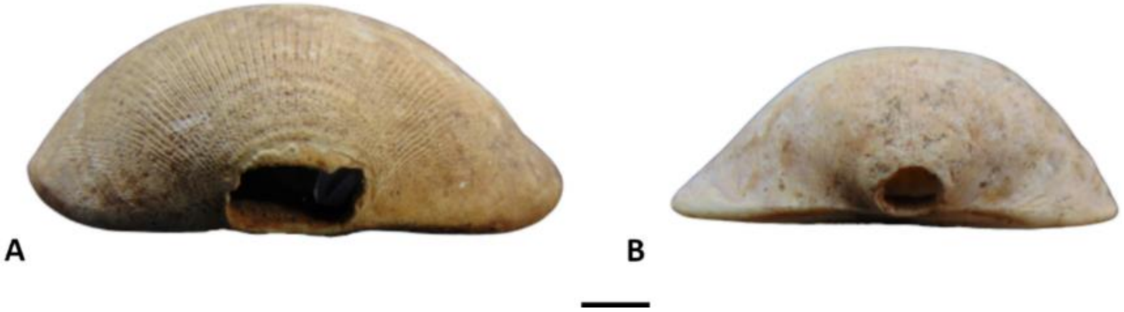


Figure 58: *Glycymeris* spp. *s*pecimens with perforated umbonal facets. A: *Glycymeris glycymeris* from layer1129-1B, and B: *Glycymeris nummaria* from 537/538-5. Scale of 1 cm.

Figure 59: Glycymeris spp. specimens with signs of abrasion. A: *Glycymeris nummaria* specimen with colour loss from layer 537/538; B: *Glycymeris glycymeris* with full abrasion of the hinge teeth 1201-2. Scales of 1 cm.

A highly polished specimen of *G. nummaria* presenting umbonal facet abrasion was also identified (Fig. 60). In this case, the reduced proportions of this specimen have make it too small to be compatible with usage as a fishing weight. Most likely, its presence in the archaeological deposit may result from cleaning nets. Similar shells have been reported to be used as adornments however, such as pendants for instance.

Figure 60: *Glycymeris nummaria s*pecimen with perforated umbonal facets from layer 537/538-5. Scale of 1 cm.

There are three relevant *Acanthocardia tuberculata* valves. One from layer 537/537 with the abrasion of the umbonal facet, and two others from 1129-1B with perforations through the dorsal side of the shell. These species have large and robust valves that have also been used as fishing weights in the past. These valves show traces of mechanical abrasion. Both valves from layer 1129-1B display bryozoans encrusted on the internal and external surfaces, indicators of a rather long biostratinomic *post-mortem* residence time over the surface (Fig. 61).

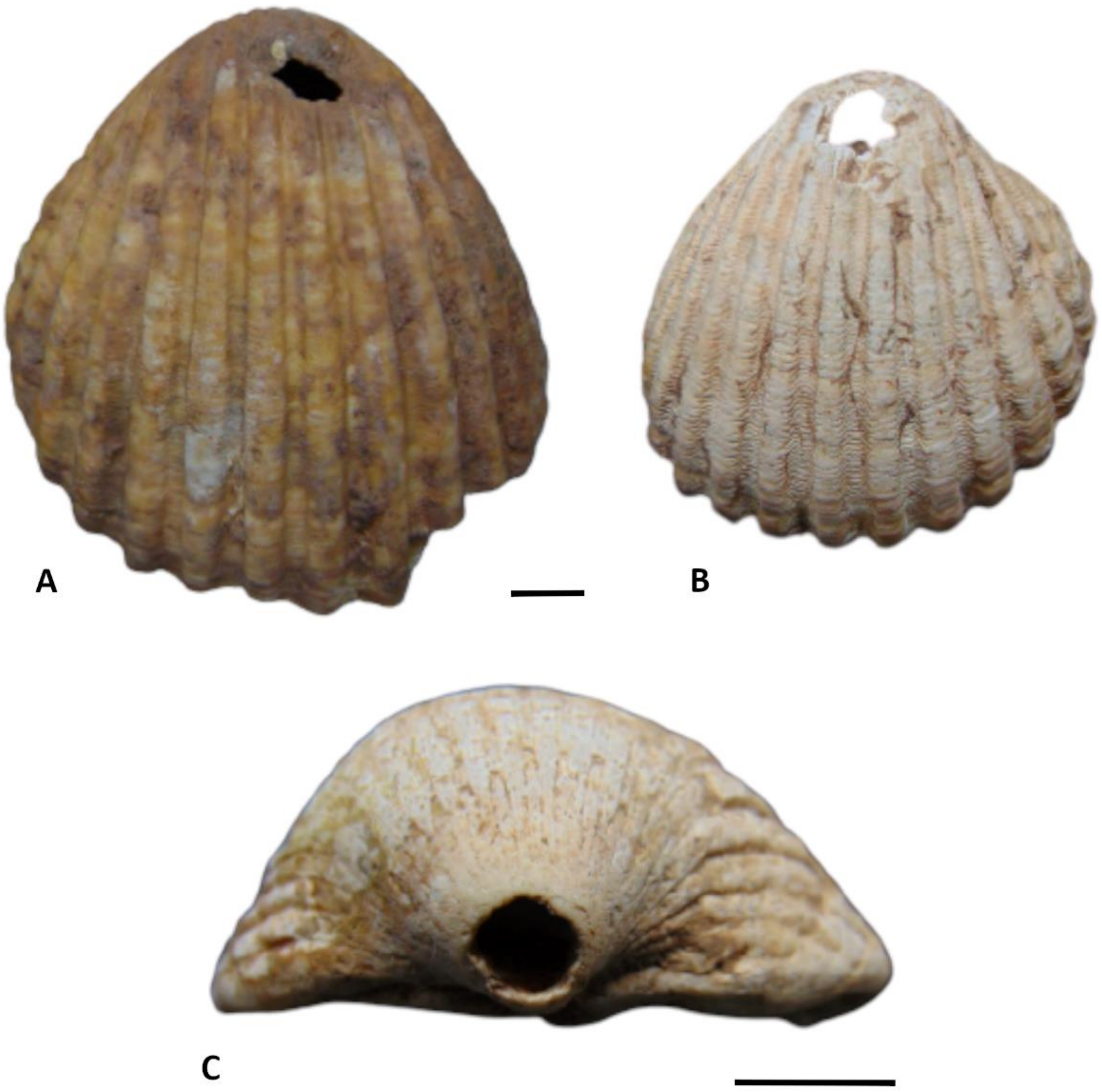


Figure 61: Specimens of *Acanthcardia tuberculata* with perforations. A and B: perforations on the dorsal side of the shell, from the layer 1129-1B; and C with the umbo perforated, from the layer 537/538. Scales of 1cm.

One final valve that presents indication that point to its reuse, is a complete *P. maximus* valve of great proportions. Albeit not showing concrete evidence of tool usage, besides combustion marks and evidence of trauma on the edges (Fig. 62). Valves of this large scallop species are known to have been used as containers. There is the possibility that this valve may have been used as a container, independently of mollusc consumption.

The curious presence of sea snails from the species *Hexaplex trunculus* and *Stramonita haemastoma* in the sample is also deserving of a mention. These edible species, also called “purple shells”, have been known since Protohistoric times to produce a prized purple pigment (Stieglitz, 1994). However, the scarce number of specimens here identified does not translate into evidence of colour production.

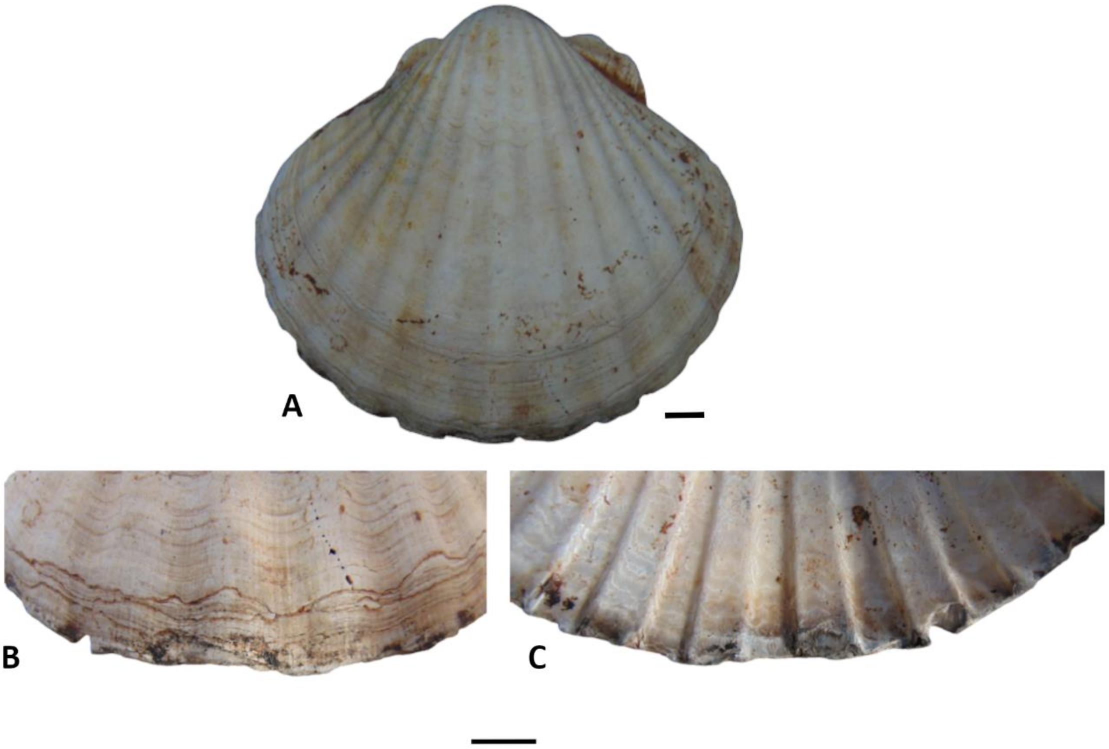


Figure 62: Specimen of *Pecten maximus* from layer 357/538 with combustion marks and trauma evidence on the edges. A: Specimen complete; B: external surface; and C: internal surface. Scale of 1 cm.

Chapter 7 CONCLUSIONS

Collected during archaeological interventions carried out in the Silves site, the mostly malacological assemblage analysed in this work came from the exhaustive sampling of 22 squares of occupation levels in the Alcazaba that expose a closed palatine residence, which was destroyed due to various transformations. This site was occupied from the 6th/7th century to the 16th century, with emphasis on an extensive Islamic settlement and its next continuity.

The zooarchaeological assemblage as resulted in the quantification of 12,605 NISP and 4089 MNI. In the course of this work, 45 taxa from four classes of invertebrates: Bivalvia, Gastropoda, Malacostraca, and Thecostraca were identified.

From the Bivalvia class, 25 taxa were identified. Of these, 23 of which up to the species level, with exceptions being *Glycymeris* sp. and *Callista* sp. due to their high fragmentation and abrasion rates.

From the Gastropoda class, 18 taxa were identified, 15 of which from aquatic environments. One of these was not identifiable to the species level (*Vermetus* sp.). Additionally, three terrestrial gastropods were identified. Besides molluscs, only one taxon from the Malacostraca class and another from the Thecostraca class were identified.

The taxonomic list is distributed among 25 families, 40 genera, and 45 species. The most representative families are Veneridae with seven species, followed by Muricidae with four species (Table IV).

When the values of NISP and MNI are compered, it can be concluded that the total number of this assemblage corresponds mainly due to high quantitative levels in the species *Ruditapes decussatus* (38.15%), followed by *Ostrea edulis* (26.44%) and *Cerastoderma edule* (25.90%). These bivalve species were produced and explored to some extent through traditional shellfish activities on the intertidal, brackish mud banks of the Arade river. These activities continue to this day in some estuarine and lagoonal areas of Algarve region, mostly in the Ria Formosa.

Also abundant in the studied bulk sample are the edible bivalve species *Mytilus galloprovincialis* (2.15%) and *Solen marginatus* (1.05%). Other species subject to sporadic gathering appear only residually in the sample under study. Wherein 99.51% of the collection was found to be allochthonous to the archaeological deposit and is the result of intentional or fortuitous transport from the coastal region nearby Silves. The remaining 0.49% correspond to terrestrial molluscs belonging to the local fauna.

Table IV: Check-list of families, genus, and species of bivalves, gastropods, and crustaceans identified in the Silves castle.

Class Bivalvia

- Family Glycymerididae
  - Genus *Glycymeris*
    - *Glycymeris glycymeris*
    - *Glycymeris nummaria*
- Family Mytilidae
  - Genus *Mytilus*
    - *Mytilus edulis*
    - *Mytilus galloprovincialis*
  - Genus *Perna*
    - P*erna perna*
- Family Ostreidae
  - Genus *Crassostrea*
    - *Crassostrea gigas*
  - Genus *Ostrea*
    - *Ostrea edulis*
- Family Anomiidae
  - Genus *Anomia*
    - *Anomia ephippium*
  - Genus *Pecten*
    - *Pecten maximus*
  - Genus *Mimachlamys*
    - *Mimachlamys varia*
- Family Solenidae
  - Genus *Solen*
    - *Solen marginatus*
- Family Cardiidae
  - Genus *Acanthocardia*
    - *Acanthocardia tuberculata*
  - Genus *Laevicardium*
    - *Laevicardium crassum*
  - Genus Cerastoderma
    - *Cerastoderma edule*
- Family Donacidae
  - Genus *Donax*
    - *Donax trunculus*
- Family Tellinidae
  - Genus *Gastrana*
    - *Gastrana fragilis*
- Family Mactridae
  - Genus *Eastonia*
    - *Eastonia rugosa*
  - Genus *Lutraria*
    - *Lutraria lutraria*
- Family Veneridae
  - Genus *Callista*
    - *Callista chione*
  - Genus *Chamelea*
    - *Chamelea gallina*
    - *Chamelea striatula*
  - Genus *Dosinia*
    - *Dosinia exoleta*
  - Genus *Ruditapes*
    - *Ruditapes decussatus*
  - Genus *Venerupis*
    - *Venerupis corrugata*
  - Genus *Venus*
    - *Venus verrucosa*

Class Gastropoda

- Family Cypraeidae
  - Genus *Zonaria*
    - *Zonaria pyrum*
- Family Vermetidae
  - Genus *Vermetus*
    - *Vermetus triquetrus*
- Family Charoniidae
  - Genus *Charonia*
    - *Charonia lampas*
- Family Nassariidae
  - Genus *Tritia*
    - *Tritia nitida*
    - *Tritia reticulata*
- Family Muricidae
  - Genus *Bolinus*
    - *Bolinus brandaris*
  - Genus *Hexaplex*
    - *Hexaplex trunculus*
  - Genus *Stramonita*
    - *Stramonita haemastoma*
- Family Volutidae
  - Genus *Cymbium*
    - *Cymbium olla*
- Family Cerithiidae
  - Genus *Cerithium*
    - *Cerithium vulgatum*
- Family Siphonariidae
  - Genus *Siphonaria*
    - *Siphonaria pectinata*
- Family Patellidae
  - Genus *Patella*
    - *Patella depressa*
- Family Trochidae
  - Genus *Phorcus*
  - *Phorcus edulis*
  - *Phorcus lineatus*
- Family Turbinidae
  - Genus *Bolma*
    - *Bolma rugosa*
- Family Subulinidae
  - Genus *Rumina*
    - *Rumina decollata*
- Family Helicidae
  - Genus *Otala*
    - *Otala lactea*
  - Genus *Theba*
    - *Theba pisana*

Class Malacostraca

- Family Eriphiidae
  - Genus *Eriphia*
    - *Eriphia verrucosa*

Class Thecostraca

- Family Balanidae
  - Genus *Perforatus*
    - *Perforatus perforates*

A study of the distribution of samples according to their provenance context shows a wide variety of species in the different squares. The average square contains 12 different taxa. The highest value was recorded in layer 1201-2, which counts 21 different species. On the opposite, 1200-2 only records a single *taxon*.

As the most prevalent species in the sampled layers are *R. decussatus, O. edulis* and *C. edule.* The higher representativeness of these bivalves indicates the exploration of the coastal and estuarine environments surrounding the archaeological site, such as the Arade river estuary. This serves the purpose of optimizing resource availability within a short distance of the city.

This optimization, as an economic strategy, occurred due to the dependence on tide cycles, tidal estuarine currents, and bathymetric zones associated with the best-represented species. The most abundant species belong to invertebrate communities that develop predominantly in the upper and middle levels of the mesolittoral or intertidal zone.

It is in these periodically exposed sandy shoals and muddy banks that one can find the most favourable ecotones for the proliferation of oyster – pavements with *Ostrea edulis.* Additionally, the soft, nutrient rich substrates are able to be colonised by dense populations of infaunal bivalves such as *Solen marginatus, Cerastoderma edule,* and *Ruditapes decussatus.* It is therefore possible to infer the possibility of shellfish gathering activity - developed daily and directly – and the exploration of these estuarine areas.

Regarding the types of substrate associated with the malacological species, it was possible to conclude the predominance of sandy or sandy-muddy bottoms by the representativeness of *R. decussatus, C. edule, S. marginatus,* and *A. tuberculata,* expected to be found in this type of environments. Other types of substrate are also well represented: rocky substrate by *O. edulis* and *M. galloprovincialis*, and sandy substrate by *Glycymeris* spp. and *P. maximus.*

Looking at each layer individuality, it is possible to observe that some display higher diversity and/or abundance values than others. Layers where a single species is predominant can result from a greater consumption of said species. On the other hand, a greater layer diversity may point to several possibilities, for instance, the fortuitous harvesting of some species and/or cleaning of fishing nets.

Although we are facing a scenario of different historical times and different social class that consumed the remains studied, significant climatic or environmental variations capable of affecting the composition and dynamics of the aquatic invertebrate communities were did not occur. In fact, the species represented in this context differ very little from the molluscan fauna found in this region of present-day Algarve.

In summary, the present monographic study on the shellfish of Silves allowed the identification of 45 species, mostly bivalves used for food consumption, that has provided a better understanding of the shellfish eating habits of the Islamic community from the Medina *Xelb,* in the final stretch of this community situated what is today southern Portugal.

The species identified in this work are mostly estuarine, intertidal, with tolerance to variation in salinity and temperature, and display a high level of fragmentation – expected in contexts of food waste od this kind. The species *Ruditapes decussatus, Ostrea edulis* and *Cerastoderma edule* prevail, as being the most consumed species in this period with substantial predominance in relation to the others.

Several shells evidentiate consumption marks, specifically trauma edges as a result of the opening the shell to access the mollusc. These marks are found mainly in *O. edulis* species, but also in *R. decussatus* and *Cerastoderma edule* species. As for combustion marks, these are very residual, found in *decussatus*, *Cerastodema edule, Glycymeris* sp. and *P. maximus* species, which substantiate that a significant part of the molluscs was eaten raw.

Were also found evidence of the use of empty shells for purposes other than consumption. Shells of *Glycymeris spp.* and *A. tuberculata* species with abrasive umbonal facets, were used probably as fishing weights. Also found, a large valve belonging to *P. maximus* species that may have served as a container.

As for traces of bioerosion and bioencrustation, these are found mostly in the valves on *O. edulis* and *Glycymeris* spp. species, caused by algae, fungi, sponges, and certain gastropods. However, they are found predominantly on the external side of the shell. In the other hand, the presence of this action in the internal side of the shell - mainly in *Glycymeris* spp. species - indicate *post-mortem* action, that is, the animal was already dead when collected.

Despite all these data and information obtained in this study, it is not possible to confidently and definitely determine a pattern of abundance and diversity variation along the stratigraphic sequence nor the total number of species. This is due to the fact that this dissertation does not study the whole malacological collection of the Silves castle. In fact, it still remains a greater deal of material to be studied. The finding of exotic taxa is yet possible, namely, of Mediterranean or West-African “warm-guests”, or even species from long-distant biotopes that would record trade and commercialization of molluscs between distant cities or regions. A topic to be studied in future works and new data may come to light.

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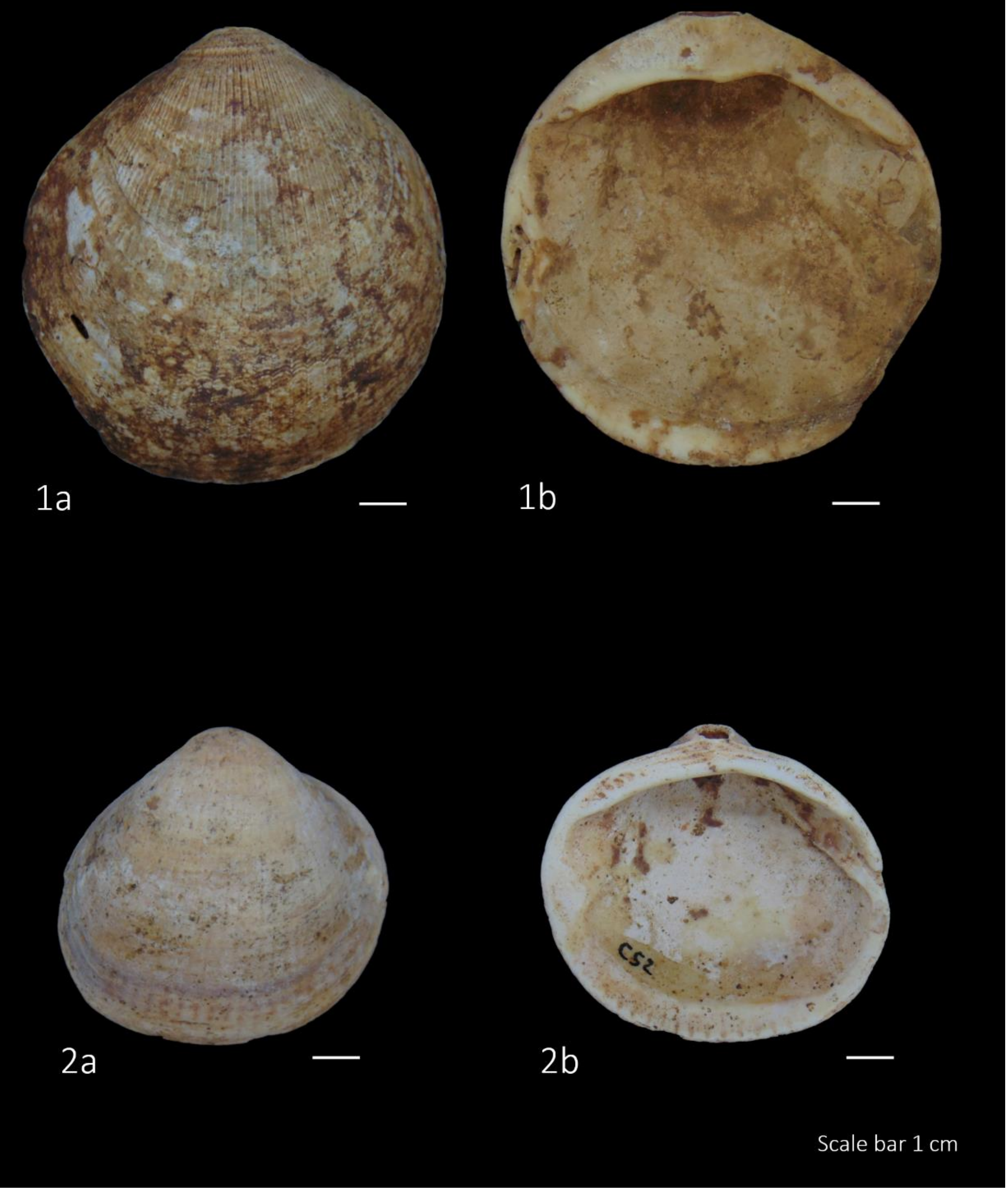
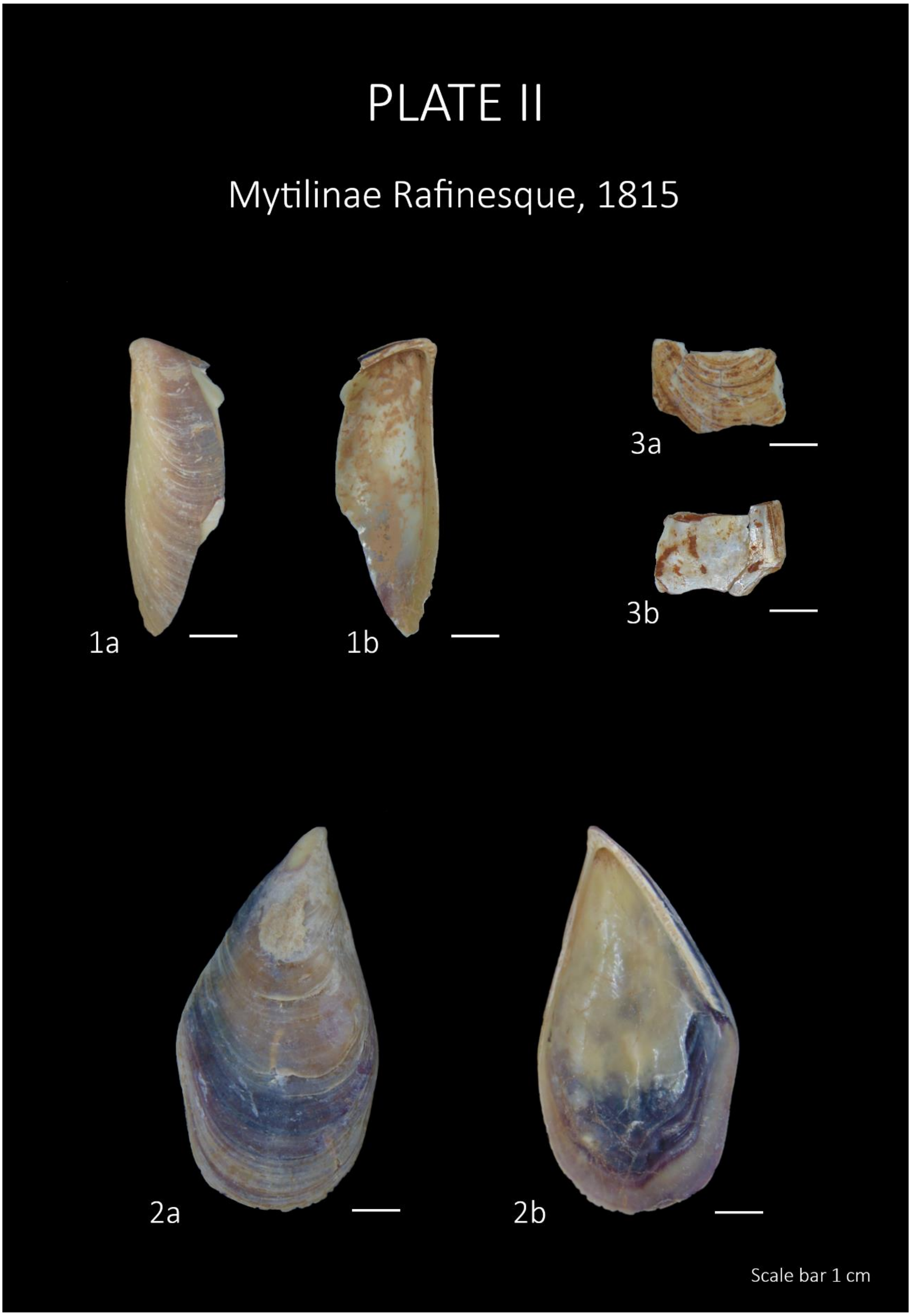
PLATES

PLATE I

Glycymerididae Dall, 1908



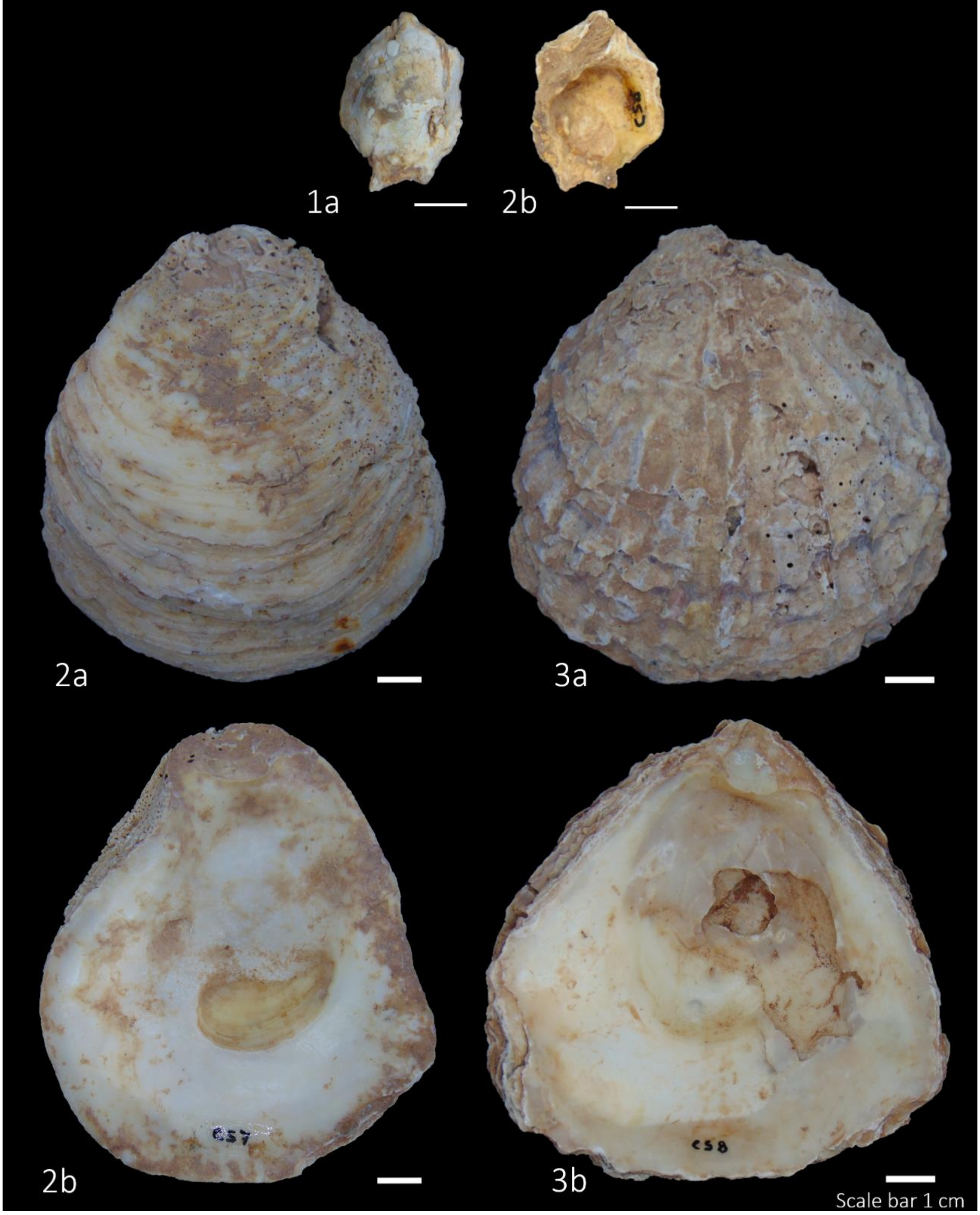
Glycymeris glycymeris (Linnaeus, 1758) – External (1a) and internal (1b) views of right valve (1129-1B).
Glycymeris nummaria (Linnaeus, 1758) – External (2a) and internal (2b) views of right valve (537/538-5).



Mytilus edulis Linnaeus, 1758 – External (1a) and internal (1b) views of right valve (1129-1B).
Mytilus galloprovincialis Lamarck, 1819 – External (2a) and internal (2b) views of left valve (537/538-1).
Perna perna (Linnaeus, 1758) – External (3a) and internal (3b) views of left valve (537/538-1).

PLATE III

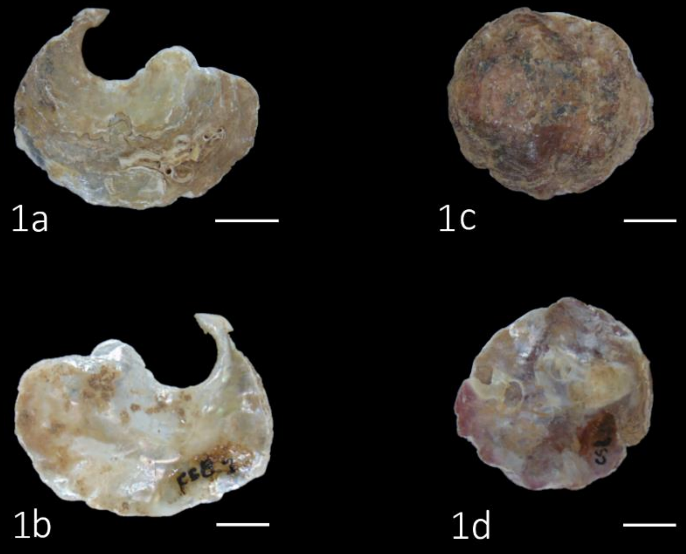
Ostreidae Rafinesque, 1815



Crassostrea gigas (Thunberg, 1793) – External (1a) and internal (1b) views of left valve (1202-2).
Ostrea edulis Linnaeus 1758 – External (2a) and internal (2b) views of left valve; External (3a) and internal (3b) views of right valve (1201-2).

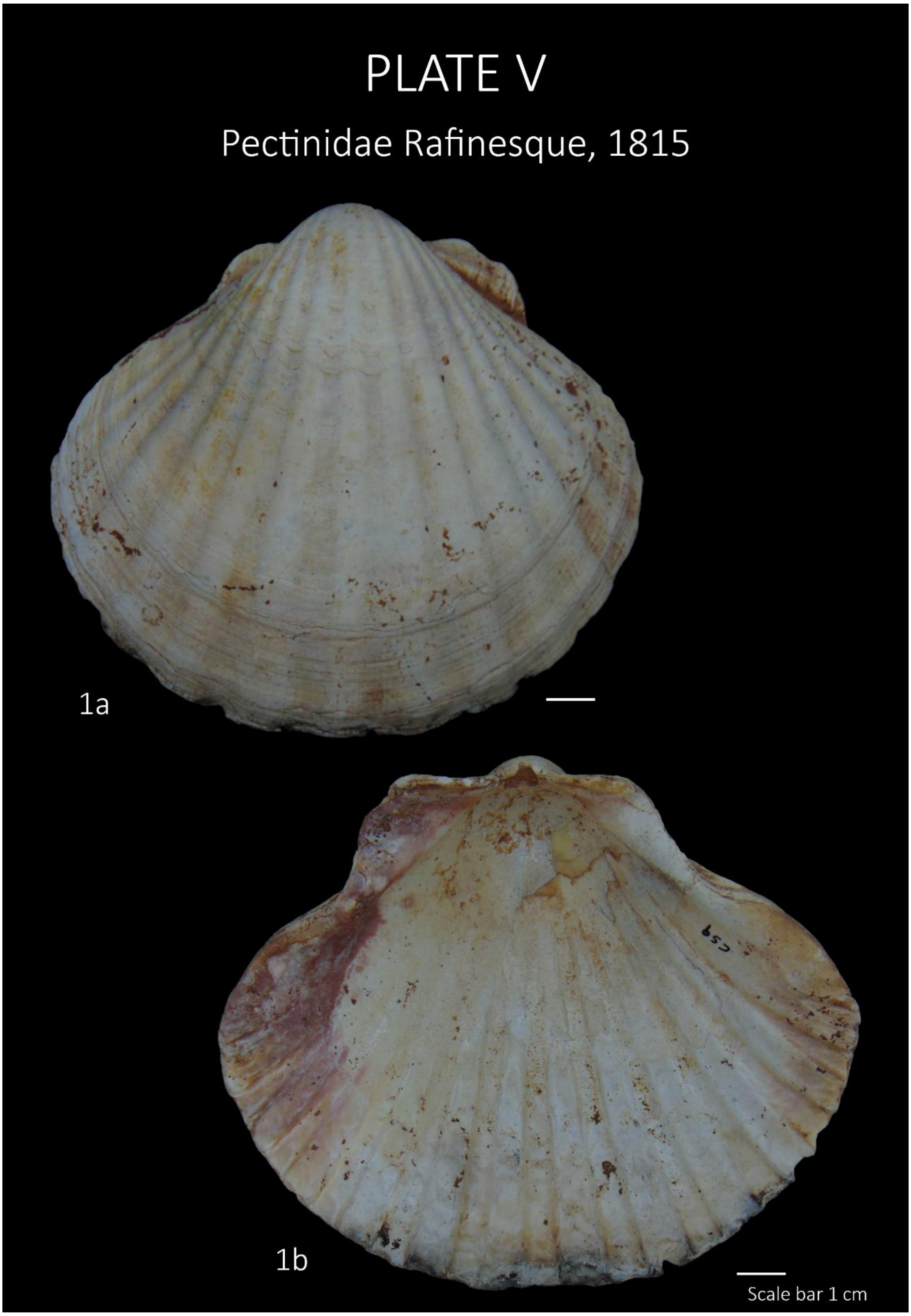
PLATE IV

Anomiidae Rafinesque, 1815

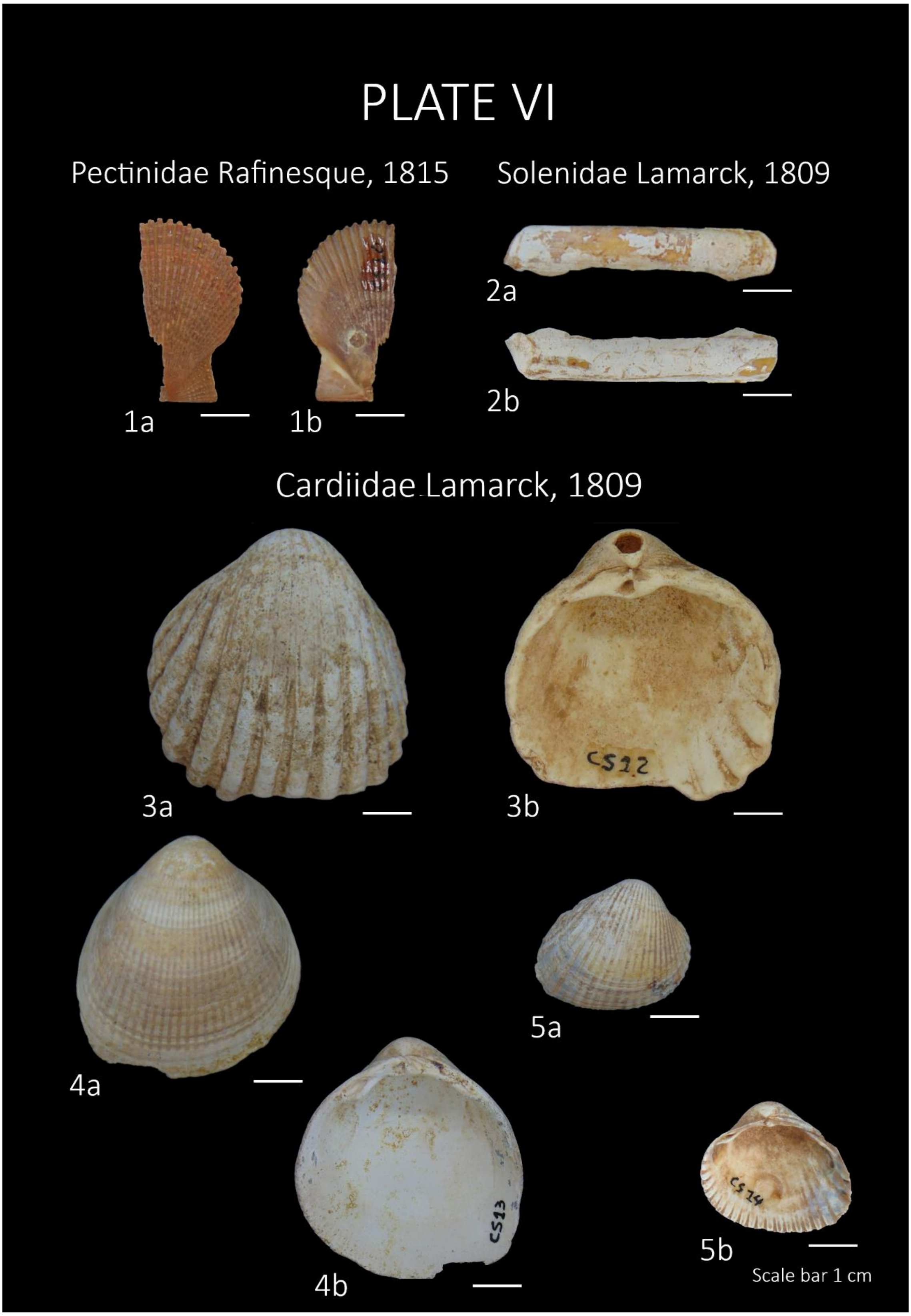


Scale bar 1 cm

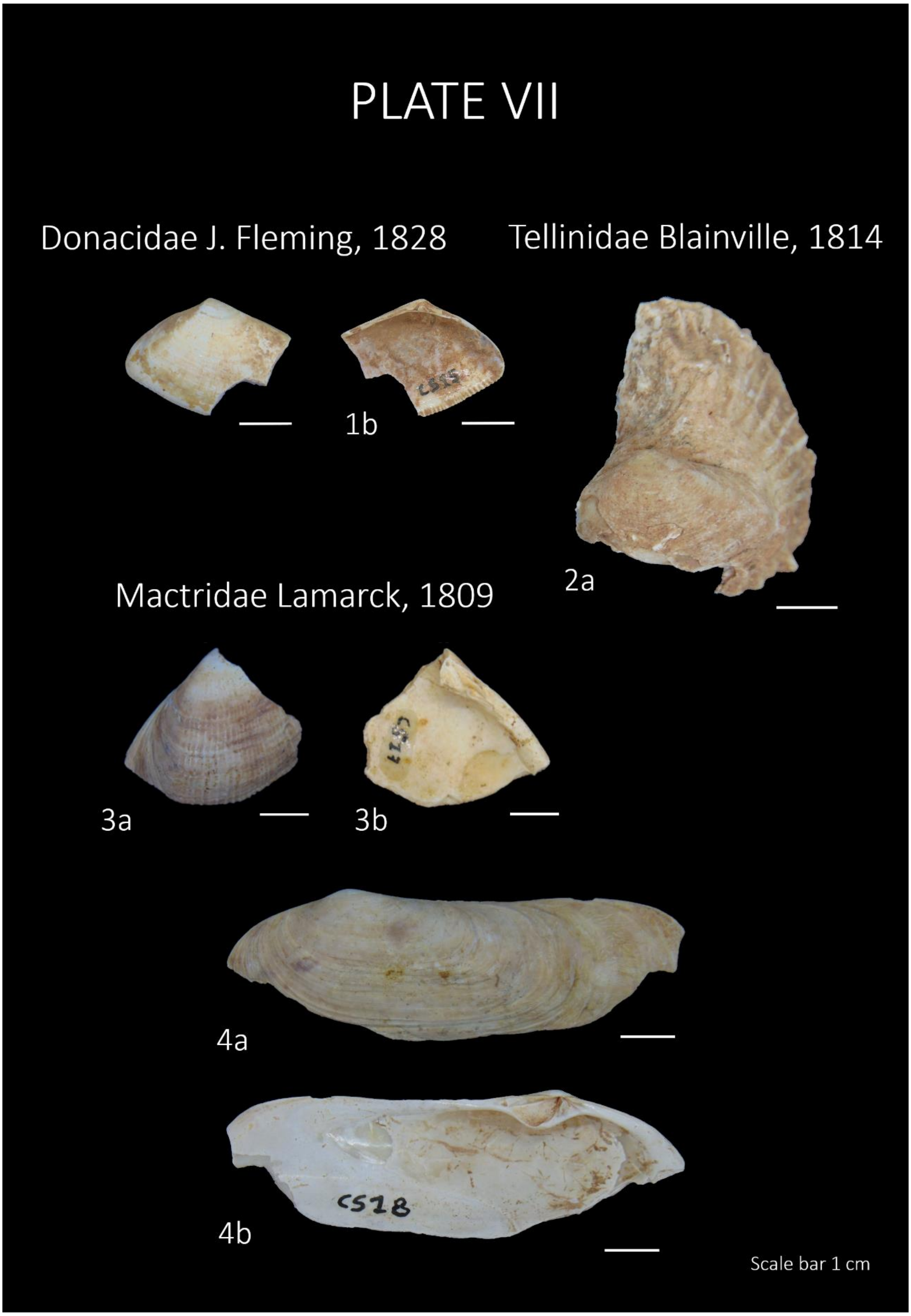
Anomia ephippium Linnaeus, 1758 – External (1a) and internal (1b) views of left valve; External lateral (1c) and internal (1d) views of right valve (1202-2).



Pecten maximus (Linnaeus, 1758) – External (1a) and internal (1b) views of right valve (537/538).



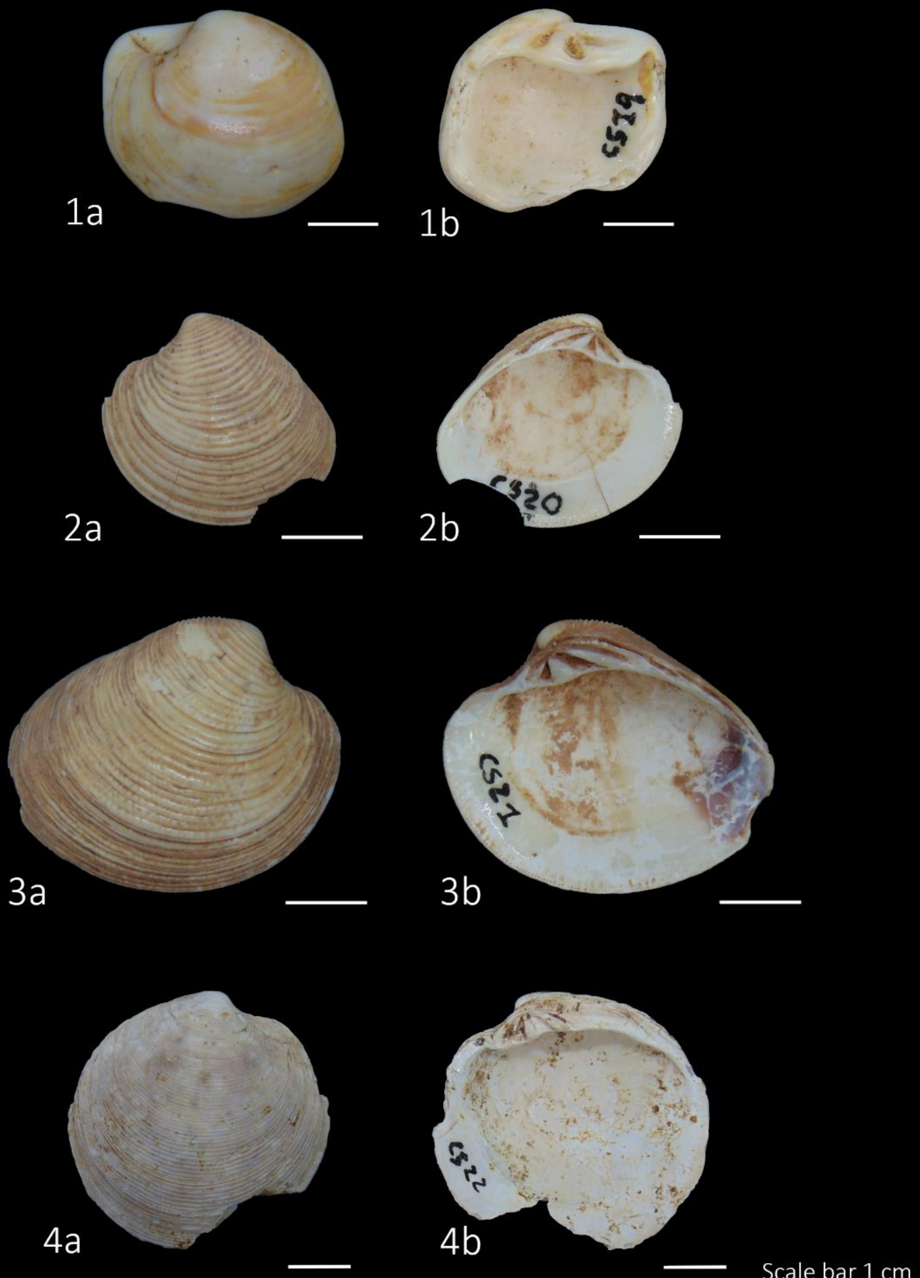
Mimachlamys varia (Linnaeus, 1758) – External (1a) and internal (1b) views of left valve (537/538).
Solen marginatus (Pulteney, 1799) – External (2a) and internal (2b) views of left valve (537/538-1).
Acanthocardia tuberculata (Linnaeus, 1758) – External (3a) and internal (3b) views of left valve (537/538).
Laevicardium crassum (Gmelin, 1791) – External (4a) and internal (4b) views of right valve (537/538).
Cerastoderma edule (Linnaeus, 1758) – External (5a) and internal (5b) views of right valve (1202-1B).



Donax trunculus Linnaeus, 1758 – External (1a) and internal (1b) views of left valve (1218).
Gastrana fragilis (Linnaeus, 1758) – External (2a) and internal (2b) views of left valve (1201-2).
Eastonia rugosa (Helbling, 1779) – External (3a) and internal (3b) views of right valve (537/537-5).
Lutraria lutraria (Linnaeus, 1758) – External (4a) and internal (4b) views of left valve (537/538-1).

PLATE VIII

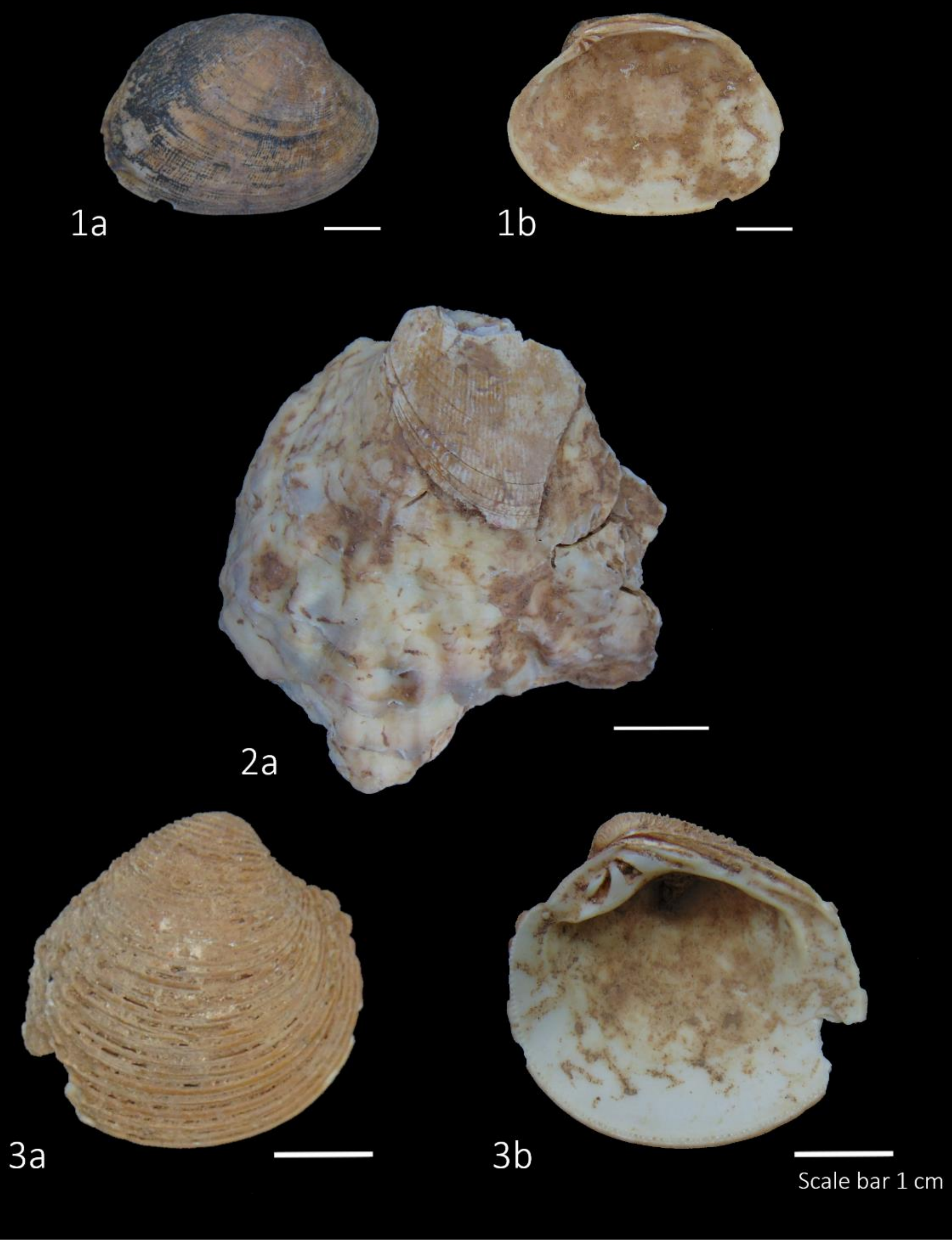
Veneridae Rafinesque, 1815



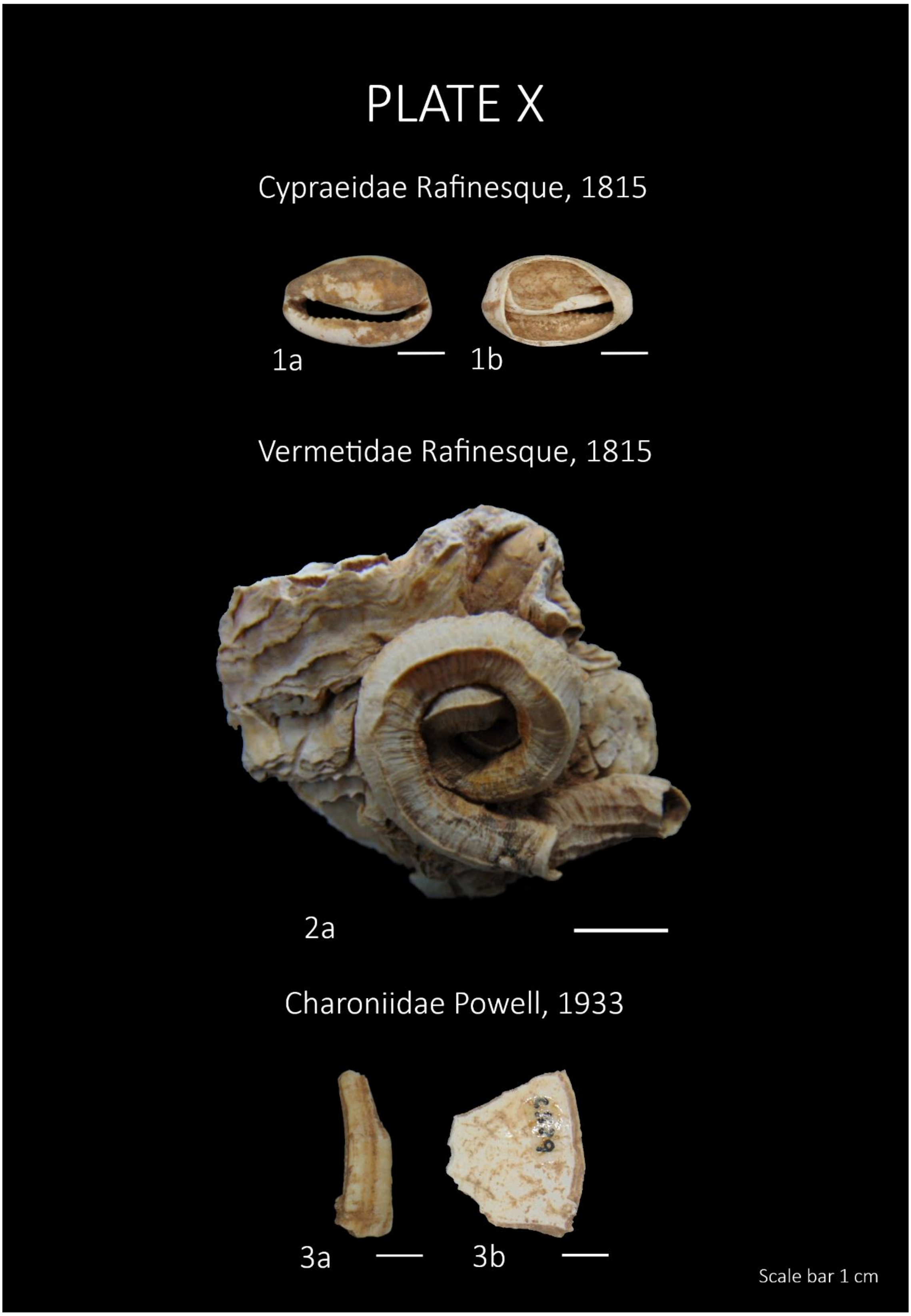
Callista chione (Linnaeus, 1758) – External (1a) and internal (1b) views of left valve (537/538-5).
Chamelea gallina (Linnaeus, 1758) – External (2a) and internal (2b) views of left valve (1202-1B).
Chamelea striatula (da Costa, 1778) – External (3a) and internal (3b) views of right valve (1127-2).
Dosinia exoleta (Linnaeus, 1758) – External (4a) and internal (4b) views of right valve (537/538).

PLATE IX

Veneridae Rafinesque, 1815



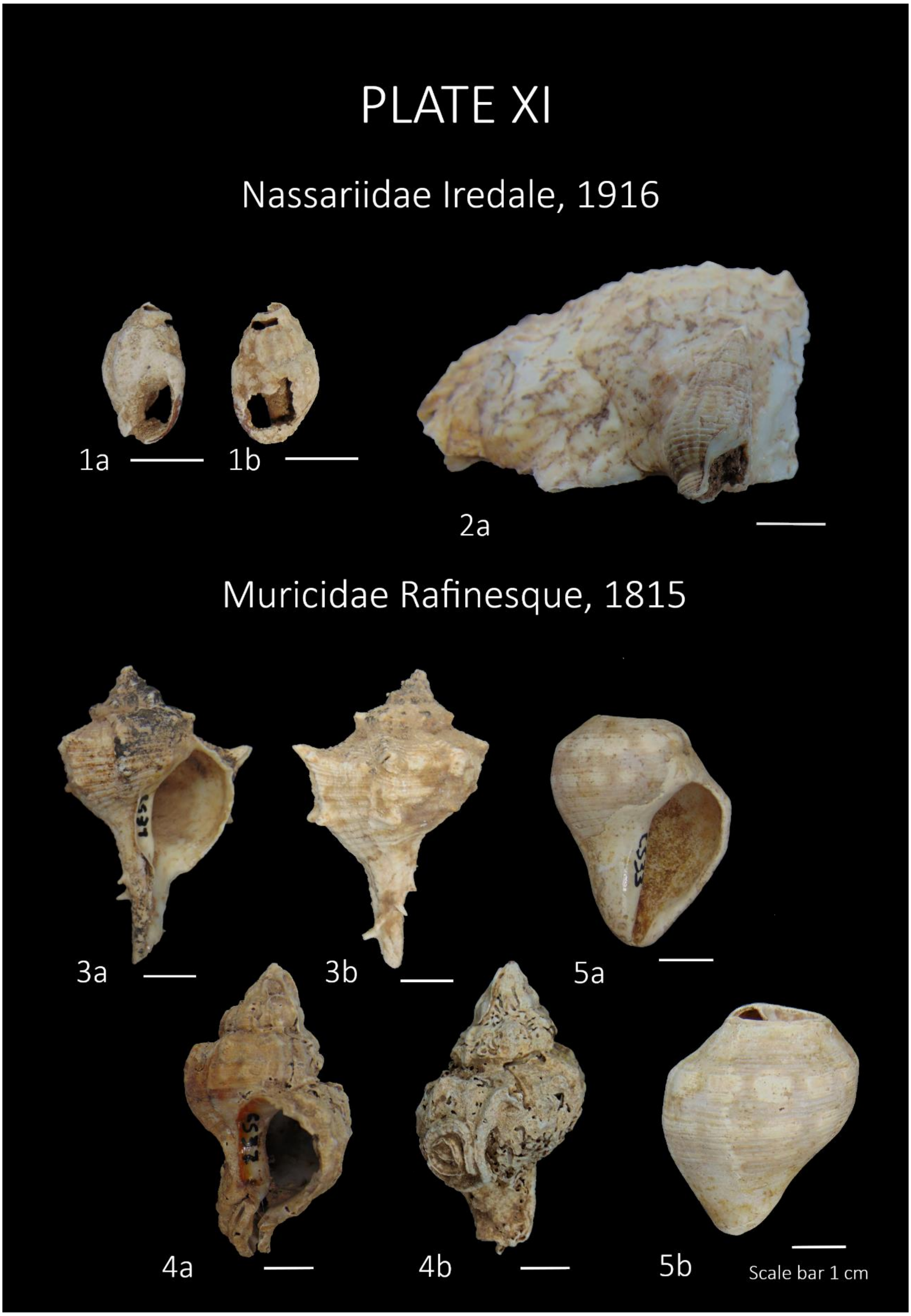
Ruditapes decussatus (Linnaeus, 1758) – External view (1a) and internal (1b) of right valve (1129-2).
Venerupis corrugata (Gmelin, 1791) – External view (2a) and internal (2b) of undefined valve (1075-2).
Venus verrucosa Linnaeus, 1758 – External view (3a) and internal (3b) of right valve (1202-2).



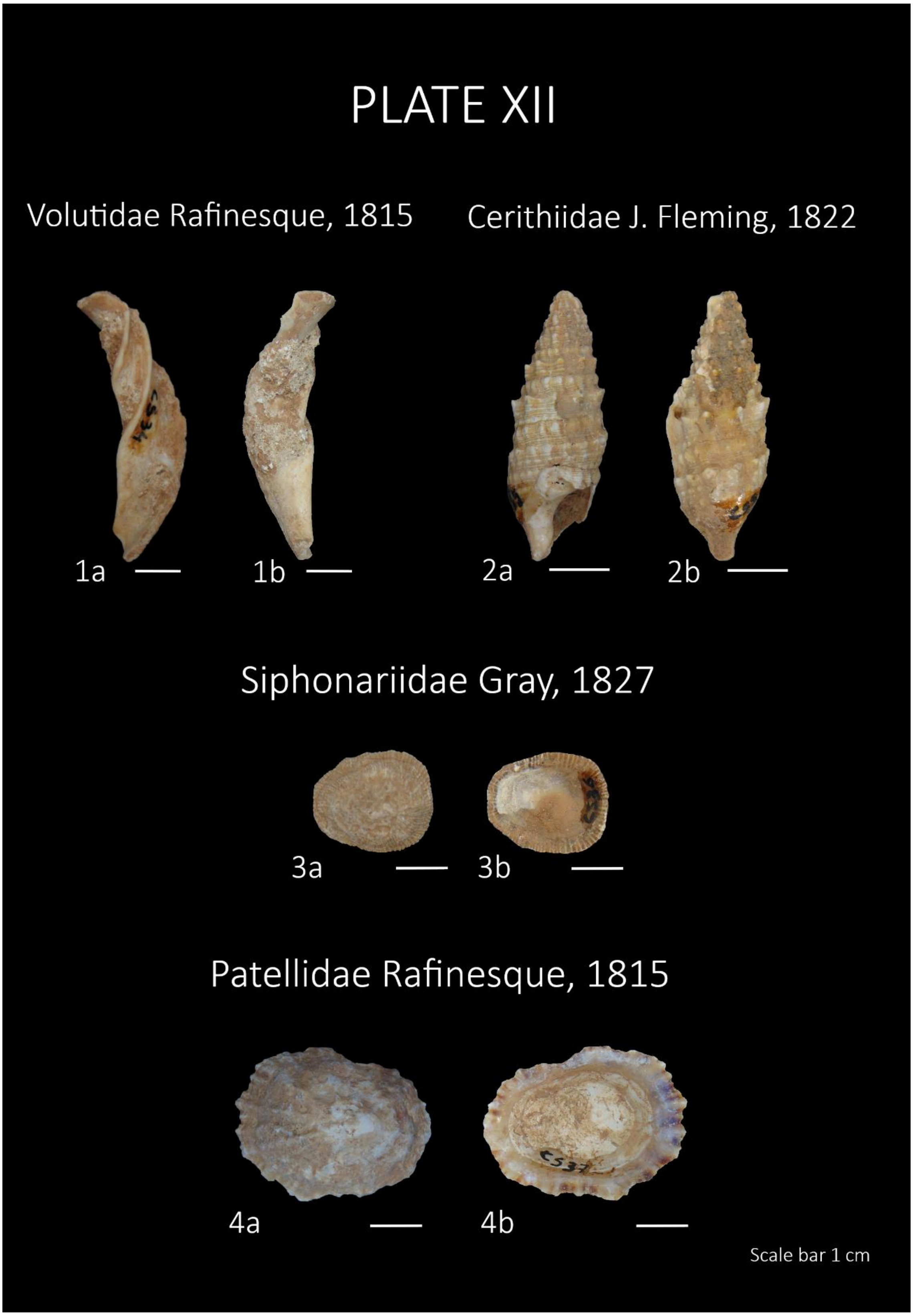
Zonaria pyrum (Gmelin, 1791) – Apertural (1a) and abapertural view (1b) (1045-1B).

Vermetus triquetrus (Bivona-Bernardi, 1832) – Apical view (2a) (1129-2).

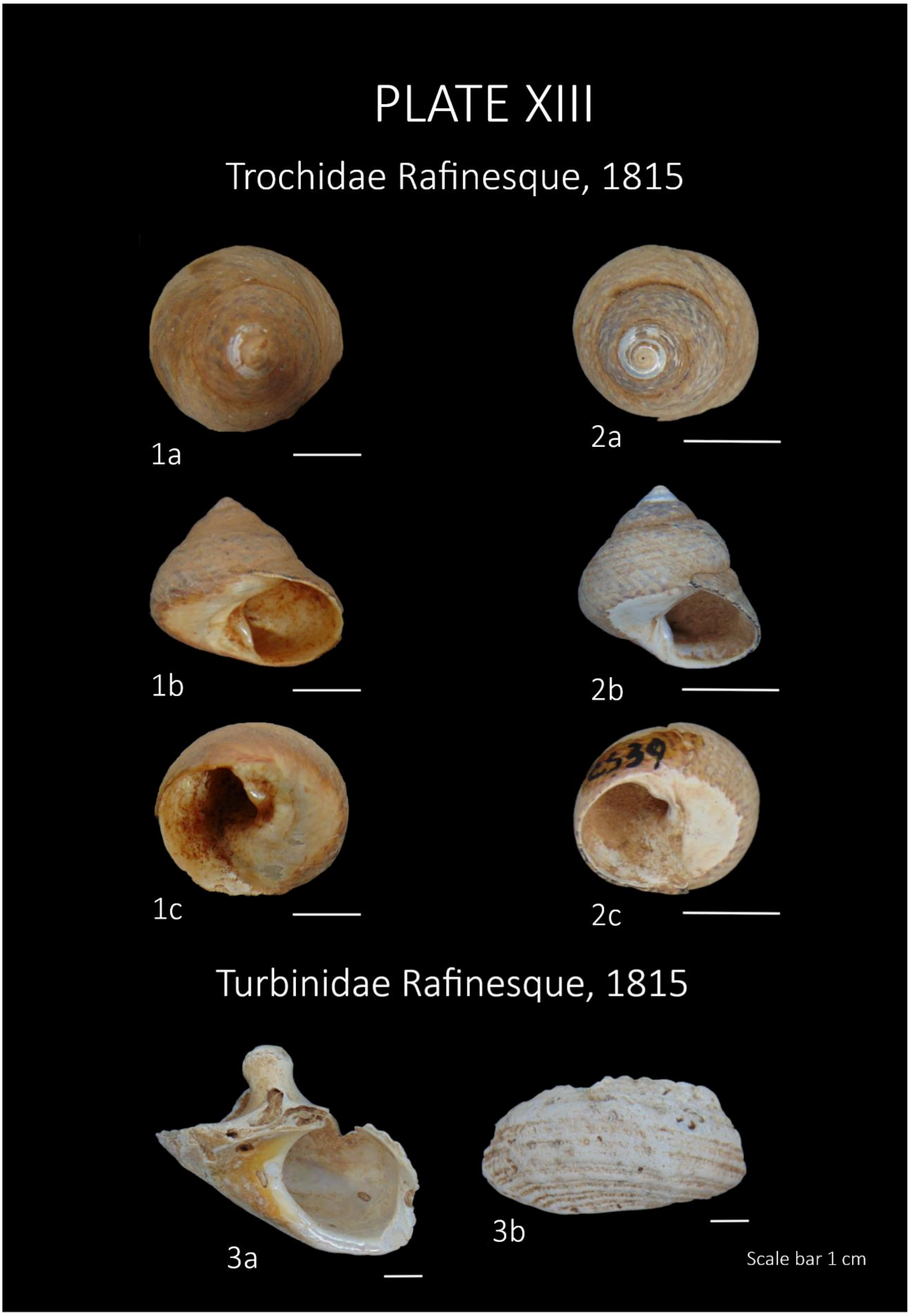
Charonia lampas (Linnaeus, 1758) – External view (3a) and internal (3b) (1218).



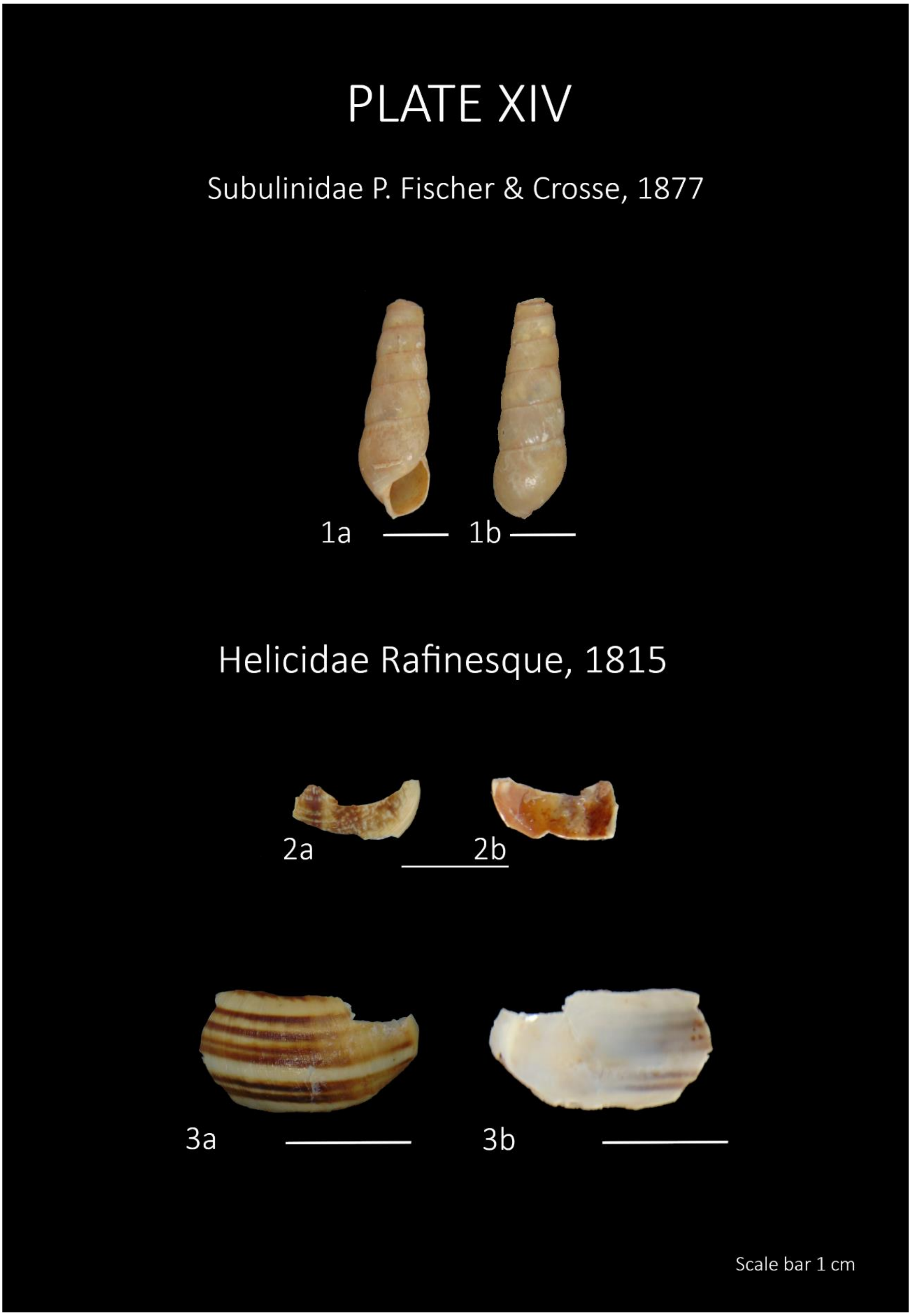
Tritia nitida (Jeffreys, 1867) – Apertural (1a) and abapertural view (1b) (1218).
Tritia reticulata (Linnaeus, 1758) – Apertural (2a) (1202-2).
Bolinus brandaris (Linnaeus, 1758) – Apertural (3a) and abapertural view (3b) (1202-2).
Hexaplex trunculus (Linnaeus, 1758) – Apertural (4a) and abapertural view (4b) (1202-2).
Stramonita haemastoma (Linnaeus, 1767) – Apertural (5a) and abapertural view (5b) (537/538-5).



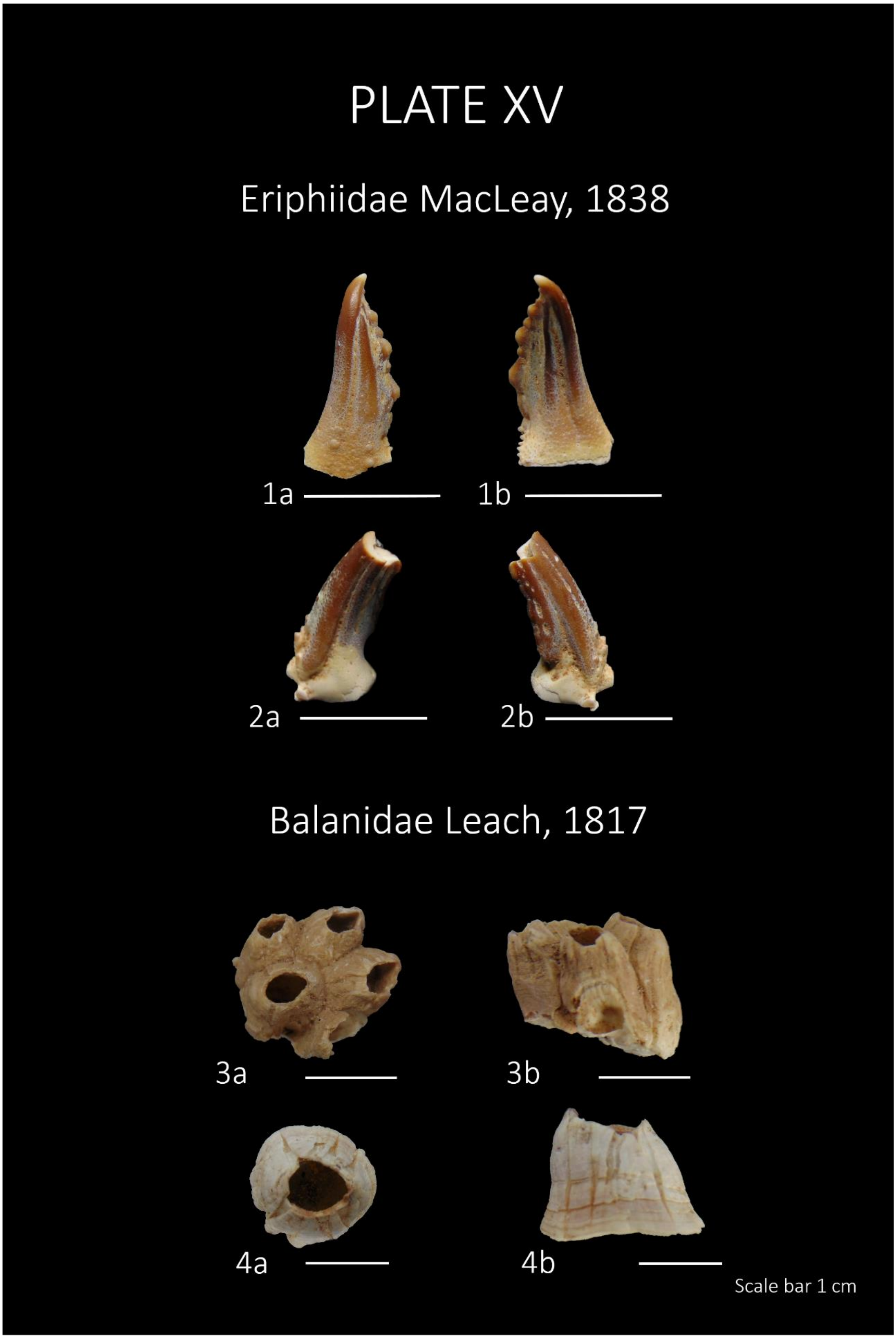
Cymbium olla (Linnaeus, 1758) – Columella view (1a and 1b) (1201-2).
Cerithium vulgatum Bruguière, 1792 – Apertural (2a) and abapertural view (2b) (1202-2).
Siphonaria pectinata (Linnaeus, 1758) – External view (3a) and internal (3b) (1218).
Patella depressa Pennant, 1777 – External view (4a) and internal (4b) (1075-2).



Phorcus edulis (Lowe, 1842) – Apical (1a), apertural (1b), and umbical view (1c) (1201-2).
Phorcus lineatus (da Costa, 1778) – Apical (2a), apertural (2b), and umbilical view (1c) (1075-2).
Bolma rugosa (Linnaeus, 1767) – Apertural (3a) and abapertural view (3b) (537/538-5).



Rumina decollata (Linnaeus, 1758) – Apertural (1a) and abapertural view (1b) (1201-2).
Otala lactea (Müller, 1774) – External lateral view (2a) and internal (2b) (537-538-1).
Theba pisana (Müller, 1774) – External lateral view (3a) and internal (3b) (537-538-5).



Eriphia verrucosa (Forskål, 1775) – 1a to 2b - 537/537-1.
Perforatus perforatus (Bruguière, 1789) – 3a and 3b – 1129-2, 4a and - 4b 537/538-1.